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**17TH CONFERENCE ON SUSTAINABLE
DEVELOPMENT OF ENERGY, WATER AND
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BOOK OF ABSTRACTS

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Conference Venue: Paphos



Paphos is a city on the southwest coast of the Mediterranean island of Cyprus. Inhabited since Neolithic times, it has several sites relating to the cult of goddess Aphrodite, whose mythical birthplace was at Old Paphos (Kouklia). New Paphos is the modern city that incorporates the harbour, and the ancient ruins of tombs, fortresses, theatres and villas at Paphos Archaeological Park. Paphos is also a cultural UNESCO World Heritage Site in Cyprus.

Paphos has been inhabited since the Neolithic period. It was a centre of the cult of Aphrodite and of pre-Hellenic fertility deities. Aphrodite's legendary birthplace was on this island, where her temple was erected by the Myceneans in the 12th century B.C. The remains of villas, palaces, theatres, fortresses and tombs mean that the site is of exceptional architectural and historic value. The mosaics of Nea Paphos are among the most beautiful in the world.

Today, Paphos has a population of about 97,000 and has a quickly developing tourist resort economy complete with beaches, an excellent harbor for sport fishing, and ancient site seeing. Paphos is divided into two main sections; Ktima is the main residential district where the majority of the cities residents reside and Kato Pafos on the sea is built around the medieval port and is where the hotels and villas to rent in Paphos, attractions, and other tourist holiday destinations are located.

Scope and Objectives

The 17th Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES) is dedicated to the advancement and dissemination of knowledge on methods, policies and technologies for increasing the sustainability of development by de-coupling growth from the use of natural resources and by a transition to a knowledge-based economy. All taking into account the economic, environmental and social pillars of sustainable development.

One of the main issues of the coming decades is to improve efficiencies by integrating various life-supporting systems, using excess from one, as resource in another in the correct moment. Integrating electricity, heating, cooling, transport, water, buildings, waste, wastewater, industry, forestry and agriculture systems will be pivotal towards sustainable development.

"History teaches us that men and nations behave wisely once they have exhausted all other alternatives"

Abba Eban

Sustainability being also a perfect field for interdisciplinary and multi-cultural evaluation of complex system, the SDEWES Conference has become a significant venue for researchers in those areas to meet, and originate, discuss, share, and disseminate new ideas:

- Sustainability comparisons and measurements (metrics and indices; multi-criteria analysis; external costs; exergy analysis; footprint methods; emergy; life cycle analysis)
- Green economy and better governance (circular economy; low carbon development/economy; resource efficiency; water reuse; jobs and regional development; macroeconomic analysis; financial and regulatory mechanisms; models and tools; rebound effect; energy economics; environmental economics; development economics; sustainability economics)
- Smart energy systems (markets; demand response; integration of power, heating/cooling, transport, water and waste sectors; smart grids; dynamic electricity pricing, microgrids)
- Energy policy (security of supply; climate change mitigation; energy transition; renewable energy support schemes; energy efficiency policy; employment creation; carbon pricing; markets; fossil fuel subsidies)
- Smart transport systems and policy (fuel/carbon economy; transport electrification; congestion and road pricing; multimodal management; alternative fuels; social aspects; autonomous mobility; railways; shipping; aviation)
- Water-energy nexus (water management; water system analysis; water pricing; water desalination; hydro energy; water-renewables integration, water resources; river basin management; arid areas)

- Environmental policy and management (waste management; wastewater management; climate change mitigation; climate change adaptation; air pollution policy; water pollution policy; land management; biomass management; rewilding; social aspects; strategic environmental impact assessment, environment and corporate social responsibility, quality management systems; environment management systems; eco management and audit schemes; occupational health and safety assessment systems; hazard analysis and critical control point; integrated management systems)
- Agricultural policy (energy and water use in agriculture and food processing; food vs. biofuels; sustainability of biofuels production)
- Social acceptance (reform; NIMBY; nuclear; wind; biofuels; hydrogen; hidden and special interests; cost based pricing; inclusion; fossil fuel subsidy; green economy and employment; gender issues; energy poverty; energy affordability)
- Sustainable resilience of systems (resilience of energy systems; resilience of water systems; resilience of environmental systems; resilience of agricultural systems; resilience of social systems; resilience of engineering systems)
- Sustainable tourism (green hotels; certification)
- Urbanism (smart cities; urban planning; zoning; transport; zero energy buildings/districts; sustainable energy action plans; district heating/cooling)
- Regional planning and cooperation (sustainable islands; regions and cities; 100% renewable regions)
- Research, innovation and development (industry-academia partnership; quadruple helix; knowledge based society; knowledge management; learning curve; technology foresight; science diplomacy)
- Education in sustainable development (governance; environmental awareness; higher education; engineering education)
- Energy system analysis (energy planning; power system planning; smart energy systems; smart energy networks; natural gas system planning; 100% renewable energy systems; high penetration of renewables; island energy systems; development of energy planning tools; internalizing environmental externalities; electrification of transport; storage vs. grids vs. demand management; long term demand planning; integration of power and district heating systems; integration of power and water systems; integration of power and transport systems; power to gas)
- Transport management (transport system analysis, dynamic road pricing; electrification of transport)
- Renewable energy resources (biomass; hydro; wind; solar; geothermal; wave and ocean; technical and economic potentials; barriers; cost and benefits; integration)
- Primary energy resources (oil peaking; gas; coal peaking; nuclear fuels)
- Renewable electricity generation systems (biomass; hydro; wind; offshore wind; high altitude wind; photovoltaic; concentrated solar thermal power; geothermal; wave; tide; ocean thermal)
- Thermal power plants (clean coal; combined cycles; advanced cycles; flexible operation and cycling; carbon capture and storage/sequestration/reuse; nuclear)
- District heating and/or cooling in smart energy systems (integration of renewable heat; cogeneration; industrial waste/excess heat; waste to energy and CHP; power to heat; electric boilers; heat pumps; integration of CHP with district heating and electricity markets; heat maps; distribution)

"You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete."

Buckminster Fuller, philosopher, futurist and global thinker (1895 - 1983)

- Nano and micro technologies and science for sustainable development of energy, water, and environment systems
- Advanced sustainable energy conversion systems (fuel cells; thermoelectric; thermionic; organic; ORC; waste/excess heat recycling; thermoacoustic; piezoelectric)
- Renewable heat systems (biomass; biofuels; biogas; solar; geothermal)
- Biofuels and biorefineries (biodiesel; bioethanol; biogas; second and third generation biofuels; waste to biofuels; algae; anaerobic digestion; BTL; biorefineries; alternative fuel vehicles; infrastructure; sustainability assessment; pyrolysis; torrefaction; coproduction)

"If there are to be problems, may they come during my life-time so that I can resolve them and give my children the chance of a good life."

Kenyan proverb

- Alternative fuels (hydrogen; electro-fuels; power to gas; synthetic fuels; BTL; DME; CNG; resources; production; vehicles; infrastructure)
- Hybrid and electric vehicles (first generation hybrid; plug in hybrid; charging; batteries; infrastructure)
- Water treatment for drinking water
- Water desalination (distillation; reverse and forward osmosis; electrodialysis; energy recovery; discharge management)

- Waste and wastewater treatment and reuse (avoiding waste; composting; recycling; waste to energy; anaerobic digestion; gasification; mechanical biological treatment; mechanical heat treatment; plasma arc waste disposal; pyrolysis; RDF/SRF; combustion modelling)
- Modelling for pollution avoidance and energy efficiency (CFD models; air pollution spreading; water pollution spreading; heat and mass transfer modelling combustion modelling)
- Cogeneration, trigeneration, polygeneration (heat/cold and power; water and power; biofuels and power; transport and energy; food and energy; applications and operation strategies)
- Storage (heat/cold storage; hydrogen storage; hydropower as storage; pump storage; compressed air storage; batteries; water storage; biofuels storage; storage optimisation modelling; financial support mechanisms; power market arbitrage)
- Electricity transmission and distribution (grid extension and robustness; long distance transmission; power quality)
- Gas security of supply (diversification; shale gas; extension of transmission pipelines; LNG; Southern Corridor)
- Energy and water efficiency in industry and mining (cement and lime; construction materials; glass; pulp and paper; food industry; metallurgy; chemical industry; process optimisation; kilns; boilers; heat exchange networks; pinch analysis; exergy and exergoeconomic analysis; energy audits; water use and waste minimisation; eco-innovation; total site integration; life cycle assessment; eco-design and eco-labelling; product cycle assessment; cleaner production, environmental impact assessment)
- Energy efficient appliances (smart appliances; labelling and standards; user behaviour)
- Buildings (nearly zero energy buildings; passive buildings; smart buildings; smart metering; ICT; load and demand side management; green buildings; building codes and standards; buildings certification; HVAC; insulation; renewables integration; heat pumps; storage; sustainable architecture)

- Energy markets (market/price coupling; liberalisation/deregulation; modelling; demand response; role of district heating; desalination and water pumping; storage; retail markets; grid parity; net metering)
- Emission markets (emission trading system; cap and trade; transport participation)
- Political aspects of sustainable development (long term planning; sustainable development goals; the role of political leaders and of voters; international conflict vs. sustainable development; security and sustainability; resource and political security)

"Then I say the Earth belongs to each generation during its course, fully and in its right no generation can contract debts greater than may be paid during the course of its existence"

Thomas Jefferson, September 6, 1789

Preface

The objective of the series of conferences on Sustainable Development of Energy, Water and Environment Systems (SDEWES) is to provide a forum for world-wide specialists and those interested in learning about the sustainability of development, to present research progress and to discuss the state of the art, the future directions and priorities in the various areas of sustainable development. This includes the improvement and dissemination of knowledge on methods, policies and technologies for increasing the sustainability of development, taking into account its economic, environmental and social pillars, as well as methods for assessing and measuring sustainability of development, regarding climate, energy, transport, agriculture, water and environment systems and their many combinations. The reason for the forum having such a wide scope is due to the need for holistic integrated solutions encompassing several or all.

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Chair of the International Scientific Committee

Prof. Soteris Kalogirou

Chair of the Local Organising Committee

Prof. Neven Duić

SDEWES Centre President

Prof. Zvonimir Guzović

Conference Secretary

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Plenary lectures

SDEWES2022.0161

Modelling and Design of Smart Resilient Net-Zero Solar Buildings and Communities

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Abstract

The presentation will focus first on systematic modelling and design of advanced solar buildings and communities that are optimized to capture solar energy through building-integrated solar systems for simultaneous production of electricity and useful heat, optimally designed windows for capturing passive solar heat gains and daylight, and efficient building-integrated energy storage systems. In addition, production of solar electricity from buildings for electric vehicles (EVs) for local transportation is presented under different scenarios. Such a design, together with optimal operation strategies applied to a community, can result in a net-zero energy community, considering both energy consumption by buildings and local transportation. A key challenge is to achieve a dynamic optimal integration with a smart grid with dynamic pricing schemes for electricity. Different scenarios are presented for utilizing the energy storage in buildings and EVs, as well as possible centralized energy storage, to be able to operate a community in self-sustaining islanded mode during emergencies, while supporting the grid and optimizing benefits for the community during normal operation. Results from Canadian high performance demonstration buildings are presented with emphasis on their optimal design, operation, and development of flexibility in their load profiles for grid interaction, particularly the Varennes Library, a smart solar net-zero energy institutional building completed in Canada in 2016 and currently being monitored and studied. Finally, recommendations for the design and development of carbon-neutral resilient communities in Canada are presented as part of a Canadian Academy of Engineering Roadmap chaired by Dr. Athienitis.

SDEWES2022.0581

Sustainability of Energy Systems for Efficient Clean Energy Transition

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Abstract

For a several decades the Islands have been lighthouses of sustainable development and clean energy transition. Not just in successful application of projects for utilisation of abundant renewable energy sources and energy storage but also demonstrating much wider sector integration. Moreover, the islands have led the way in development of shared ownership projects, community involvement and advanced use of public funding. In the last decade, the achievements in system integration, digitalization and democratization provided the ground to development of the Smart Islands initiative, the approach that goes far beyond pure decarbonization. Even though it was possible to demonstrate on the islands the feasibility of 100% renewable electricity generation together with use of high share of renewables in other sectors and showing the importance of water-energy-food nexus , the transfer of knowledge and experience to more densely populated cities and countries requires adaptation of methods and more complex and sophisticated approaches. The regional planning provides more opportunities regarding energy markets, transportation, and resources potentials but also brings many challenges related to technology value chains, policy issues and geopolitics.

The presentation will include research results from several international and national projects like INSULAE , YENESIS etc as well as overview of SDEWES conference contribution to the efficient clean energy transition in the last two decades.

SDEWES2022.0051

Smart Renewable Energy Systems and Decarbonization

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Abstract

This presentation focusses on how societies can design and implement renewable energy and decarbonization strategies. The presentation presents and discuss a set of methods and criteria to design Smart Energy Systems, while considering the context of 100% renewable energy on a national level. Countries should handle locally what concerns local demands, and at the same time acknowledge the international context when discussing resources and industrial and transport demands. To illustrate the method, it is applied to the cases of Denmark and European within the context of a global fully decarbonized energy system.

Recently, the Danish Government supported by the Danish Parliament decided for the target of a 70% decrease in Greenhouse gasses by 2030. This presentation includes a list of theoretical and methodological considerations as well as a concrete proposal on how such targets can be implemented. It is highlighted that already now one must think beyond 2030 to prepare for the next step to achieve a full decarbonization by 2040 or 2050. It is also highlighted that a country such as Denmark must consider how to include its share of international shipping and aviation as well as how to design a solution with Denmark's share of sustainable biomass resources.

Moreover, the presentation includes the results of detailed hourly modelling of the EU "A Clean Planet" scenarios for a fully decarbonized Europe in 2050 and compare it to a "smart energy systems" alternative. The case illustrates how the focus on a fully sector-coupling as expressed in a smart energy systems approach will lead to higher energy efficiency and the identification of a more affordable green transition in Europe.

SDEWES2022.0317

The Role of Research and Innovation in the European Plans for the Clean Energy Transition and an Effective Strategic Autonomy

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Abstract

The lecture describes the most relevant European Union policies, programmes and initiatives focused on research and innovation, as the basis of the plans for a green and digital transition. The Union has set ambitious goals to reach in the next years aiming to achieve an effective transformation of the society and the economy. The lecture will start with a brief overview of the European policies to ensure an effective and inclusive green transition (namely the green Deal and the Fit455 Package, with particular reference to the revision of the energy efficiency and the renewable energy sources directives). The second part will focus on the role of the clean and affordable technologies to reach the targets set for 2030 and beyond, touching upon the centrality of Horizon Europe instruments to support industrial decarbonisation and the reduction of the societal carbon footprint. Particular reference will be made to the efforts to integrate the knowledge triangle across the European single market (in particular through the renewed plans to build a European Research, Education and Innovation Area) and to the role that the European Institute of Innovation and Technology and the Joint Undertakings can play in this regard. The final part of the lecture will be dedicated the recent initiatives taken by the Commission towards ensuring a strategic autonomy in key supply chains and in the energy landscape, with specific reference to the new industrial strategy, the European Innovation Area and RePowerEU.

Special session: Clean energy technologies and systems for sustainability

The issue of environmental sustainability and the growing demand for energy are crucial global challenges that have been attracting increasing attention from a diverse range of academic, industrial, government and policy stakeholders. Clean energy technologies and systems are required to tackle these challenges and support sustainable development and growth. This special session focuses on research advancements, case studies and practices that promote clean energy utilisation in a variety of applications, covering methods, processes, components, and systems for high-efficiency and low-emission collection, recovery, utilisation, conversion and storage of energy for heating, cooling and power provision. Emphasis is based on innovative technologies and renewables exploitation including solar, wind, geothermal and biomass, amongst other. The themes of this special session include the following topics:

- Cogeneration and polygeneration systems
- Carbon capture and storage
- Energy policy and economic assessment for sustainability
- Energy and cost saving strategies in buildings
- High-performance energy conversion devices and components
- Hydrogen related technologies including generation, storage, transportation and utilisation
- Integration of clean energy technologies in low-carbon energy systems
- Large-scale electrical energy storage via thermal and mechanical processes
- Renewable energy technologies and hybrid renewable energy systems (HRES)
- Solar energy technologies for heating, cooling and power provision
- Technologies for the decarbonisation of heating and cooling (e.g., heat pumps)
- Thermal energy storage
- Waste-heat recovery and conversion to heating, cooling and/or power with advanced cycles

Dr. Jian Song, Imperial College London, London, United Kingdom

Prof. Christos N. Markides, Imperial College London, London, United Kingdom

Jian Song - Dr Jian Song is the Deputy Group Leader of the Clean Energy Processes (CEP) Laboratory at Imperial College London, and he is the Managing Editor of Applied Thermal Engineering and Review Editor of Frontiers of Energy Research. Dr Song received his PhD degree from Tsinghua University in 2018 (Outstanding PhD Thesis Award by CSICE, Beijing Outstanding

Postgraduate Award, Wu Zhonghua Outstanding Postgraduate Award). He won Zijing Scholar Fellowship and joined CEP Laboratory in 2018. He visited the Whittle Laboratory at University of Cambridge in 2016 and gained engineering experience during the internship in Mitsubishi Heavy Industries in Takasago Japan in 2015. Dr Song's research focuses on clean energy technologies for sustainability, in particular the hybrid utilisation of renewable energies (solar, geothermal, biomass, etc.), innovative systems for heat and power provision and high-performance power conversion components, aiming to achieve efficient energy conversion and support sustainable development.

Christos N. Markides - Christos N. Markides is Professor of Clean Energy Technologies in Department of Chemical Engineering of Imperial College London, where he heads the Clean Energy Processes (CEP) Laboratory. He is the Editor-in-Chief of Applied Thermal Engineering, on the Editorial Board of the UK National Heat Transfer Committee, the Scientific Board of the UK Energy Storage SUPERGEN Hub, and is a member of the Assembly of World Conferences on Experimental Heat Transfer, Fluid Mechanics and Thermodynamics, the Global Energy Association, and the International Energy Storage Alliance. His current research interests focus on high-performance processes, technologies and systems for the recovery, utilisation, conversion or storage of energy for heating, cooling and power, with emphasis on renewable, solar and waste heat, thermodynamics of and heat/mass transfer effects in heating/cooling devices and heat-to-power conversion technologies, and advanced experimental techniques for detailed flow, heat/mass transfer in turbulent, multiphase and interfacial flows.

Invited submissions

SDEWES2022.0057**Development of Data-Driven Compressor Efficiency Maps for Small-Scale Heat-Pumping Applications**

A. Olympios, J. Song, A. Ziolkowski, V.S. Shanmugam, C.N. Markides*

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Abstract

The performance of vapour-compression heat pumps and other energy-conversion technologies depends crucially upon the selection and design of key components, and in particular, the compressor, which plays a vital role in the systems' operation. In domestic applications, heat pumps involve three main types of compressors: rotary-vane, scroll and piston. When optimising the design and operation of systems, modellers often take advantage of existing compressor efficiency maps that can predict performance for a set of given working conditions. The novelty of this work lies in the development of a consistent modelling framework to technoeconomically compare compressors targeted for domestic applications. This involves collecting published performance information for 120 commercially available compressors and developing performance maps and costing correlations that predict compressor isentropic efficiency and cost for a wide range of working conditions. Then, utilising an existing domestic air-source heat pump model and considering an average UK household as a case study, a comparison of domestic heat pumps based on rotary-vane, scroll and piston compressors is performed. When rotary-vane compressors are an available option (i.e., for compressor inlet volumetric flowrates up to $5 \cdot 10^{-3} \text{ m}^3/\text{s}$), they achieve a consistent and high isentropic efficiency ($> 65\%$) for the investigated volume ratios (1.5 - 5.5). Scroll compressors achieve an isentropic efficiency higher than 70% for low volume ratios (< 4.5), but this drops down to as low as 50% at higher volume ratios. On the other hand, piston compressors perform best at high volume ratios (3.5 - 5.5) with an isentropic efficiency higher than 70%. Rotary-vane compressors are shown to be the most cost-effective option for an average UK household, resulting to a levelised cost of heat of 170 £/MWh and a payback time (when switching from an electric boiler) of 2.7 years for a heat pump with a nominal capacity of 10 kW_{th}. However, the comparison of compressor types is shown to largely depend on the weather characteristics and heat-pump size requirements. The developed maps and the results of this paper can be a useful tool for technology modellers when optimising heat-pumping or other energy-conversion systems.

SDEWES2022.0106

A Novel Liquid Air Energy Storage System Integrated with Cascade Latent Heat Cold Thermal Energy Storage - Experimental Investigation and Numerical Analysis

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Abstract

As largely showed in literature, Liquid Air Energy Storage system efficiency is largely affected by the thermal performance of the sub-thermal energy storages, among which the High Grade Cold Storage is by far the most important one. The objective of the present work is to numerically investigate and compare the thermal behaviors of different novel cryogenic packed beds filled by different Phase Change Materials (PCMs). The performance of the investigated configurations is compared with that of the conventional sensible heat thermal energy storage (SH). For this purpose, a simplified transient one-dimensional numerical model to simulate both the charge and discharge phases of the HGCS system has been developed and validated against experimental results provided by an experimental campaign carried out on a lab scale HGCS at TESLAB@NTU. In addition, a preliminary economic evaluation has been performed in order to assess whether the technical advantage achieved by the introduction of the PCMs is likewise economically feasible.

SDEWES2022.0144**Data-Driven Approaches for the Techno-Economic Assessment of Waste Heat Recovery and Utilisation in the Industrial Sector**

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Abstract

The industrial sector is a critical element in the sustainability transition as it is currently the largest consumer of fossil fuels, and the consumption is forecasted to continue to increase. Approximately one-fifth of the total industrial primary energy consumption is wasted due to the lack of proven attractive schemes for effective recovery. When addressing the opportunities of industrial waste heat recovery (WHR), it is found that the feasibility depends on multiple factors, including the forms and capacities of the heat sources, the potential heat sinks, and the effectiveness, technological maturity, and economic impact of available technologies. Developing systematic approaches to identify optimal WHR options for different applications is key to effectively reduce plant-scale energy consumption. In particular, power consumption accounts for more than half of the industrial energy use, and its share is expected to grow with the expansion of electrification aspirations. In this paper, industrial WHR technologies are investigated, and tools are developed to understand the sustainability and techno-economic impact of integrating these technologies within industrial processes. We specifically propose a data-driven technology-agnostic approach to evaluate the use of heat engines, which can in practice be organic Rankine cycle (ORC) systems, and of thermally-driven (i.e., absorption) heat pumps in the context of industrial WHR for plant-scale power demand reduction. The scope of this work explores three pathways to achieving efficiency improvements in bulk chemicals plants, represented by olefins production facilities, which are: (i) direct onsite power generation; (ii) enhancement of existing power generation processes; and (iii) reduction in power consumption by compressor efficiency improvements through waste-heat-driven cooling. The techno-economic performance of these technologies is assessed, with particular attention to industrial facilities that reside in hot climates, using fine-tuned technology-agnostic thermodynamic and market-based costing models. Finally, decision-aiding performance maps are derived by varying the quantity and the quality of waste-heat sources and heat sinks, offering application-specific guidelines for selecting appropriate waste-heat recovery schemes. These findings reveal valuable factors for selecting such integration schemes for various industries and scenarios.

SDEWES2022.0202

Thermo-Economic Optimization of a Carbon Dioxide Hydrate-Based Vapor Compression Refrigeration System Using Partial Storage Strategies

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Abstract

This paper presents optimization analyses on thermo-economic performance of a new two-stage carbon dioxide (CO₂) hydrate-based vapor-compression refrigeration system using partial cold storage strategies, from levelling-load storage (0%) to full storage (100% cold storage during off-peak time). A numerical model was developed for a city scenario with a tropical desert climate, and then simplified for reducing the computational cost in full-year modelling. The empirical model has the residual sum of square of 0.12. The simulation results indicated that, with increasing the partial storage from 0% to 100%, the initial capital cost and total power consumption increase, and with the incentivization of electricity prices ratio of on and off-peak from 1.5 to 2.5, the operation cost and total annual cost raise, too. CO₂ emissions of the system were also discussed. Applying the UK economy-10 electricity tariffs, 40% of partial storage is the optimal strategy when the system lifetime is 15 years.

SDEWES2022.0266

Suitability of Hydrogen Production from Wind: a Case Study

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Abstract

Hydrogen production through electrolysis is expected to give a great contribution to decarbonization. Strong growth of renewable energies, in particular wind and solar PV, is also predicted and planned by many countries. When coupled with these renewable sources, characterized by an intermittent and variable nature, electrolyzers are subjected to part-load and dynamic operation. This can lead to low capacity factors of the electrolyzers that, in turn, can affect the overall hydrogen production cost. The design and the choice of the size of such a system is a trade-off between the maximization of renewable energy utilization and the minimization of costs. In this study, the analysis is focused on a wind - electrolysis system in which different values of the overall nominal power of the electrolysis unit are investigated. A dynamic model of the electrolyzers was developed in MATLAB, and simulations of the system operation were performed for a reference year and a fixed nominal power of the wind plant.

The impact of the overall nominal power of the electrolysis unit on key techno-economic parameters was studied. An overall nominal power equal to about 40% of the nominal power of the wind farm was found to give the maximum annual net income. The equivalent hydrogen price, defined as the selling price at which the same net income that would be obtained by selling

all the electricity produced is reached, ranged between about 3.75 and 4.9 €/MWh, for the lowest and the highest electrolysis nominal power, respectively.

SDEWES2022.0286

The Effect of Hydrogen Enrichment on Thermoacoustic Instabilities in Laminar Conical Premixed Methane/Air Flames

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Abstract

The effects of hydrogen enrichment (HE) on flame dynamics are not trivial and must be considered accurately when designing modern combustion systems. Using HE of a standard fossil fuel, thermo-acoustically stable systems may turn unstable, showing intolerable large-amplitude acoustic oscillations which may cause severe damage or performance reduction of the system. However, the linear stability of such a system has yet not been investigated in the literature. This work provides a numerical study of the effect of HE on the stability of a methane-air premixed laminar conical flame in a cylindrical tube with both ends open. The flame is modelled by the linearized G-equation, whereas acoustic propagation is modelled by one-dimensional plane waves. The flame and acoustic domain are coupled by assuming that the velocity perturbation at the flame position generates a travelling wave starting from the burner rim and propagating along the flame at a phase speed different from the mean flow velocity. The results show that the instability of the system can be enhanced for small values of H₂ concentrations, whereas a stable operation range is obtained in an interval of high H₂ concentrations, $0.56 < \xi_{H_2} < 0.71$.

SDEWES2022.0310

Integration of Ocean Thermal Energy Conversion and Pumped Thermal Energy Storage

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Abstract

The increasing penetration of variable renewable energy (VRE) in electric generation systems is a fundamental goal to reduce greenhouse gases emission. The variability and unpredictability of these energy sources require energy storage systems to reduce power fluctuation in electricity networks and avoid curtailment.

Several types of energy storage have been proposed in the literature, but few of them are able to operate at high charging or discharging power. Thermally-Integrated Power to Heat to Power (TI-PTES) systems are an interesting technology that can be used for this scope if the heat source adopted for thermal integration can provide significant thermal power. The ocean temperature gradient in tropical areas is an attractive heat source to be coupled with the PTES system to realise an efficient electric storage system. In this study, a heat pump refrigerated by the warm tropical surface water uses electricity surplus from VRE to heat an amount of water contained in an end-life cargo ship, used as water storage. End-life ships allow the storage of several thousands of tons of hot water corresponding to some tenth MWh of thermal energy, which also benefits a second life of the vessels. The system discharges the stored energy through an ORC cycle refrigerated by the cold deep seawater when VRE production is low. Therefore, the PTES is externally integrated through the realisation of an Ocean Thermal Energy Technology (OTEC) system. A sensitivity analysis of the storage size and temperature is proposed through detailed modelling of the system. Results show that the round-trip efficiency may achieve values higher than 60 %, and an equivalent electric battery capacity of 20 MWh is ensured by using commercial bulk carriers or tankers ship as end-life ships acting as energy storage.

SDEWES2022.0315**System-Driven Design of Hybrid Electricity- and Hydrogen-Based Systems for Domestic Heat Decarbonisation**

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Abstract

This paper explores various combinations of electric heat pumps (EHPs), hydrogen boilers (HBs), electric boilers (EBs), hydrogen absorption heat pumps (AHPs) and thermal energy storage (TES) to assess their potential for delivering cost-efficient low-carbon heat supply. A technology-to-systems approach is adopted in the paper based on comprehensive thermodynamic and component-costing models of various heating technologies, which are integrated into a whole-energy system optimisation model to determine cost-effective configurations of heating systems that minimise the overall cost for both the system and the end-user. Case studies presented in the paper focus on two archetypal systems that differ in terms of heat demand and availability profiles of renewables (North and South). Modelling results indicate a preference for a portfolio of low-carbon heating technologies including EHPs, EBs, HBs and TES, while AHPs are not chosen for investment due to their high investment cost. Capacities of the four heating technologies are found to vary significantly depending on system properties such as the volume and diversity of heat demand and the availability profiles of renewable generation. The bulk of heat (83-97%) is delivered through EHPs, while the remainder is supplied by a mix of EBs, HBs and TES. The results also suggest a strong impact of heat demand diversity on the cost-efficient mix of heating technologies, with higher diversity (i.e. lower coincidence factor) favouring less EHP and more of the other, less capital-intensive heating options. Finally, if only a subset of heating technologies is available for investment, the modelling suggests that coupling EHPs with TES is the second best solution in the North system, while in the South it was the combination of EHPs and EBs.

SDEWES2022.0316

System-Driven Design of Flexible Nuclear Power Plant Configurations with Thermal Energy Storage

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Abstract

Nuclear power plants are expected to make an important contribution to the decarbonisation of electricity supply, together with variable renewable generation. Previous work by the authors identified significant potential benefits of coupling nuclear reactors with thermal energy storage (TES) and secondary power generation cycle systems to improve the plant operational flexibility. This paper presents a system modelling approach to identifying configurations of flexible nuclear plants that minimise the investment and operation cost in a decarbonised energy system, effectively proposing a system-driven design of flexible nuclear technology. Case studies presented in the paper explore the impact of system features on plant configuration choices. The results suggest that cost-efficient flexible nuclear configurations should adapt to the system they are located in. In the main low-carbon and net-zero carbon scenarios and for a standard-size nuclear unit, it was found to be cost-efficient to install around 500 MW_{el} of secondary generation capacity and 4.5 GWh_{th} of TES capacity, resulting in an equivalent TES duration of 2.2 hours. Enhancing the nuclear plant flexibility was found to be less attractive when applied to a large number of nuclear units or when exposed to high interest rates, but more attractive if battery storage cost was higher or there was no option to invest in carbon offsetting technologies. Net system benefits per unit of flexible nuclear generation for the main scenarios were quantified at £29-33m/yr for a wind-dominated system and £19-20m/yr for a solar-dominated system.

SDEWES2022.0380**Dynamic Simulation of Solar Thermal Field for District Heating and Cooling Applications: Development and Validation of a Novel Optimization Tool**

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Abstract

District heating and cooling (DHC) systems, especially the fifth-generation ones driven also by renewable energy sources, can successfully reduce the energy consumption and carbon dioxide emissions in different countries. Among the possible renewable energy generation systems to be coupled to DHC networks the solar-based are certainly the most suitable ones. In this framework, simulating both the thermal and hydraulic behaviour of the solar field assisting the thermal network is essential to identify its optimal layout design, components sizing, and operating logic, also with the aim of guarantying the highest solar fraction to the district network system to which it is coupled to. In this context, this study presents a novel dynamic simulation tool for solar thermal generation plants performance assessment, developed in Matlab-Simscape/Simulink environment. The developed simulation tool, taking into account a large number of pivotal system parameters, and capable of detailly assess also the hydronic behaviour of the system, is also capable to perform suitable multi-objective optimizations to minimize different objective functions by also considering possible operational constraints (such as minimum and maximum field/user flow rate, minimum and maximum temperature required by the users, etc.). To verify its reliability, the mathematical model was suitably validated against experimentally gathered data of an existing solar field in the service of the district heating system of Geneva. The resulting validated tool will be then adopted to perform suitable optimization of the proposed Geneva solar field aiming at improving its solar fraction over the entire year. The same analysis can be conducted to perform comprehensive optimization of existing and new solar fields in order to maximize their production as a function of the investigated layout, control logic, and weather zone. Finally, predicting control strategies will be tested to evaluate the possibility of further maximising the renewable energy share of the district heating and cooling network.

SDEWES2022.0386**Analysis of the Performances of a Solid Oxide Fuel Cell Fed by Biogas: an Integrated Experimental and Simulative Approach**

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Abstract

Solid Oxide Fuel Cells (SOFC) are efficient, modular and fuel-flexible electrochemical devices. This technology can be coupled with biomass-derived gases to realize an efficient, decentralized and zero-emission energy conversion based on local renewable resources/waste. Limitations of stationary operation of a SOFC fed with a biogenic gas are related to the power output, due to low fuel content in the feedstock, other than possible degradation of performance in time. In this work an integrated experimental/simulative analysis is carried out for an electrolyte supported SOFC single cell (100 cm²) fed with a biogas mixture obtained by simulation of anaerobic digestion and subsequent clean-up plant layouts to evaluate SOFC performances under this fuel. Experimental tests are carried out in different conditions (hot/cold recirculation; fuel utilization factor UF_f between 65-85%) to map the SOFC performances. A two-step 0-D model of the gas conversion processes is developed in MATLAB, comprising both chemical and electrochemical gas conversion routes which is compared and validated by experimental data obtained by Gas Chromatography (GC) measurements. Results show that suitable and stable cell performances are obtained while feeding the SOFC samples by biogas (720-800 mV; 0.16-0.2 W/cm²). Simulation results (gas composition and UF_f) show good correspondence with the GC data (error range <5% for the matrix gases and <10% for water) evidencing that the SOFC processes under clean biogas are close to chemical equilibrium and can be represented to a certain extent by a thermodynamic model.

SDEWES2022.0470**Experimental and Theoretical Analysis of a Micro-Cogenerative Solar ORC Equipped with a Variable Speed Sliding Rotary Vane Expander**

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Abstract

A Promising solution for the combined heat and power (CHP) production is certainly the Organic Rankine Cycle (ORC)-based power unit. Solar-based ORC power units are frequently employed in CHP systems in residential buildings ensuring a simultaneous production of thermal energy and electrical power with lower emissions with respect to a separate production. Solar-based ORC plants frequently work in off design conditions due to the variability of the hot source thermal energy caused by the variation of solar power availability and Domestic Hot Water (DHW) requirements. For this reason, the design and the selection of the components should be carefully performed. In this sense, the choice of the expander is fundamental being this component the one which affects most the plant behavior. For such small-scale applications, volumetric devices are generally preferred for their capability to address off-design conditions, elaborate two-phases working fluid and their lower revolution speed. Among volumetric machines, Sliding Rotary Vane Expander (SVRE) is one of the most adopted solutions thanks to its reliability, low manufacturing cost and operating flexibility. This latter feature is amplified when the revolution speed of the machine can be varied for many reasons. Indeed, it is known that acting on the revolution speed the expander permeability can be changed. Permeability is defined as the attitude of the machine to be crossed by working fluid, thus, acting on this parameter the expansion ratio can be kept close much as possible to the design value. For this reason, the revolution speed variation is a very effective control parameter which, together with the pump speed variation (i.e. flow rate variation) guarantees the widening of the operating range of the plant. Nevertheless, the expander behaviour, and consequently that of the whole plant, is highly affected by the variation of the expander speed. Hence, the relation between revolution speed and the performance of expander and of the whole plant should be carefully assessed. To achieve this goal, in the present analysis a fully instrumented ORC unit was developed. Here, two 24 kW electric resistances simulates the solar source heating up 135 L of water stored in a Thermal Energy Storage reservoir. The water acts as hot source of the ORC unit and its temperature is continuously modified by the thermal energy requests. The key component of the plant is a 0.75 kW SVRE whose revolution speed was varied via a regenerative inverter. A dedicated experimental campaign was carried out observing the expander and plant performance as a function of main relevant variables, main one the expander speed of revolution. The experimental analysis was supported by a dedicated expander permeability model validated thanks to the huge experimental dataset.

Special session: Energy efficiency and renewable energy sources: progress and developments towards eco-friendly, fuel-efficient, and decarbonized future

The worldwide attention to climate changes, the reduction of the energy demand, the spread of renewable energy sources are key points on which to act for a future decarbonisation of our countries and for a reduction of greenhouse gas emissions of 80–95% by 2050. All these actions may significantly affect the economic, energy and social policies of Countries around the World.

For these reasons, energy efficiency actions in building-plant systems and transport sector, the exploitation of renewable energy sources, development of energy community are being investigated by researchers all over the World.

The development and diffusion of energy efficiency actions are oriented to: energy diversification, reduction of polluting emissions, development of local green economies and many others. However, several aspects need to be investigated and improved. For example, there is the non-programmability of the energy produced by renewable systems which poses many critical issues for the management of energy grid. Thus, the implementation of suitable energy planning strategies is also crucial to find a balance between supply and demand.

In this context, this Special Session aims at collecting the most significant and recent studies dealing with the following topics not limited to:

- Energy Planning
- Polygeneration systems based on renewable energy sources
- Geothermal power plants
- Geothermal energy for heat production
- Advanced thermal storage
- Advanced electrical storage: novel batteries, compressed air energy storage (CAES), flying wheels, supercapacitors, etc.
- District heating and cooling systems, 4th and 5th generation
- Water pumping by renewables
- Thermally driven water desalination
- Electrically driven water desalination
- Integration of renewables in the transport sector for electrical vehicles
- Use of biofuels in transport sector
- Integration of renewables for biomethane production
- Energy efficiency in wastewater treatment plants

- System dynamic simulation
- Integration of renewable systems in buildings
- Net or Plus Zero Energy Buildings
- Energy efficiency and integration of renewables in HVAC systems
- Heat metering
- Innovative renewable energy systems (solar technologies, wind turbines, geothermal wells, biomass, wave, hydropower plants)
- Optimal integration of different renewable energy sources
- Innovative high energy efficiency systems (heating, cooling, lighting, etc.)
- Economic assessment and funding policies
- Impact of pandemic situation on energy consumption

Prof. Laura Vanoli, Università degli Studi di Napoli Parthenope, Napoli, Italy

Prof. Francesco Calise, University of Naples Federico II, Naples, Italy

Dr. Diana D'Agostino, University of Naples Federico II, Naples, Italy

Dr. Maria Vicidomini, University of Naples Federico II, Naples, Italy

Laura Vanoli - Laura Vanoli is a full professor of Applied Thermodynamics at the Engineering Department of the University of Naples Parthenope. In 1997 she obtained her five years master degree with honours in Mechanical Engineering from the University of Cassino. In 1999 she gained her Ph.D. in Industrial Engineering at the same University. From November 1999 to October 2003 she was an assistant professor at the Department of Industrial Engineering at the University of Cassino. From November 2003 to January 2005 she worked as an assistant professor at the Department of Food Science of the University of Naples Federico II. In September 2004, she was visiting researcher at the Energy Management Institute of Virginia Polytechnic Institute and State University (USA). From January 2005 to October 2008 she has been working as an associate professor at the Department of Food Science of the University of Naples Federico II. From November 2008 to December 2016 she was an associate professor at the Engineering Department of the University of Naples Parthenope. From December 2016 to February 2019 she was a full professor at the Civil and Mechanical Engineering Department of the University of Cassino and Lazio Meridionale. Her research interests cover: thermodynamic and thermoeconomic analysis of advanced energy systems, energy saving, renewable energy sources, thermo-fluid-dynamic measurement. Over the last ten years, she has been working on simulation optimization and exergy analysis of hybrid SOFC-gas turbine power systems, dynamic simulation and thermoeconomic analysis of polygeneration systems based on renewable technologies and sources. On these subjects, she has written more than 100 scientific papers, mostly published in International Journals and Proceedings of International Conferences. She has coordinated and participated in several research projects funded by the Italian Ministry for Research (MIUR), and

private companies. She thought several modules at the Universities of Cassino, Napoli Federico II and Napoli Parthenope: Energetics for Master of Science degree in Mechanical Engineering, Applied thermodynamics for BA degree in Food technology, Applied thermodynamics for BA degree in Industrial Engineering, Exergy analysis for BA degree in Management Engineering, Energy Management for Master degree in Management Engineering. Since 2015 she has been an adjunct researcher at the Engines Institute of the Italian National Research Council. Currently, she is the coordinator of the Ph.D. international program in Energy Science and Engineering of the University of Naples "Parthenope".

Francesco Calise - Francesco Calise was born in 1978 and graduated cum laude in mechanical engineering from the University of Naples Federico II, Italy in 2002. He obtained the Ph.D. degree in Mechanical and Thermal Engineering in 2006. From 2006 to 2014, he is a Researcher and Assistant Professor of applied thermodynamics at the University of Naples Federico II. In 2014 he has been entitled as Associate Professor at the University of Naples Federico II. His research activity has been mainly focused on the following topics: fuel cells, advanced optimization techniques, solar thermal systems, concentrating photovoltaic/thermal photovoltaic systems, energy saving in buildings, solar heating and cooling, Organic Rankine Cycles, geothermal energy, dynamic simulations of energy systems, renewable Polygeneration systems and many others. He was invited lecturer for some courses or Conferences (UK and Finland). He teaches several courses of energy management and applied thermodynamics at the University of Naples Federico II for BsC, MS and PhD students. He was a supervisor of several Ph.D. degree theses. He is a reviewer of about 30 international Journals. He was involved in several Research Projects funded by EU and Italian Government. He is Member of the Editorial Board of 10 International Journals. He was a Conference Chair and/or member of Scientific Committee in several session of International Conferences. He is Vice-Chair Cross Reader for the FET OPEN Projects funded by EU

Diana D'Agostino - Diana D'Agostino (Naples, Italy, 1987) is an Engineer graduated cum laude on 2013 in "Construction Engineering" at the University of Naples Federico II (Italy), with a thesis on Net Zero Energy Buildings. From 2012 to 2014 she collaborated with an engineering firm, focusing on projects in the energy sector. From 2015 to 2017 she won three scholarships at the Department of Industrial Engineering (DII) of the same University, within the "I-TOWN" European project: her research activity focused on the optimization of building-plants system with reference to energy efficiency and performance of air conditioning systems. Since January 2018 she is a Ph.D. student in Industrial Engineering at the DII. On 13th of October she earned the Ph.D. degree. From December 2021 she is a research fellow at DII. Her main research topics are: use of low enthalpy geothermal energy source in air conditioning systems, particularly by earth-to-air heat exchangers and geothermal heat pumps; Nearly, Net or Plus Zero Energy Buildings; energy refurbishment of existing and historical buildings; systems that use solar renewable energy, such as photovoltaic, concentration photovoltaic, solar thermal and CPV/T (concentrating photovoltaic/thermal). She reviewed several articles in the field of energy and engineering on International Journals indexed on Scopus and since April 2020 she is an editorial board member of Journal of Advanced Thermal Science Research. She was co-supervisor of more than 40 Master's Degree theses in Engineering. Since 2020 she participates to Med-EcoSuRe (Mediterranean University as Catalyst for Eco-Sustainable Renovation), a project funded by the European Union, under the ENI CBC MED program: this program aims to promote cross-border cooperation in the Mediterranean region in order to identify the best strategies for the energy and eco-sustainable retrofitting of buildings. She was a conference chair of the International Conference SDEWES 2020.

Maria Vicidomini - Maria Vicidomini was born in 1988 and graduated cum laude in Environmental engineering at the University of Naples Federico II, Italy in 2013. From 2013 to 2014, she was a fellow researcher at the University of Naples Federico II. She obtained the Ph.D. degree in Industrial Engineering in 2018. In 2019 she has been entitled as Researcher at the University of Naples Federico II. Her research activity has been mainly focused on the development of dynamic simulation models for the energy, exergy, economic and environmental analysis and impact of innovative systems for distributed polygeneration systems, supplied by renewable energy (geothermal, solar, wind energy) and natural gas. Building Integrated Solar Thermal Systems and internal combustion engines for the production of heat, cool and power. Solar heating and cooling systems. Solar desalination systems. Hybrid renewable system based on wind, solar and geothermal energy. Electrical storage. Electric vehicles. Her research activity is also developed in cooperation with several international institutions (Portugal, Iran, Turkey, Denmark, China, Croatia, Poland, Germany, Canada). She was a supervisor of several BsC, MS and PhD students at the University of Naples Federico II. She is a reviewer of about 15 international Journals. She was guest editor in special issues on International Journals. She is a member of the scientific committee of several international conferences and she is also involved in the organizing committee of the CEER 2020 Conferences. She was a conference chair and presenter in several sessions of International Conferences.

Invited submissions

SDEWES2022.0018

New Computational Workflow Based on Genetic Algorithm for Robust Multi-Objective Optimization for the Nzeb Target

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Abstract

Net Zero Energy Buildings (NZEBS) play an important role in energy decentralization by using new strategies to save and harvest energy. However, uncertainties concerning stability of energy production from renewables and unpredictable scenarios that may occur during building life frequently cause measured performance of the building-plants system to differ from predictions. For the achievement of NZEB target, it is crucial to investigate, early in the project, the best design alternatives, also considering uncertain circumstances. The scope of this work is to provide a new workflow based on multi-objective optimization that sets the robustness of the building-HVAC system configurations as an optimization Key Performance Indicator, along with financial aspects, also verifying optimal design solutions for NZEB target. An integrated technique that combines open-source coding language Python with dynamic energy simulation engine EnergyPlus is proposed. First obtained results on the attainment of robust energy self-sufficiency of NZEBs favour designs with lower energy demand that use ground source heat pumps GSHP and variable refrigerating flow systems VRF for air conditioning and medium-high size of photovoltaic panels, although with high investment costs.

SDEWES2022.0019

HVAC Systems, Covid-19 Infection Risk Mitigation and Energy-Cost Analysis

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Abstract

In March 2020 a state of emergency was declared, due to the worldwide spread of the new SARS-CoV2 virus. The main way of spreading the Covid-19 infection is inhalation of respiratory droplets produced by an infected person. For this reason, the World Health Organization (WHO) highlights the important role of mechanical ventilation in buildings. In this paper various HVAC systems were analysed, evaluating which of these is the most efficient to reduce the contagion from Covid-19. The Walles-Riley model was used to derive the number of external air changes per hour needed to reduce contagion. The analyses were conducted on an existing office building in Central Italy dynamically simulated, both under standard conditions and in conditions that counter the spread of the virus. The energy model was validated through energy bills. An energy cost investigation was also carried out to assess the increase in expenditure compared to standard conditions. The results show that 5 vol/h is the number of external air changes necessary to drastically reduce the probability of Covid-19 infection, but this value requires a high energy consumption. A solution to this problem could be to couple the intervention on the HVAC system with energy efficiency measures on the building envelope.

SDEWES2022.0040**Numerical Simulation of Biogas Chemical Looping Reforming in a Dual Fluidized Bed Reactor**

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Abstract

Climate changes call for both an increase in renewable sources utilization and the development of efficient energy conversion processes. Biogas, a product of the anaerobic digestion of organic matter, is a renewable gaseous mixture of CH₄ (45%–65%), CO₂ (55%–35%), H₂O (2%–10%), and minor impurities. The amount of heat produced by biogas combustion directly depend on the CH₄ content since all the other species behave as inert. Biogas upgrading (removal of CO₂) and cleaning (separation of impurities) is consequently mandatory to increase its calorific power. Alternatively, biogas can be reformed into syngas, a gaseous mixture of H₂ and CO that may further be exploited for hydrogen, power production, and biofuel syntheses. In the present work a biogas Chemical Looping Reforming (CLR) process is proposed and numerically studied. The proposed model couples a hydrodynamic simulation of a Dual Fluidized Bed (DFB) system equipped with non-mechanical valves for bed solids circulation with a 1D, dynamic and non-isothermal CLR model developed to determine temperature and oxidation degree of solids and gaseous species concentration at the exit of both Air and Fuel reactors. The DFB, consisting of a riser and of a bubbling fluidized bed (BFB) as Air and Fuel reactors respectively, was modelled as a combination of interconnected blocks (riser, cyclone, L-valve, BFB, loop-seal) after selection of constitutive equations. Nickel (II) oxide was selected as oxygen carrier. The effects on process performances of variations in biogas CH₄/CO₂ ratio and water content, as well as in the fuel reactor operating conditions, have been addressed.

SDEWES2022.0043

Biomass-Based Renewable Energy Community: Energy and Environmental Assessment of the Tirano Municipality

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Abstract

Recent European Directives have promoted Renewable Energy Communities as pivotal drivers to achieve energy and environmental European targets.

Thus, this paper analyses the energy and environmental feasibility of a Renewable Energy Community in the Northern Italy. An energy audit is carried out to identify the electricity balance within the primary substation and the thermal energy demand of the existing district heating network. The technical features of the energy conversion systems serving the Renewable Energy Community are determined: a biomass-based congenator, a mini-hydro, and a distributed photovoltaic system. Different scenarios are identified, in terms of congenator operating mode and photovoltaic systems peak power.

The results show that, in the best scenario, the annual renewable electricity increases by 25.5% and 69.9% of the total thermo-electric requests are satisfied through biomass utilization. The bi-directional interactions with power grid are reduced from 60.0% to 51.7%. The electricity sharing allows a reduction of carbon dioxide emissions equal to 18.5%.

SDEWES2022.0055

Biogas to Biomethane: Feasibility Assessment of an Integrated Anaerobic Digestion and Power-to-Methane System

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Abstract

In this study, the integration between anaerobic digestion and Power-to-Gas system is proposed and numerically investigated. The rationale behind the proposed layout is that direct conversion of biogas CO₂ content to CH₄ without its prior separation increases biomethane yield and reduces to nearly zero carbon dioxide emissions from biogas cleaning/upgrading process. Detailed design of a methanation unit composed of multistage adiabatic reactors is presented by combining a thermodynamic equilibrium analysis carried out by means of the Aspen plusTM software and process simulations at steady state (including kinetic modelling) implemented in MATLAB. The performances of the proposed layout are benchmarked against those of conventional biogas upgrading techniques in terms of methane losses and purity and CO₂ recovery. The proposed system not only equals conventional technologies with respect to produced methane purity (95%) but also outperforms them with respect to CH₄ losses (~0%) and CO₂ recovery (>97%).

SDEWES2022.0271

Assessing the Eco-Sustainability of Sewage Sludge Management

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Abstract

Sludge management has become one of the most challenging issues for wastewater treatment plants, especially due to strict regulations for its reuse or disposal. Indeed, on one hand, the practices commonly used for sewage sludge management are no longer readily acceptable, on the other hand, new policies need to present affordable standards. At the same time, unlocking the potential of sewage sludge is recognized as a way to improve circular economy and sustainability of wastewater sector, as promoted by the European Green Deal. For these reasons, both the industrial and academic communities are investigating new solutions to improve the sustainability of sludge treatment.

In this context, assessing the environmental and economic sustainability of sludge management is fundamental to compare different strategies. The pertinent available literature on sludge management proposes indicators that take into account:

- specific aspects, such as production, reuse or treatment/disposal costs;
- different categories of environmental impact through the methodology of life cycle assessment.

This work aims at defining a comprehensive and intuitive assessment method that allows taking into account both the economic and the environmental impact of sludge management. A benchmarking of the most common practices for sludge management as well as of virtuous case studies proposed in the literature is carried out in order to identify different classes of environmental and economic sustainability that could be used to assess different scenarios. The proposed assessment method is finally demonstrated by applying it to a case study.

SDEWES2022.0382

Dynamic Modelling of Geothermal Heat Pump System Coupled with Positive-Energy Building

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Abstract

During the last decades, several studies have shown that heat pumps are a promising solution to reach the European Union targets on climate change mitigation, since they satisfy the energy needs for heating, cooling and hot water production employing a single device and using a significant share of renewable energy. However, the full exploitation of the energy-saving potential of heat pumps is a difficult task for designers to achieve, as several factors, such as the variability of outdoor climatic conditions, the control logic of the system and the system configuration, influence the energy performance. High Coefficient of Performance (COP) and low environmental impact make Ground Source Heat Pump (GSHP) systems one of the most suitable technologies for the heating and cooling services, to promote the decarbonization of the building sector, especially in urban areas. This study aims to evaluate a set of optimal strategies for heat pump systems to obtain the best exploitable performance. To do this, the authors analyze the performance of an office building, located in Swansea University Bay, which is already featured with renewable energy technologies for electricity and heat generation: an integrated photovoltaic roof to generate electricity and a wall- photovoltaic thermal system. The current configuration ('baseline scenario') of the building-plant system was modelled in the TRNSYS 17 suite and the influence of different parameters was studied. To complement the already high use of renewables the authors propose an alternative scenario for the Active Office Building integrating the use of geothermal heat pumps with the existing systems. The two scenarios were compared. The comparison of the results of the energetic analysis shows an energy saving of 11% in terms of primary energy and a reduction of GHG emissions.

SDEWES2022.0387

Environmental Performances of the Geothermal Production of Electricity and of District Heating and Cooling Measured by Means of Life Cycle Assessment and Emergy Accounting

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Abstract

The worldwide consumption of energy has been characterized by a significant increasing trend in the last decades and is still projected to grow in the next years. This is due to the advancement of human societies and of technological development. However, this comes with the cost of increased pollution and contribution to environmental degradation. The energy sector is one of the major contributors to the emissions of significant amounts of greenhouse gas. A fair access for everyone to energy sources capable of meeting the global needs without further degrading natural and urbanized ecosystems has become of paramount importance both from a scientific and from a regulatory point of view. In this work, a sustainable medium enthalpy geothermal system for the production of electric and thermal energy is proposed and assessed for its environmental performances. The investigated case study is set in Campania region, Southern Italy, in an area known for a relevant volcanic activity. The system is composed by an Organic Rankine Cycle (ORC) for electricity production and by a grid providing district heating and cooling to residential and office buildings. The environmental performances are assessed by means of the Emergy Accounting (EMA) method, measuring the support to the process from the techno and the bio spheres and the load of the system on the environment, thus providing a holistic understanding of the case study. The calculation of the EMA conversion factors, the Unit Emergy Values (UEVs), could benefit from the use of reliable inventories. The databases used within the Life Cycle Assessment (LCA) method provides a huge amount of reliable, peer reviewed inventories used at global level. This work proposes a calculation procedure of UEV values based on the LCA inventories, comparing them to previous calculated ones. The system is also compared to current and to improved strategies for the heating and cooling of the buildings and for electricity production, confirming it as a sustainable energy production pattern characterized by low environmental loads. The calculated UEVs seem to be reliable when compared to literature values, strengthening the bond between LCA and EMA methods. The obtained results confirm the environmental feasibility of the analyzed system and its beneficial environmental performance, also when compared to fossil based and renewable energy production system, validating its fitness within a decarbonization perspective.

SDEWES2022.0404

Sustain-El: the Heat Pump Based on a Solid State Refrigerant Showing Elastocaloric Effect

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Abstract

Recently, a progressive interest toward elastocaloric cooling, belonging to solid-state technologies based on caloric effects, as promising alternatives to vapor compression technology, has grown. Elastocaloric effect is a physical phenomenon manifesting in pseudoelastic materials, Shape-Memory Alloys (SMA), where a temperature change occurs when a mechanical structural stress field is adiabatically applied. This technology is completely sustainable, since the refrigerants employed are solid-state and therefore are not due to a direct contribution to global warming, and it can be more efficient than vapor compression. To date, the elastocaloric prototypes developed in the world are about a dozen and they are still far from prospects of commercialization for residential cooling application.

In this context the SUSSTAINABLE (acronym of "a Solution Using Solid-STate-cooling: An INvestment Eco-compatible") project was born: the development of the elastocaloric device, called SUSSTAIN-EL, has the purpose to make it be the first Italian elastocaloric prototype that could not limit itself in residing in the target of proof-of-concept but, thanks also to its size addressable to the macroscale, it can be relied for heat pump and air conditioning applications.

A twin 2-D numerical model of SUSSTAIN-EL has been developed and used to perform the investigation toward the identification of its most suitable design parameters in order to exploit at maximum its thermofluid-dynamic behavior. The structure of the model, the analysis, the sets of operating conditions, the results and the conclusions drawn are reported in this paper.

SDEWES2022.0405

Cooling of Electronic Circuits Through Elastocaloric Solid-State Technology: the Development of the Check Temperature Prototype

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Abstract

In recent years, elastocaloric cooling, belonging to solid-state technologies based on caloric effects, have attracted great interest representing a new and viable alternative to vapour-compression. The physical phenomenon on which solid-state systems are based is elastocaloric effect manifesting in shape memory alloys, where a temperature change occurs when a mechanical structural stress field is adiabatically applied. This technology is completely sustainable, since the refrigerants employed are solid-state and therefore are not due to a direct contribution to global warming, and it can be more efficient than vapor compression.

Controlling the temperature of electronic equipment is also essential and, currently, there are not elastocaloric devices specifically addressed to this application. In this context CHECK TEMPERATURE (acronym of “Controlling the Heating of Electronic Circuits: a Key-approach Through Elastocaloric Materials in a Prototype Employing them as Refrigerants of an AcTive UltrasMall Refrigerator”) project was born: the main purpose of this project is to develop an elastocaloric device targeted on miniature scale for environmentally friendly cooling of electronic components. The development of the numerical model of CHECK TEMPERATURE is a necessary and preliminary operation to conduct parametric investigations aimed for the evaluations of the energy performances under various working conditions. In this paper preliminary results are presented.

SDEWES2022.0414

Sustainability Assessment in Renewable Energy Communities

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Abstract

In Italy, Collective Self-Consumption (CSC) and Renewable Energy Communities (REC) are addressed within the Integrated National Energy and Climate Plan (INECP), whose main objective is to implement a new energy strategy to mitigate environmental, social and economic issues. The aim of the INECP is based on some fundamental points such as making citizens and enterprises at the center of the energy transition and enhancing the current electric grid. The recent regulation actions related to these new actors have enhanced the implementation of almost 30 RECs initiatives, in the last year, active or in the process of being activated. This type of regulation incentivizes the electrification of end uses, rewarding RESs/ CSCs participants with a fee for each kWh of shared electricity. To enhance the electrification, the Italian regulation also imposes a minimum capacity of renewable electric energy generators for new constructions and recharge stations in parking areas. This type of mandatory installations has usually a high cost, moreover the incentive related to the renewable electric energy generation and consumption are received only for the share of the generation exceeding the minimum power capacity installed. Another constrain in the REC incentive scheme is the impossibility to sell electric energy to a third party. The configuration proposed by RECs and CSCs could bring three main advantages: economic benefits, possible thanks to incentives that promote the use of shared renewable electric energy; environmental benefits, given by the production of energy from renewable sources instead of fossil fuels; social benefits, given by the economic and environmental paybacks shared by all the members of the REC. All these benefits are maximized if the renewable electric capacity installed is suitable according to the consumption trend, which changes with the intended use of the buildings. For this reason, the present work focuses on evaluating the advantages related to the combinations of different types of users and the optimum PV capacity to install when applying the REC incentive. This is done comparing the outputs of a techno-economic assessment for two identical new buildings, whose heating and cooling services are provided by geothermal heat pumps, considering different PV capacity installation, different intended use and different incentive scheme. The incentive schemes considered are two: one foresees the participation to a REC, while the other provides revenues to the user, thanks to the on-site exchange of PV electrical power incentive and the sale of the EVs recharge service for the commercial buildings, which, for the current Italian legislation, is not allowed.

SDEWES2022.0455

Dynamic Simulation of a Solar System for the Liquefied Biomethane Production by Anaerobic Digestion: a Case Study for a Harbour in Naples

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Abstract

This work aims at developing a dynamic simulation model of a solar powered anaerobic digestion system including upgrading and liquefaction processes for the production of liquefied biomethane. The investigated layout includes anaerobic digesters supplied by the organic municipal solid wastes, biogas upgrading units, biomethane liquefaction units, photovoltaic panels, evacuated solar thermal collectors, electric and thermal storage systems. Solar thermal collectors are used to supply heat to the anaerobic digesters. The photovoltaic field is employed to supply electricity to the auxiliary devices included in the plant. The developed dynamic model includes the algorithm evaluating the electric consumption for the biogas upgrading and biomethane liquefaction units as well as the dynamic evaluation of the thermal load of the anaerobic digesters. The whole plant is designed to produce liquified biomethane to be supplied as fuels to some ships traveling from the mainland to the islands of the Gulf of Naples (South of Italy). The anaerobic digester, biogas upgrading and biomethane liquefaction units models are developed in MATLAB® environment and subsequently integrated in TRNSYS18 environment, where the whole plant is modelled. Model results highlight that such system can achieve a significant energy saving and CO₂ emission reduction, that is a strategic outcome for the harbours located in densely populated cities. In particular, the proposed system is able to reduce the energy consumption for producing liquefied biomethane by 38%. Moreover, considering the present Italian funding policy for biomethane, such system also exhibits a simple payback period of 4.47 years.

Special session: Harnessing the resource potential of our seas in a sustainable manner

The sea represents a huge resource for renewable energy (Blue Energy - BE). BE is the energy which can be harnessed from the ocean or the marine wind and it is comprised of five main types according to the origin of the extracted power, namely marine (offshore) wind, surface waves, tides/currents, and thermal and salinity gradients. Although the growth of offshore renewable energy technologies has so far been relatively slow compared to those onshore, it is anticipated that in the future BE will substantially contribute to the energy demands of coastal and insular areas, at the same time protecting and conserving the marine environment.

The Blue Growth Strategy proposed by the Commission in 2014 emphasized that harnessing the economic potential of BE in a sustainable manner represents a key policy area for the EU, which requires the involvement of the widest possible range of stakeholders in order to optimize capacity building and to achieve the necessary critical mass. The BE sector was, in fact, indicated as one of five developing areas in the 'blue economy' that could drive the creation high-quality jobs and pave the way for a new breed of science-trained professionals, enhancing eco-efficient value creation all along the value and supply chain. Moreover, exploiting this indigenous resource would help reduce the EU dependence on fossil fuels for electricity generation, and enhance energy security. In particular, islands and remote coastal regions can especially benefit from BE development, as it would provide a viable alternative to expensive and heavily polluting **fossil** fuelled plants, and contribute to their energy self-sufficiency.

The exploitation of Blue Energy clearly opens new frontiers in the maritime sector, by creating synergies with long established traditional activities, yet opening the door to knowledge-driven **innovation**. It offers the opportunity to pool costs and boost several connected economic sectors. Some examples of synergic activities that are welcome in this Special Session include: BE Studies and technology design; Estimation of BE exploitable resources; Marine environment assessments for BE exploitation; Evaluation of synergies with aquaculture and/or fisheries; BE exploitation in the naval sector; Energy production from Algae; Design and management of multipurpose offshore platforms; Socio-economic assessment of BE exploitation.

Dr. Hrvoje Mikulčić, University of Zagreb, Zagreb, Croatia

Hrvoje Mikulčić - HRVOJE MIKULČIĆ defended his PhD thesis in 2015 at the Department of Power Engineering, Energy and Environment, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb. His main research area includes: Numerical modelling of fluid flow; Solid fuel combustion; Endothermic calcination reaction; Pollutant formation, Greenhouse gasses emissions analysis and accounting; Energy intensive industry; Energy system analysis; Renewable energy; Multiphase flows; Waste-to-Energy, Carbon capture and utilization; Pollution reduction; Green ammonia. From 2009 till 2018 he worked on the research project "Numerical modelling of multiphase flow and combustion processes" financed by the Austrian Institute for internal combustion engines AVL List GmbH. He has also been working on the national scientific project: Smart energy storage for sustainable development of energy systems, financed by the Ministry of Science, Education and Sport of the Republic of Croatia. From 2016 till 2019 he was a project manager of a European INTERREG MED project PELAGOS - Promoting innovative networks and clusters for marine renewable energy synergies in Mediterranean coasts and islands. From 2019 he is a project manager of a European INTERREG MED project BLUE DEAL - Blue Energy Deployment Alliance, responsible for the Croatian part of the project. He is an author of 72 scientific papers, in scientific journals (SCI). His current Scopus h-index is 25. He is

the Associate Editor of the Journal of Cleaner Production (IF2019= 7.246). From 2014 he serves as a SDEWES Special Issue Guest Editor in the Journal of Cleaner Production (IF2019= 7.246), in the Journal of Environmental Management (IF2019= 5.647), in Optimization and Engineering (IF2019= 1.829), and from 2020 in the international journal Fuel (IF2019= 5.578).

Invited submissions

SDEWES2022.0013

A Paradigmatic Case of Long-Term Colocated Wind-Wave Energy Index Trend in Canary Islands

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Abstract

ERA5 reanalysis 40 year wind and wave data has been used around Canary Islands, since previous authors have identified strong historical increments of wind speed in this region without the corresponding increment of wave height using remote sensing data. This decoupling of long-term trends for wind and wave data is not habitual, and can be considered paradigmatic, with important results for wind and wave hybrid or co-located energy production. ERA5 wind and wave data have been validated using the Sailor Diagram for bi-dimensional evaluation of wind vector (air density and wind speed) and wave vector (wave height and period) against two buoys. After that, a wind-wave energy co-location index has been computed around the islands between 1981-2020 showing the corresponding reduction of the index along the decades. Furthermore, realistic wind and wave energy production has been computed at interesting hot-spots using an specific floating wind turbine co-located aside a oscillating buoy type wave energy converter. The seasonal study of the decadal evolution for this realistic hybrid production shows even more intense decoupling of both marine renewable energies, mainly for winter and summer, in which the Alisius winds govern the Canarian climate.

SDEWES2022.0015

Impact of Hydrodynamic Conditions on Optimum Power Generation in Dual Stage Pressure Retarded Osmosis Using Spiral-Wound Membrane

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Abstract

The Dual Stage Pressure Retarded Osmosis technique is considered for power generation. The influence of feed flow rates, hydraulic pressure, and pressure drop on mass transfer and solute diffusion in a full-scale membrane model was investigated for the first time to maximize power generation. Dead Sea-seawater, Dead Sea-reverse osmosis brine, reverse osmosis brine-wastewater, and seawater-wastewater salinity gradient resources were investigated for power generation. Results revealed a 71.07% increase in the specific power generation due to the dual-stage pressure retarded osmosis process optimization using Dead Sea-seawater salinity gradient resources. The increase in the specific power generation due to the dual-stage pressure retarded osmosis optimization was 108.8%, 63.18%, and 133.54%, respectively, for Dead Sea-reverse osmosis brine, reverse osmosis brine-wastewater, and seawater-wastewater salinity gradient resources. At optimum operating conditions, using the dual-stage pressure retarded osmosis process as an alternative to the single pressure retarded osmosis process achieved up to a 22% increase in the energy output. Interestingly, the hydraulic pressure at optimum operating conditions was slightly higher than the average osmotic pressure gradients in the dual-stage pressure retarded osmosis process. The study also revealed that power generation in the dual-stage pressure retarded osmosis process operating at constant mass transfer and solute resistivity parameters was overestimated by 2.8%.

SDEWES2022.0193

Data-Driven Tool for the Allocation of Favourable Areas for Offshore Wind Farm Development

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Abstract

The process of allocation of areas at sea for various human activities including, among others, aquaculture, renewable energy, tourism, and shipping, requires geo-spatial data, expertise on the activity sector, and the identification of the various interactions and constraints between sectors and the marine environment. For example, aquaculture and renewable energy installations cannot

be collocated within shipping routes; thus, such interactions and constraints result to a complex problem of Maritime Spatial Planning (MSP). Focusing on offshore wind farm (OWF) projects with floating structures, a rapidly expanding blue energy sector over the last decade, the identification and evaluation of the optimal sites for such development is crucial due to the variety of planning and environmental restrictions.

In this context, it is essential to establish the most determining technical criteria and analyze them appropriately for management and spatial planning purposes. In this work, we propose a method for identifying areas favourable for floating OWF development. The method leverages on geo-spatial data and an iterative optimization method that identifies favourable areas with the potential

of offshore renewable energy facility installation. Specifically, an objective function is used that includes the conditions for the operation of a floating OWF, i.e., water depth and wind speed, two main technical (or engineering) factors for the construction of a floating OWF under for both financial and technological terms. Additional constraints are considered related to other activities and infrastructure, such as distance from shore, distance from ports, and the existence of suitable electrical grid infrastructure.

The objective function, made of heterogeneous criteria, forms a multimodal surface with multiple locations of possible renewable energy installations. To solve the optimization problem we develop an optimization method that combines gradient descent and sequential Monte Carlo methods. We assess the effectiveness of the method in consistently identifying areas of deployment of floating wind energy installations and compare two variations of the method in terms of efficiency and computational expense. The proposed method is implemented in the central Aegean Sea to pre-evaluate candidate regions as regards potential floating OWF development. Further in-depth assessment is necessary in a local spatial scale combined with site-specific technical, environmental, and socio-economic data for a more reliable conclusion.

SDEWES2022.0197

Photovoltaic Module Degradation Models for On-Shore and Off-Shore Floating Systems

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Abstract

The degradation trend of photovoltaic modules depends on the technology, manufacturing techniques and climatic conditions of the site where they are installed. Longer useful life of the PV modules means that they will be able to produce much more energy than was used to build them, thus extending the useful life of the modules is a benefit for the environment and it increases the cost effectiveness of PVs. The problem of land use has prompted the development of agrivoltaic systems to exploit the same land both for the production of energy and for agriculture, and on water surfaces such as lakes and dams (floating PV).

The exploitation of floating PV systems in onshore and off-shore areas is currently under study, this constitutes an opportunity in which many factors must be taken into account; a fundamental aspect is the environmental impact, in which some recent studies have focused. Another aspect is the impact of the marine environment on PV system reliability and durability, due to stressing operating conditions.

The aim of this preliminary study is to evaluate the influence of the marine environment on the degradation trend of photovoltaic modules, based on existing models whose inputs are meteorological data from off-shore locations.

The results obtained from the application of a cumulative exposure model, unexpectedly reported a lower degradation value in the off-shore environment than on the mainland. This is because the model does not take into account some environmental factors typical of the marine environment, as highlighted in the results section.

SDEWES2022.0207**A Pod Analysis Upon Aerodynamic Structures in Wind Turbine Blades on Turbulence Conditions**

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Abstract

Applications as diverse as micro- and nano-scale UAVs, middle-scale wind-turbines and small aircrafts show a common feature: they employ airfoil-based aerodynamics as a working principle. Due to their relatively small scale and to the low wind velocities they face, their chord-based Reynolds numbers lie in the range 10^4 - $5 \cdot 10^5$, which lie within a regime known as transitional flow. Likewise, the low-altitude atmosphere they operate within makes them subject to moderate freestream turbulence levels (FTLs), ranging up to 15% according to some authors. The transitional aerodynamic structures developed upon the surface of the airfoil, particularly the so-called laminar separation bubbles (LSBs), make the task of predicting the aerodynamic behaviour of the airfoils rather complex, mainly because their high sensitivity to the external flow conditions such as the Reynolds number, the angle-of-attack of the airfoil or the FTL itself. An experimental campaign is undertaken for shedding light upon the dynamic nature of the LSBs, carrying out wind tunnel experiments on a NACA0021 airfoil subjected to a set of different Reynolds numbers and FTLs. Lift and drag forces, and pressure coefficients are measured for different angles-of-attack under the set of distinct flow conditions, and the resultant datasets are temporally analysed via the proper orthogonal decomposition (POD) technique. The decomposition of the temporal series of surface data and the processing of the most energetic POD modes recovers the position of the LSBs, properly capturing the closure point of the separation bubbles and hence the turbulence transition location. Some of the most energetic POD modes observed are closely related, in terms of shape, to the POD modes present at the reattachment point on a 5:1 rectangular cylinder. This could indicate there is a recognizable pattern in the coherent structures of pressure fluctuations when it comes to a reattached flow. Therefore, a principal component analysis as POD could be used to determine the reattachment position of the flow or the transition point in presence of a LSB.

SDEWES2022.0452

Assessment of Ship Emissions and Estimation of the Effectiveness of NO_x Emissions Control Area (Neca) Scenario for Ports in the North Adriatic Sea

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Abstract

In response to global warming, the International Maritime Organization (IMO) set rules of 50% Greenhouse Gas (GHG) reduction by 2050, from 2008 levels. Signatory countries to the IMO's regulation require frequent assessment of the contribution of GHG emissions from shipping calling at their ports or trading in their territorial waters to ensure their compliance with the regulations. This demands a rapid and accurate method to assess shipping's contribution to GHG emissions.

Current methodologies for estimating emissions from ships can be described on a scale between bottom-up and top-down methods. Top-down methods provide rapid estimates – primarily based on fuel sales reports - without considering individual vessel details. Therefore, they are less accurate and do not provide a breakdown of emissions by ship types or in specific regions. Bottom-up methodologies are detailed vessel-based estimates; however, they are data and time-demanding.

The Ship Emissions Assessment method (SEA) (Topic et al., 2021) fills the gap between bottom-up and top-down methods by providing an innovative hybrid solution for rapid but accurate ship emission estimation. It uses publically available, cost-effective data sets previously unused for emission estimates. The SEA method is a practicable tool to estimate ships' emissions in designated areas to understand regulations' effectiveness and provide emission quantification evidence. This research objective was to apply the SEA method to quantify CO₂, SO_x and NO_x exhaust emissions from containerships for the three crucial containership ports: Trieste, Rijeka and Venice, in the North of the Adriatic Sea.

The National regulations of countries sharing the Adriatic Sea coastline do not require ship compliance with the strictest IMO NO_x standard (Tier III), and consequentially the NO_x emission levels from ships remain unregulated and their quantities unknown.

The SEA methodology was applied to assess emissions and forecast efficiency in scenarios of different regulatory measures. A reduction in NO_x emissions was estimated for the event of the implementation of NECA in all three ports. Results showed that 447.13 tonnes of NO_x could be reduced each year in the North Adriatic Sea area around the ports of Rijeka, Trieste and Venice in the event that NECA regulations are stipulated.

SDEWES2022.0475

Carbon Emission Pinch Analysis for Optimal Diet Configuration Targeting

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Abstract

Carbon emission neutralisation is the future target in many countries. To achieve this target, many sectors should contribute their strength, as well as to the breeding industry. Relying on the rich marine resources in coastal cities, carbon emissions can be reduced by adjusting breeding and dietary structure. Different types of breeding species have their carbon emission extracting or generating capacities. However, complex mathematical models hinder the policymakers from adopting scientific-based solutions in the decision-making process, and those models seldom link national greenhouse gas reduction targets to local breeding policy targets. This study applies Carbon Emission Pinch Analysis and Cost Pinch Analysis to optimise the diet configurations and breeding policies to target the possible greenhouse gas reduction. The limitation of the area for breeding, the species types and the natural conditions are considered in the targeting along with their carbon emission generations. Several scenarios with different aims are considered. This study provides a visualised tool to set the breeding policy and diet configuration target.

Special session: Hydrogen Valley

Hydrogen Valley is a defined geographical area where hydrogen serves more than one end-user application, encompassing all energy-demanding sectors (mobility, industry, heating, and power). In a so-called Hydrogen Valley, hydrogen is not only an energy vector but also becomes a source of value through the achievement of cross-sectoral integration. Thus, being hydrogen just an electron and a proton, it is the most indicated energy vector to couple power and gas sectors, to be used in high efficiency and low-emission fuel cells and to decarbonise the heavy-duty transport and the hard-to-abate sectors. Earlier Hydrogen Valleys are the first base bricks to build Net-zero communities, yet a giant leap toward a fully decarbonized hydrogen economy. The ambition of a Hydrogen Valley is to completely manage internal energy resources, attempting to energy autarky. The development of such projects must be strongly supported by the local governments, in coordination with international public authorities and green recovery and resiliency plans (i.e. European Green Deal funds).

In this new collective energy paradigm, advanced knowledge and skills are called in the entire hydrogen technology chain and the complex management underpinning the build-up of synergies among the production, storage, distribution of hydrogen, and its many usages. Professional skills are not related just to hard-science technical fields but also to social sciences (i.e., a deep understanding of human mechanisms behind the market and social acceptance of hydrogen technologies). Moreover, viable economic solutions to hydrogen production from renewable energy, distribution, storage, and use still have to be found and applied.

This special session aims to collect studies from all the technical, scientific, and social disciplines to support the development of Hydrogen Valleys, to promote a debate around new insights, policymaking, theoretical system analysis, as well as reports of demonstration experiences. Scientific contributions from several fields of knowledge are welcome, intending to explore the full sustainability of this development model and its technological pillars.

Topics of interest include but are not restricted to technical, economic, social, and environmental analysis of:

- Clean hydrogen production technologies (e.g., from electrolysis, gasification reforming or partial oxidation coupled with CCUS);
- Hydrogen distribution and storage technologies (e.g. chemical hydrogen vectors, liquified and compressed hydrogen and so pipeline, trucks, trailers, compressors, tanks);
- Hydrogen technologies for mobility and hard-to-abate sectors (e.g. low and high temperature fuel cells technologies also not fuelled directly by hydrogen, hydrogen refuelling stations, hydrogen in heavy industries);
- A combination of the above mentioned technologies
- Cross-sectoral integration strategies enabled by hydrogen.

Dr. Giovanni Cinti, Università degli Studi di Perugia, Perugia, Italy

Dr. Arianna Baldinelli, Università degli Studi di Perugia, Perugia, Italy

Prof. Umberto Desideri, University of Pisa, Pisa, Italy

Prof. Enrico Bocci, Marconi University (USGM), Roma, Italy

Giovanni Cinti - Researcher at FCLab of Department of Engineering. Member of research units within projects developed by University of Perugia in the fuel cell area. Competences in the microCHP fuel cell based system design and test. Specifically, the latter relates to experimental test on Solid Oxide Fuel Cells (SOFC) and Solid Oxide Electrolyzer SOE. SOFC studies focus mainly on effect of innovative fuels (syngas, ammonia, biogas) in terms of efficiency and system integration issues. Contaminant effect is part of these studies with particular attention to H₂S and TAR as contaminant of biogas and syngas respectively. Due to the high interest in energy storage, research activity was extended to hydrogen production and, in particular, to high temperature electrolyzes both in electrolysis and in co-electrolysis, analyzing through experimental investigation the impact of temperature equilibrium on thermal and energy balance

Arianna Baldinelli - Arianna Baldinelli (Gualdo Tadino, Italy, 1989) is a researcher and lecturer at the University of Perugia, Department of Engineering. In 2017 she was awarded a Ph.D. degree in Industrial Engineering with a thesis on new pathways for electrochemical power production through fuel cells. Afterward, she has been carrying on with her research activity in hydrogen energy electrochemical technologies for power production and energy storage. Her main interests relate to the multiple uses of hydrogen as a sectoral integrator. She is a member of Elsevier (Sustainable Energy Technologies and Assessments, Fuel Communications) and MDPI (Processes) editorial boards.

Umberto Desideri - Full professor of Thermal Machines at the University of Pisa. Member of the Editorial Board of the ASME Journal of Fuel Cell Science and Technology since 2005 Member of the Editorial Board of the Journal Applied Energy since 2007 and Associate Editor since 2011. Member of the Editorial Board of the Journal Applied Thermal Engineering since 2013. Chair of the organizing committee of the International Conference ICAE2011. Member of the International Scientific Committee of ICAE2012, ICAE2013, ICAE2014, ICAE2015, ICAE2016. Chair of the Coal Biomass and Alternative Fuels Committee of the International Gas Turbine Institute from 2006 to 2008 Vice Chair of the Coal Biomass and Alternative Fuels Committee of the International Gas Turbine Institute from 2004 to 2006 Since 1994, Member of the American Society of Mechanical Engineers Since 2010 is member of the Codes and Standard Committee of the ASME which is developing the Performance Test Code 48 "Overall Plant Performance with Carbon Capture" Member of the Administration Board of the University of Perugia from 1 January 2011 to 31 December 2013. Since 2008 member of the Taskforce Technology of the European Union Zero Emission Platform

Enrico Bocci - Associate Professor of Thermo Electro Chemical Energy conversion systems at Guglielmo Marconi University in Rome. His main research areas are: assessment and environmental impacts aspects of innovative thermochemical and electrochemical energy conversion processes (biomass power plants; small-scale ORC; gasification and hot gas conditioning processes; hydrogen, fuel cells; powertrain advanced thermo-electrochemical energy conversion processes course and management of advanced power systems course) for generating heat, electricity and fuels and for propulsion systems. In the last 17 years he has participated and conducted research activities in more than 20 EU projects, mainly focused on gasification and fuel cells. He is now coordinating the EU funded GICO project (<https://www.gicoproject.eu/>) aiming at design, implement and demonstrate a biomass

gasification integrated with CO₂ capture, storage and conversion coupled with SOFC/SOEC and methanol production; and BLAZE project (www.blazeproject.eu) aiming at design, implement and demonstrate a biomass gasifier coupled with 25 kWe SOFC. He published around 100 articles (H Index 26 in Scopus database), 3 books on renewable Energy Technologies and 2 patents, he is a reviewer of about 20 international Journals, and in his carrier he has been a supervisor of more than 100 BSc, MSc and PhD students.

Invited submissions

SDEWES2022.0507

The Use of Recycled Catalyst for Molten Carbonate Fuel Cell Fueled by Methane

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Abstract

The paper presents a mathematical model of a molten carbonate fuel cell with a recycled catalyst in anode channel. The catalyst was created from production residues from the electrodes of the molten carbonate fuel cell, which would otherwise be thrown away.

As a result, nickel is the major component of the recycled catalyst. The reforming process will also take place at the anode of the cell itself, but thanks to the use of an additional catalyst, we will obtain a larger surface on which the reforming process will take place. The fuel fed the modeled system was methane. The described system includes a model of the steam reforming process occurring in the anode channel of the MCFC fuel cell and the model of the cell itself. A reduced order model was used to describe molten carbonate fuel cell operation and kinetic model – for methane steam reforming. The calculations of the reforming were done in Aspen HYSYS software. Four values of the steam to carbon ratio (2.0, 2.5, 3.0 and 3.5) were considered when planning the tests of the reforming process. The performance of the fuel cell was also tested for different methane flows to determine the flow at which benefits are achieved in relation to the cell without additional catalyst. In the first phase, the reaction kinetics model was based on data from the literature. Then the model was calibrated.

SDEWES2022.0510

Alcohols as Hydrogen Carriers for Direct Utilization in Molten Carbonate Fuel Cells

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Abstract

Experimental investigations of Molten Carbonate Fuel Cell (MCFC) fed directly with liquid fuels have been performed. Due to high energy cost of pure hydrogen generation, storage and distribution, different ways of hydrogen bounding and utilization should be considered what could be used for existing energy systems. One solution is to use hydrogen bounded in liquid hydrocarbons (e.g. alcohols), what gives an opportunity to utilize existing storage and distribution systems (pipelines, cisterns or other vessels used for liquids storage). Alcohols have high energy density in standard conditions comparing to pure hydrogen, also when biofuels applied, the installation can be defined as renewable energy generator. For the evaluation purpose various low molecular hydrocarbons occurring in standard conditions in liquid state have been used for energy generation in the MCFC (methanol, ethanol, propanol, butanol and glycerol). Those alcohols may be subjected to the steam reforming process when mixed with water in specific ratios, thus they can be delivered directly to the fuel cell in liquid state where hydrogen will be released and utilized for electricity and heat production. As MCFC works in temperatures of 650°C and the anode is made of nickel, this gives perfect conditions for the steam reforming process to occur. Alcohols have been mixed with water in ratios of: 1:2, 1:3, 1:4, what gave 15 different fuel mixtures for the fuel cell. The results have been compared to the MCFC fed with pure hydrogen as a fuel. Threats such as carbon deposition on the fuel cell surface resulting from steam reforming process have been analyzed after disassembly of experiment samples of MCFC. The advantages of using hydrogen bounded in liquid fuels and opportunities of this type of fuels in Hydrogen Valleys have been outlined.

SDEWES2022.0512

Integration of Solid Oxide Electrolysis (Soe) with Conventional Power Plants for Their Converting into Hydrogen Generators

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Abstract

Current geo-political situation expects rapid transition towards near-zero and zero-emission energy technologies. While the installed capacity in renewables nearly doubles every year, numerous conventional power plants remain operations. The former typically seek for sufficient energy storage systems (ESS) which can aid in full utilization of the installed capacity and reduction of the level of curtailment. The later are expected to meet the strict emission standards which gradually become hard to reach. Eventually, one can expect number of power plant to be decommission due to their inability to remain economically viable in the light of carbon taxation. Under such circumstances utilization of fossil fuel-based power plants will be limited and the potential will no longer be explored. The HYDROGIN project (2020-2023) comes with a solution to the energy markets in Europe, with a special focus on the Central Eastern Europe (CEE) which currently operates a decent number of power plants with the installed capacity between 30 and 500 MW each.

The concept behind the project focuses on repowering conventional power plants by the deep integration of high temperature electrolyzers with steam cycles. HYDROGIN system which is discussed in the work integrates solid oxide electrolyzer with steam cycle which is generating up to 80 tonnes of steam per hour using biomass as a fuel. This unit was retrofitted to accommodate the electrolysis island which draws the steam from the turbine and feeds it directly to the cathodic compartments of SOE. It was demonstrated that such a coupling can be replicated and becomes a viable option for numerous power plants. Hydrogen generated in such hybrid cycles can be produced with an outstanding efficiency exhibited by low demand for electricity per each kilogram of hydrogen produced. Several alternative paths for coupling solid oxide electrolyzers with steam cycles are presented, and selected challenges are discussed.

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SDEWES2022.0524

Two Years Experience with an Innovative 100 kWth Dual Fluidized Bed Gasifier

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Abstract

Gasification is a technological high-temperature conversion process to exploit low-quality resources producing a valuable gaseous fuel. In particular, the dual fluidized bed gasifiers allow the production of H₂-rich syngas avoiding the dilution with N₂. The sand of the bed is generally used to transfer heat from the combustion to the gasification chamber. To maximize the heat transfer and reduce heat losses, a new design consisting of a single vessel with two concentric cylindrical reactors has been developed. The internal reactor is the combustor, while the external is the gasifier. In the BLAZE project (Horizon 2020), the gasifier unit is part of the combined heat and power plant which consists of novel hot gas cleaning and conditioning, solid oxide fuel cell, and anode off-gas recirculation to produce renewable electricity and heat from residual biomass. This work reports the results of the experimental tests carried out in the last two years on this pilot-scale.

Several tests have been carried out varying the operating conditions. The produced gas has been characterized in terms of dry gas composition, humidity content, and organic and inorganic contaminants. Additionally, the amount of char residue and yield of the produced gas was evaluated. Hazelnut shells were used as the biomass feedstock at a feeding rate of 15 and 20 kg/h. The steam flow rate was kept constant during the tests, thus varying the steam to biomass ratio (S/B).

As observed the H₂ concentration increases with temperature. Furthermore, it is slightly higher at 15 kg/h than at 20 kg/h, probably due to the higher steam to biomass ratio. The average tar content is around 10 g/Nm³_{dry} for both feed flow rate. The calorific value of the syngas is around 10 MJ/Nm³.

Furthermore, a preliminary test was carried out with a filter candle filled with catalyst and installed in the freeboard of the gasifier, to evaluate the in situ hot gas cleaning and conditioning performances.

The results show that the tar content dropped to about 2 g/Nm³, and the H₂ concentration increased up to 39% (while concentrations CO₂ and CH₄ decreased), which confirm the activity of the selected catalyst for tar and methane steam reforming and WGS reactions. Particulate matter was not detected in the syngas downstream the filter candle. The H₂S measured in the gas is in the range of 100 ppm.

Further tests will be carried out to increase the freeboard temperature (around 736 °C up to now) to enhance the catalyst activity for further conversion of tar.

SDEWES2022.0530**High Efficiency Recirculation System for Ammonia-Fueled SOFC in Maritime Application**F. Mondì^{*1}, H. Lund Frandsen²¹DTU - Technical University of Denmark, Denmark; ²Technical University of Denmark, Denmark (*framon@dtu.dk)**Abstract**

In a global scenery where cutting greenhouse gas emission and reaching a true sustainable development is arguably the hardest challenge humanity is facing, ammonia could represent one of the key elements to solve the energy puzzle. This molecule is carbon free and holds a great potential as energy vector thanks to the high H₂ content and the possibility to be stored in liquid state at moderate pressure and/or temperature; these characteristics make it an ideal candidate for the use in several energy systems and in particular solid oxide fuel cell (SOFC) systems.

This study focuses on the use of ammonia as a fuel for SOFC powertrains in maritime applications, a growing sector currently using exclusively fossil fuels and considered “hard to abate”. The proposed system is characterized by direct feeding of NH₃ without pre-cracking and with partial recirculation of the fuel electrode waste gas, containing unconverted fuel. This configuration enables very high (> 70 %) system efficiency and the opportunity to feed the SOFC a mixture of gas different from pure NH₃. However, the direct feeding of pure ammonia has shown to be challenging due to nitridation of Ni and steel, leading to microstructural damage of the cell, stack and system components.

In this work, we investigate the performance of SOFCs under the operating conditions of the above described system. The system operating point was simulated by feeding a commercial SOFC cell with a mixture of NH₃/H₂/N₂ and an equivalent mixture of H₂/N₂ to simulate a complete pre-cracking of ammonia. The test, carried out at 750°C, shows a very limited penalty introduced by recirculation: the highest value of recirculation tested (90%) leads to a -1.6% performance decrease @0.4 A/cm², 70% fuel utilization. A similar penalty is introduced by the use of direct NH₃ instead of pre-cracked ammonia, with an average very limited penalty of -1%. The combined penalty of direct NH₃ and recirculation does not exceed -2% with respect to the reference case of 0% recirculation and pre-cracked NH₃. The obtained efficiency is significantly higher than the ≈50% of naval diesel engines, with the further advantage of avoiding CO₂ and pollutant emissions.

Special session: Local climate planning for climate-neutral and resilient cities

Cities are responsible for 80% of energy consumption and CO₂ emissions and are particularly vulnerable to extreme weather events caused by climate change, which are becoming more frequent and of increasing magnitude also due to the growing urbanization and intrinsic complexity of urban areas.

Making cities safer, climate resilient and sustainable are common priorities around the world, and especially in Europe, which aims to become climate neutral by 2050 delivering the European Green Deal, with an interim goal of reducing net emissions of greenhouse gases of at least 55% by 2030.

Striving for a climate-neutral and climate-resilient society will require consistent improvements in all parts of society and economic sectors, promoting a more sustainable and smarter configuration of current energy systems, and, at the same time, increasing the resilience of infrastructures and urban ecosystems.

This transition needs to be based on a clear vision of the desired sustainable future and a systematic medium-long term climate planning, aligning actions in key areas, promoting innovative technological solutions (e.g. increased energy efficiency and use of renewable energy, nature-based solutions) and an effective process to enable citizens to act on climate change.

The aim of this special session is to present the results of new research, case studies and practices aimed at supporting cities in their transition towards a low-carbon and adaptive future. In particular, the special session will be focused on the following topics:

- Urban mitigation planning
- Urban adaptation planning
- Integrated strategies for mitigation and adaptation in urban areas
- Climate neutral and adaptive cities
- Transition towards decarbonised local energy systems
- Approaches to increase city resilience to climate change
- Co-benefit approaches to climate change mitigation/adaptation
- Smart sustainable cities
- Nature-based and technological solutions
- Empowering citizens in climate action
- Enhancing city leadership to address climate change

Dr. Monica Salvia, CNR - National Research Council of Italy, Tito Scalo (PZ), Italy

Dr. Filomena Pietrapertosa, CNR - National Research Council of Italy, Tito Scalo (PZ), Italy

Prof. Paris Fokaides, Frederick University, Nicosia, Cyprus

Prof. Byron Ioannou, Frederick University, Nicosia, Cyprus

Monica Salvia - Monica Salvia is senior researcher (Primo Ricercatore) at CNR-IMAA. She holds a degree in Environmental Engineering (M.Sc.) and a Ph.D. in Methods and technologies for environmental monitoring. Monica has a strong background in energy systems analysis and models development and a solid experience in supporting local authorities on sustainable resource-efficient strategies. Research activities are mainly focused on local climate planning, mitigation and adaptation strategies, rational use of energy, renewable energy sources and smart cities. Monica has proven experience in international cooperation in science and technology: she is part of the coordination team of the EURO-LCP Initiative on local climate planning, she acted as Project Coordinator of the Interreg MED project "PrioritEE" (2017-2019) and Scientific Project Manager in the Italian Ministry of Education, University and Research (MIUR) funded "SMART Basilicata" project (2012-2018). She was Scientific Project Manager of CNR-IMAA in the SEE "RE-SEETies" Project and Communication Manager on behalf of her own institute in the INTERREG IVC "REENERGY" project (2012-2014). She was Rapporteur for the COST Association and member in the Management Committee of Actions TU1104 "Smart Energy Regions" and TU0902 "Integrated assessment technologies to support the sustainable development of urban area". She has contributed to the EERA/JP "Smart Cities" and JPI Urban Europe/UERA (the Urban Europe Research Alliance) activities. Monica has also a proven experience in the management and evaluation of national and European S&T projects (Piedmont Region - Bando PASS, the International German Federal Ministry of Education and Research - BMBF, the Croatian Science Foundation, ERANETMED, Italian Ministry of Economic Development - MISE, Smart City Innovation Awards Italy, FP7 "Environment - including Climate Change"). She acts as guest editor and anonymous refereeing for major international journals and proceedings. Her scientific activities have originated several papers appeared in international Journals and Conferences.

Filomena Pietrapertosa - Filomena Pietrapertosa is researcher at CNR-IMAA since 2005. She holds a degree in Environmental Engineering (M.Sc.) and a Ph.D. in Methods and technologies for environmental monitoring. Since 2000 she has been working as energy systems' modeler implementing analysis with the MARKAL/TIMES model generators at local and national scale. Her research interests include climate change mitigation and adaptation strategies, energy efficiency measures, renewable energy and awareness raising strategies. She cooperates to and provides support to local authorities in developing and implementing sustainable energy strategies. Filomena is Project Coordinator of the Interreg MED PrioritEE PLUS project (2020-2021) and acted as local coordinator in the INTERREG MED PrioritEE project (2017-2019). Moreover, she has actively involved in more than ten European research projects on low-carbon energy transition and climate change adaptation, among which: REENERGY INTERREG IVC project (2012-2014) - thematic expert, RE-SEETies SEE project (2012-2014) - Project Manager Assistant, she participated in the COST Action TU0902 "Integrated assessment technologies to support the sustainable development of urban area" (2009-2013) and was Substitute Member in the Management Committee of COST Action TU1204 "People Friendly Cities in a Data Rich World" (2014-2017). On climate change adaptation themes, she provided technical and scientific support to the Basilicata region in the implementation of the ORIENTGATE SEE project (2012-2014). She is core member of the EURO-LCP Initiative focusing on climate change plans and policies. Filomena contributes to the Urban Europe Research Alliance (UERA) of JPI Urban Europe on sustainable and economically livable urban areas as Thematic expert for CNR in the

TWG2: Urban Environmental Sustainability and Resilience. Filomena has also a proven experience in the evaluation of national and European S&T projects. She is Member of editorial board of the UCL OPEN: Environment Journal and acts as guest editor and anonymous refereeing for major international journals and proceedings. Her scientific activities have originated several papers appeared in international Journals and Conferences.

Paris Fokaides - Dr.-Ing. Paris A. Fokaides is an Associate Professor at the School of Engineering of Frederick University, Cyprus, and a research mentor at Kaunas University of Technology, Lithuania. In Frederick University, Paris is lecturing the courses of Fluid Mechanics and Heat Transfer at the Department of Mechanical Engineering, as well as the courses of Sustainable Energy Resources, and Energy Design of Buildings in the Masters Programme of Energy Engineering, which he also coordinates. He is also the supervisor of 5 PhD students and 2 PhD graduates. Paris holds a PhD from the University of Karlsruhe, in Germany in the field of Process Engineering and a Diploma in Mechanical Engineering of Aristotle University in Thessaloniki, Greece. Paris research is mainly related to sustainable energy technologies for the built environment, as well as novel energy related applications in constructions. Paris is involved in research, having actively participated in over 25 research projects related to the field of sustainable built environment over the past 10 years. His research projects are related to the promotion of Industry 4.0 practices for the assessment of the energy performance of the built environment, smart buildings, as well as the field of digitization and analysis of energy related processes. Paris has also served as consultant of the Republic of Cyprus in numerous projects related to the transposition of the European Acquis into the national legislation, in the policy fields of energy, environment and transportation. Paris leads the Sustainable Energy Research Group at Frederick University, an ISO 9000 certified self-funded research team consisting of 10 FTE researchers, involved in European and national funded R&I activities. He is also actively involved in the publications section, being editorial board member in four Q2 and Q3 Springer, Taylor and Francis and MDPI journals in the field of sustainable energy. As of early 22, Paris has authored and co-authored over 125 Scopus indexed studies, and has an h-index of 30.

Byron Ioannou - Byron Ioannou is an Associate Professor of Urban Planning, Vice Head of the Department of Architecture, and Coordinator of Urban Planning and Development Unit (UPDU) at the School of Engineering of Frederick University. He studied Architecture (Dip. Eng.) and Urban & Regional Planning (MSc and Ph.D.) at the National Technical University of Athens. He has also studied Planning Law (PG Cert) at Leeds Beckett University. Byron has worked as a research and teaching staff in a number of institutions of the Mediterranean Region. He has extended professional and research experience in spatial planning, built environment assessment, design, and urban development issues. He is a member of ETEK (CY), TEE (GR), and the Royal Institute of Town Planners (UK), and a member of the Planning Board and of the Committee for the Environmental Assessment of Plans and Projects of the Republic of Cyprus. His current research focuses on development plans, environmental aspects of urban development, building utility management, built environment risk assessment, and renewable building energy systems. Byron is also an awarded consultant in a number of international planning and urban design competitions. He is a reviewer and an editorial board member at a number of scientific journals, TandF, Mdpi, etc. He is an external expert/ evaluator at the European Commission Research Agency, the European Parliament, COST Research Organisation, and AIKA Latvia.

Invited submissions

SDEWES2022.0167

Are "smart Cities" Also "Climate Smart"? An Assessment of the EU Mission "Climate-Neutral and Smart Cities"

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Abstract

The EU Mission "Climate-Neutral and Smart Cities", recently launched a call for starting a pathway towards "100 climate-neutral and smart cities by 2030". A list of 336 candidate cities for this mission was published at the end of February 2022. These cities constitute a very large and diverse sample that was used to conduct this timely research to identify the main factors that can drive and support a smart and sustainable transition of cities. A critical discussion of the main achievements in five main driving factors (local climate planning, climate emergency declaration, participation in networks, international projects and competitions) provides an important knowledge base on the main factors driving these cities towards climate smart actions. The results of this study can be useful to decision-makers at all levels, but especially to other cities, providing useful information on steps to be taken to accelerate the transition to carbon neutrality.

SDEWES2022.0170

Climate Proofing Urban Planning in Valencia with Nature- Based Solutions

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Abstract

The paper exposes the experience of the city of Valencia in the incorporation of climate change perspective in the revision of the General Urban Development Plan, boosting the deployment of Nature-based Solutions (NbS) as adaptation measures.

A climate change vulnerability and risk assessment, including modelling and spatial analysis exercises, is carried out on the 23 functional areas in which the General Urban Development Plan sectorizes the municipality of Valencia, for the identification of the most vulnerable ones against heat stress, as one of the priority hazards included in the Valencia Climate Change Adaptation Plan.

A heat stress map is developed using URbCLim model. Copernicus hourly data on air temperature, relative humidity, and wind speed for the period January 2008- December 2017 and a spatial resolution of 100 m x 100 m, to identify a corresponding day of future heat stress due to climate change. A heat index is then calculated, combining temperature and humidity data.

Indicator-based vulnerability and risk assessment is applied following the approach of the fifth assessment report of the Intergovernmental Panel of Climate Change where risk is a function of hazard, exposure and vulnerability, and vulnerability a function of sensitivity and capacity of response. A data model of 18 indicators is built characterizing demography, land use, social and cultural identity, public facilities, public space, mobility, housing and well-being features.

A diagnosis sheet is elaborated for the 23 functional areas showing the level of risk and the indicators' contribution to each of the risk component. General recommendations and detailed planning guidelines are provided, with specifications for NbS deployment as adaptation measures in the functional areas that show the most significant risk.

A remarkable result is that in the functional areas in the south and east of the city, conflicts related to the climate emergency process will arise where NbS must be strengthen against risks derived from high summer temperatures. From a planning perspective the study positively informs both, the General Urban Development Plan, and the City Green and Biodiversity Plan, a new instrument for planning and management the green infrastructure of Valencia.

SDEWES2022.0196

An Online Bim-Enabled Platform for the Integration of Heritage Buildings into the Contemporary Built Environment

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Abstract

In an era of rapid technological improvements, state-of-the-art methodologies and tools dedicated to protecting and promoting our cultural heritage should be developed and extensively employed in the contemporary built environment and lifestyle. At the same time, sustainability principles underline the importance of the continuous use of historic or vernacular buildings as part of the building stock of our society. Adopting a holistic, integrated, multi-disciplinary strategy can bridge technological innovation with conserving and restoring heritage buildings. The paper presents ongoing research and results of the application of Machine Learning methods for the remote monitoring of the built environment of the historic cluster in Cypriot cities. This study is part of an integrated, multi-scale, and multi-discipline study of heritage buildings towards the creation of an online HBIM platform for urban monitoring.

SDEWES2022.0199

Nature Based Solutions for Nearly Zero Energy Buildings in Mediterranean Climate

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Abstract

In the context of the ambitious targets set out by European Commission (EU) to become carbon neutral by 2050, the European community try to find the best solutions to respond in different sectors of the energy system. Building sector is still one of the most resource consuming sectors in the European Union. According to the European Construction Sector Observatory (ECSO), buildings account for 40% of total EU final energy consumption and produce about 36% of all greenhouse emissions. Moreover, the construction wastes suppose around the 33% of the total wastes.

Adopting nature-based solutions for reducing energy demand in built environment is an alternative to the traditional solutions for new building and renovation and several initiatives and research projects are proposing these kinds of solutions.

In this context, the authors of this paper, who are participants in the LIFE Project, ReNatural NZEB Recycled and natural materials and products to develop Nearly Zero Energy Buildings with low carbon footprint, are willing to share the initial findings of the Portuguese case study and related solutions to achieve nearly Zero Energy Building with low carbon footprint, using recycled and natural materials. The Portuguese case study is simulated taking into account the conventional construction materials and also using several scenarios where natural materials are used. The energy balance towards Passive house standards and nearly Zero Energy Buildings according with Portuguese buildings legislation, are calculated.

SDEWES2022.0203

Walkability Indexes and Energy - Climate Adaptation Plans. Bridging the Gap

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Abstract

A walkability index is a tool that usually elaborates on population data, densities, street intersections and geometry, the density of bus stops, and density of pedestrian trip generating/supporting establishments which define qualitative data on the attractiveness of the routing environment. In any case, their general purpose is to measure and assess the built environment features that promote daily pedestrian activity and increase the individual preference for not using a private vehicle or partially replacing their daily vehicle routes with walking. In this sense, it seems to be a distance between the ambitious strategic climate adaptation plans of the national or regional level and the neighborhood walkability approach since they lay in a different scale, context, and focus levels. Despite this fact, the increase in walkability is essential in order for several goals of adaptation plans to be fulfilled. The aim of the paper is at first to present the basic features of the “Sustainability Index” a new walkability index adjusted to the particularities of Nicosia/ Cyprus city layout, designed with the latest version of pyQGIS. In a concluding step, it aims to outline the next steps in order to examine the effectiveness of the index in terms of its alignment to the principles of Cyprus' Integrated National Energy and Climate Plan and especially the provisions and the goals of the transportation system.

SDEWES2022.0210

Combine Strategic Planning Tools for Co-Creating Resilient Urban Solutions

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Abstract

In an increasingly urbanized world, cities are facing various challenges to cope with mitigation and adaptation to climate change, promoting new ideas that seek to implement inclusive co-design processes in planning interventions towards a future low carbon and resilient.

The vision of the H2020 VARCITIES project is to fully exploit nature-based solutions from a digital, social and cultural perspective, through a co-creation process for increasing the health and well-being of citizens exposed to different climatic conditions in and around Europe. The implementation of these so called Visionary Solutions (VSs) aim at supporting cities in their transition to become climate-neutral, in line with the project vision.

This paper aims to illustrate part of the work done within the Work Package 3, which was dedicated to provide a common knowledge baseline to guide and support local administrations in this process.

In particular, the main objective of the research here synthetised is to identify the key drivers (meant as enablers, forces, and opportunities) and barriers (like challenges, and constraints) that can affect the implementation of these solutions, how they can be detected and how the main impacts can be assessed. The paper describes all the activities carried out using the outcomes of the 1st and 2nd co-creation workshops held in each pilot areas, organized during the year 2021, with local stakeholders.

The main drivers and barriers are uncovered and analysed through the application of two strategic planning tools (i.e. PESTLE and SWOT analyses) that can provide both micro and macro perspectives. In particular, the PESTLE analysis is applied for the detection of external factors that can affect the analysed solutions; the SWOT analysis is useful for linking these external forces with the internal ones. An impacts assessment is also performed applying a multiple-benefits approach.

The most relevant findings emerging from the study are:

- **PESTLE:** among drivers the political, economic, and legal factors are the ones less identified by pilot areas; about barriers, 3 pilot areas out of 7 didn't identified possible challenges to be faced during the implementation of solutions.
- **SWOT:** almost all the pilot areas have recognized some internal and external, as well as positive and negative, factors affecting their area.
- **Impact assessment:** the main impact expected from the VSs implementation is the collaboration among peoples; while the common expected impact of the VARCITIES project is the improvement of life quality.

The results show that the pilot areas are intensely working given the implementation of the proposed solutions, however, some challenges and gaps are in place as the process is complex and several aspects must be considered. Finally, the combination of various strategic planning methods allows us to get an overview of the entire context.

SDEWES2022.0294

Towards Climate Neutrality: a Decision Support Tool to Design Energy Efficiency Strategies for Municipal Public Buildings in the Euro-Mediterranean Region

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Abstract

The EU is committed to becoming climate-neutral by 2050, underlining its willingness in the European Green Deal strategy. In this context, the energy efficiency of municipal public buildings (MPBs), such as schools, sports facilities and municipal offices, is a priority for local authorities both for budgetary savings and environmental and socioeconomic benefits, helping to support innovation. The successful implementation of municipal energy efficiency (EE) strategies requires a preliminary analysis of the challenges that may limit EE investments in municipal buildings, including architectural constraints, insufficient knowledge of energy consumption, municipal staff's implementation capacities, and budgetary restrictions. Therefore, it is of utmost importance to develop easy-to-use decision-making tools that can support public administrations to decide where to invest with the available budget to reduce energy costs and CO₂ emissions.

The Decision Support Tool (DSTool), a free online application developed in the Interreg Med PrioritEE and subsequently upgraded in the PrioritEE PLUS transferring project, was designed in cooperation with the local administrators and main stakeholders to support the selection of suitable interventions in the energy renovation of MPBs. The data input includes information on the area in which the buildings are located and the main technical, financial and energy information (e.g. building features, HVAC systems, physical constraints). The DSTool output highlights the effectiveness of a predefined set of EE and renewable energy source measures by indicating the priority among the different technological options for a single building or set of buildings in terms of energy, financial and environmental key performance indicators. A benchmarking function allows obtaining an overview of several selected buildings, their prioritisation and comparison before and after renovations according to the selection criteria. The selection process results are also reported in an editable final report, including tables and graphs.

The application of the DSTool for the analysis of MPBs and the design of local energy efficiency action plans in several municipalities in Italy, Spain and Portugal will be presented, highlighting the transferability of the tool to other territories and its usefulness to support the implementation of the Sustainable Energy Climate Action Plans - SECAPs in the framework of the Covenant of Mayors initiative.

Special session: Modelling, Selection and Adoption of future energy systems technologies across buildings, electricity and mobility sectors

Building models and foreseeing their selection by stakeholders is part of the contribution of energy modelers to shape reality and support policies. The increasing commitment for the ecological transition from fossil-based energy systems to the renewable-based ones includes innovative solutions calling for new adjustments of the models or even new ones. In addition, the application in each context calls for tailored technologies, modelling techniques and planning strategies especially with the intent of involving several sectors such as built environment, power grid and transportation. Changes are also pushed by the market and the geopolitics, often correlated, requiring flexibility or the involvement of new players.

Hence, this Special Session will mainly focus on:

- Models built and interlinked for Future energy systems;
- Modelling and planning at different scales, technologies and connection;
- Optimization techniques and strategies;
- Smart Energy System approach coupling electricity, heating/cooling and transport sectors;
- Blue energy technologies: offshore wind, floating PV, wave and tidal current converters;
- Storage technologies for increasing variable RES penetration;
- Energy analytics and techno-economic optimization for selecting the best configuration;
- Innovative building energy systems and performance gap for Future Cities;
- Energy policies and strategies for achieving decarbonization targets at different scales.

Prof. Benedetto Nastasi, Sapienza University of Rome, Rome, Italy

Prof. Davide Astiaso Garcia, Sapienza University of Rome, Rome, Italy

Dr. Daniele Groppi, Sapienza University of Rome, Rome, Italy

Dr. Matteo Giacomo Prina, EURAC research, Bolzano, Italy

Benedetto Nastasi - Benedetto Nastasi is Assistant Professor & Senior Energy Planner at Department of Planning, Design and Technology of Architecture, Sapienza University of Rome and Guest Researcher at Department of Architectural Engineering & Technology, TU Delft University of Technology. He got the PhD title with Honors with a dissertation in Energy Systems Planning and Design. The core of his thesis was published in Energy (Elsevier) and became one of the Most Cited Paper 2016. He was rewarded for the Best Poster at 2nd SEE SDEWES Conference 2016 and Best Senior Researcher at SES4DH Conference 2018. Previous affiliations

include TU/e Eindhoven University of Technology, The Netherlands, International Solar Energy Society and Guglielmo Marconi University, Italy. He is Editor at Renewable Energy (Elsevier) and Energies (MDPI), Associate Editor of Sustainable Buildings (EDP Sciences), Guest Editor at Frontiers in Energy Research, International Journal of Hydrogen Energy and Energies. His work is related to Power-to-What solutions for energy systems design with a specific focus on Built Environment. He authored more than 80 publications (H Index 32 in Scopus database).

Davide Astiaso Garcia - Davide Astiaso Garcia is Assistant Professor of Thermal Sciences, Energy Technology and Building Physics at Sapienza University of Rome and General Secretary at Italian Wind Energy Association (ANEV). He is currently the Project Coordinator of the EU Interreg Med project PRISMI PLUS “Transferring a toolkit for RES Integration in Smart Mediterranean Islands and rural areas”, and is currently involved as Principal Investigator for Sapienza University of research team in two H2020 projects (GIFT - Geographical Islands FlexibiliTy - and ILIAD - INTEGRATED Digital Framework FOR Comprehensive MARITIME DATA AND INFORMATION SERVICES), and one EEA project (YENESIS - Youth Employment Network for Energy Sustainability in ISlands). His full operating skills include, among others: Renewable energies, smart energy systems, energy efficiency in buildings, energy modelling, energy forecasting, environmental impact assessments, pollution risk management, indoor and outdoor air quality monitoring and mitigation measures. He is contracted by the European Commission Research Executive Agency (REA) as expert for the evaluation of the project proposal under H2020 calls “FET OPEN (Future Emerging Technologies)”. He is Editor at Journal of Energy Research and Reviews and Guest Editor at Applied Science and Frontiers in Energy Research. He is author of more than 100 scientific publications mainly concerning energy themes (H index 25 in Scopus database).

Daniele Groppi - Daniele Groppi is a post-doc researcher at Sapienza University of Rome. Daniele Groppi graduated with Honors as Energy Engineering M.Sc with a thesis regarding the feasibility analysis of an active District Heating Network with a case study in Bologna, Italy. His research fields are energy planning, energy systems modelling and design. Within his Ph.D. project, he analysed Smart Energy Systems in order to increase the RES penetration of energy island systems by fully exploiting the synergies offered by sector coupling and demand side management solutions aiming at an optimal energy use. He has been collaborating in several EU funded projects such as the PRISMI project (<https://prismi.interreg-med.eu/>) where he dealt with the energy plan of Favignana island, Italy; and the GIFT project (<https://www.gift-h2020.eu/>) in which he will analyse the flexibility potential of the local energy community in the island of Procida, Italy, and will then investigate on the introduction of a capacity market on the island. Results of his work have been published in more than 30 papers in Scopus database leading to a h-index of 11.

Matteo Giacomo Prina - Matteo Giacomo Prina is a post-doc researcher at EURAC research, institute for renewable energy. He holds a PhD in energy engineering based on a collaboration between EURAC research and Politecnico di Milano. His PhD has been based on renewable energy high penetration scenarios using bottom-up modelling. He has worked within several projects in the energy system modelling and scenario generation topic: Integrids, E2I@NOI, H2020 Trust-PV and a Twinning on Ukraine. His expertise varies from the development of algorithms for energy system modelling to the analysis of high amount of data and visualization of them. He participated actively at the OpenMod initiative meetings of Frankfurt and Milan. He was rewarded for the Best paper award at 4th SEE SDEWES Conference 2020, Best presentation award at SES Conference 2020 and the 2° place at the EUREGIO young researcher award.

Invited submissions

SDEWES2022.0109

Estimation of Load Shifting Potential on Energy Expenditure and Self-Consumption in the Residential Sector

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Abstract

Demand side management is an increasingly diffused practice for large energy consumers, while the disaggregated nature of residential loads makes its adoption in the residential sector more complex. Among the demand side management practices, load shifting allows to match demand and production. In the case of prosumers, harnessing the load shifting potential from available technologies allows to increase self-consumption ensuring benefits both for the customer and the local grid. In order to evaluate the actual potential of load shifting in the residential sector, two major steps are needed. Firstly, a reliable and disaggregated, both with respect to time and technologies, estimation of demand curves and, secondly, an evaluation of the actual possibility to shift each load and its corresponding impact on self-consumption and energy bills. In this work, both steps have been conducted for the Wallonian residential sector. Demand curves have been obtained for a set of representative cases through a framework composed of different open-source models, allowing to obtain the electricity consumption from appliances, electric boilers for domestic hot water, heating through heat pumps and electric vehicles charging. Load curves have been validated by comparison to historical real-world data. The load shifting potential has been estimated both considering tariff-driven consumption and, in case photovoltaic panels were present, self-consumption maximization, also through batteries. Results have highlighted the contribution to load shifting from each different technology, suggesting that correctly structured tariffs could reduce peak hour demand and increase self-consumption.

SDEWES2022.0122

The Role of Alternative Fuels in Transport Sector and Industry Sector, Examination in H2RES Energy Model

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Abstract

The transport and industry sectors worldwide are among the top sources of greenhouse gas emissions as well as pollution itself. Therefore, these sectors have to be decarbonized. Decarbonization of transport and industry sectors is achieved by the introduction of renewable fuels as well as with the introduction of electricity-based energy solutions. Electricity based energy solutions include energy carriers created with the use of electricity. These are hydrogen and electrofuels. Also, the role of currently used fossil fuels is considered. Therefore, in the transport sector research investigates the switch from an almost fully fossil fuel-based sector towards the solutions that use electricity. A similar analysis is accomplished for the industry sector. The system analysis and simulations are carried out in the H2RES model. H2RES model is a linear optimization program. It considers capacity expansion, decommission and unit commitment in the sectors of power generation, heating, industry, and transport sector. For the purposes of this research, the model was expanded to include the modelling of electrofuels. Initial results display that most of the transport system is being transitioned to battery electric vehicles, while the remaining part is being fuelled by the hydrogen fuel cell and electrofuels. The industry sector on the other hand displays the majority of processes being transitioned towards hydrogen. The contribution of this research is reflected through the ability to give the policymakers the tool capable of performing the decisions on the development of energy system, particularly in the parts of the sectors that cannot be easily electrified. Also, the modelling adds the level of insurance concerning the ability to transform sectors such as industry even without the investments into new equipment.

SDEWES2022.0125**Long Term Energy System Decarbonization Under Water-Food NEXUS
Considerations with the H2RES Model**F. Flores¹, F. Feijoo^{*2}, L. Herc³, A. Pfeifer⁴

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Abstract

To stop current global warming crisis, energy systems must be decarbonized by the latest, mid-century. Several authors have proposed different modelling tools that help policy makers to assess different carbon reduction policies and the impact that they will have on the energy system and related emissions. However, several of the Energy System Models (ESM) that account for high temporal resolution of variable renewable sources normally lack the integration and further assessments of the links that the energy systems have with others, such as the Land Use and Forestry sector or the water sector. Models that indeed account for such integration of systems are known as Integrated Assessment Models (IAMs). However, due to their complexities and computational requirement, IAMs are normally solved in 5 (or 10) year time steps without proper representation of variable renewable sources.

This research seeks to address this gap by linking two different models. The H2RES is a long-term optimization model of energy systems with hourly representation of variable renewable sources. The H2RES model, as other ESM, does not have proper modelling of the existing links of the energy sectors with the water, food, or land sectors. Therefore, we proposed a soft-linking approach of the H2RES model with the Global Change Analysis Model (GCAM), one of the most recognized Integrated Assessment Models. The soft-linking approach seeks to provide demand levels and capacity investment levels from GCAM into H2RES. The proposed soft-linking approach is developed to analyse the decarbonization of the Chilean Energy System and to assess the role of flexibility options. Results indicate that when no flexibility options are allowed, large levels of wind and solar energy suggested by GCAM are not feasible. When flexibility options are available, power-to-heat, stationary storage and Hydrogen options are capable of accommodating renewable investments with low levels of CEEP.

SDEWES2022.0147

Smart Energy Systems for Renewable Energy Communities: a Comparative Analysis of Power-to-X Strategies for Improving Energy Self-Consumption

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Abstract

Renewable Energy Communities (RECs) represent the new scheme for promoting the distributed renewable generation, which must be managed in order to maximise the local energy self-consumption (SC). The aim of this paper is to assess and discuss strengths and weaknesses of small-scale sector coupling strategies in residential Renewable Energy Communities (RECs). The state-of-art of Power-to-Gas, Power-to-Heat, Power-to-Vehicle and Power-to-Power has been critically reviewed. Furthermore, the four Power-to-X strategies have been applied to twenty-seven REC configurations so as to maximise the energy SC. Power-to-Heat strategy turn out to be the most cost-effective solution for integrating the RES excess, however, its potential often is not enough to fully accommodate it. Power-to-Vehicle has low infrastructure costs, but its limit depends on the EVs penetration and on the citizens' participation. The competitiveness of Power-to-Power is extremely linked to the REC electrification level. Power-to-Gas is promising in high-RES excess conditions, but rarely it represents the best solution due to the current high electrolyzers cost. Energy storage systems' implementation is crucial for improving the local SC and generally the cross-sector integration turns out to be a better solution in energy, economic and environmental terms than those that focus only on the electricity sector.

SDEWES2022.0148**From Landfill to Hydrogen: Techno-Economic Analysis of Hybridised Hydrogen Production Systems Integrating Biogas Reforming and Power-to-Gas Technologies**G. Lo Basso^{*1}, L.M. Pastore², A. Mojtahed¹, L. De Santoli³¹Sapienza University of Rome, Italy; ²Sapienza, University of Rome, Italy; ³University of Rome Sapienza, Italy (*gianluigi.lobasso@uniroma1.it)**Abstract**

Hydrogen is one of the main energy vectors of future sustainable energy systems. In the new hydrogen economy, bio-hydrogen derived from organic material can represent an opportunity to valorise current waste management systems. The present work deals with innovative systems for producing hydrogen from landfill gas combining Power-to-Gas plants and biogas reforming. Currently, landfill gas recovery plants are often exploited by internal combustion engines operating as a genset. Thereby, the waste heat hailing from the internal combustion engines could be recovered whether those plants worked as Combined Heat and Power (CHP) systems. The heat recovery is integrated in the proposed hybrid configurations and both electrical and thermal outputs are fully exploited for supplying all the systems components. Two main branches compose the hybridised hydrogen production systems. The first one is based on water electrolysis, whilst the second one is composed by a biogas upgrading plant together with a steam reforming process downstream for the hydrogen production. Different technical options have been analysed. Pressure Swing Adsorption (PSA) and Chemical Absorption by TSA have been assessed for biogas upgrading. Furthermore, both high temperature electrolysis by SOECs (solid oxide electrolysis cell) and low temperature electrolysis by PEM (proton exchange membrane) and Alkaline electrolyzers have been considered. Combining those technologies, ten hybrid configurations have been proposed and simulated. The layouts have been compared each other by using the Levelized Cost of Hydrogen (LCOH) production as a key performance indicator. Furthermore, a sensitivity analysis has been carried out on the main techno-economic assumptions. In detail, system capacity factor variations and potential future SOEC's CAPEX reductions have been assessed and discussed. A case study, characterised by 600 Nm³/h of landfill gas production and a CH₄ fraction of 45%, has been considered. Assuming a capacity factor equal to 70% for the reference scenario, the potential hydrogen production rate in such hybrid configurations ranges between 26 and 28 kg_{H₂}/h. Furthermore, the LCOH value turns out to be in a range between 2.5 and 3.9 €/kg_{H₂}. In such a way, it is possible to positively contribute to the landfill gas power plants greening process, since those systems are typically considered not so much environmentally-friendly.

SDEWES2022.0204

Optimal Future Energy Mix Assessment Considering the Risk of Supply for Seven European Countries in 2030 and 2050

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Abstract

The scope of energy system modeling is to support policy-makers in the definition of an effective energy strategy to achieve key targets (emissions, energy security, affordability, etc.). The aim of this article is to study the future optimal energy mix needed to reach European energy targets by also containing the risk of supply for seven European countries in 2030 and 2050. The considered countries are the following: Spain, Italy, France, Germany, Netherlands, Poland, and Sweden. The energy system framework that will be used for this purpose is EPLANopt which couples the deterministic simulation model EnergyPLAN developed by Aalborg University with a Multi-Objective Evolutionary Algorithm built on the Python library DEAP. The multi-objective approach allows for the assessment of the optimal future scenarios considering both an economic and environmental objective function. Moreover, a constraint on the security of supply will be adopted in order to limit external risks while satisfying the energy targets of 2030 and 2050. The results obtained in terms of variable renewable energy penetration, taking into account ground-mounted, rooftop photovoltaics, onshore and offshore wind power, are compared to the penetrations obtained from the scenarios of ENTSOE.

SDEWES2022.0270

Renewable Energy Transition, Transmission System Impacts and Regional Development

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Abstract

The renewable energy transition rests on several pillars including the electrification of heating, transportation, and industry to enable the better exploitation of renewable energy sources like wind and solar power. This also entails a change in the geography of the energy system and more specifically the electricity system, where power changes from being centrally produced to being more geographically distributed while demand increases. Especially the electrification of industry and the use of Power-to-x will potentially add several large point demands to the electricity system. The distributed generation, large point demands and a generally higher level of electricity transit all suggest transmission and distribution system impacts beyond design levels. This paper probes into the effects of these developments for the region of Northern Jutland in Denmark to see whether the existing transmission grid can withstand the changes and to what extent grid limitations create barriers for regional industrial development. The work is based on GIS-based analyses of production and demand, survey-based stakeholder consultation to unveil expected demand and production development and grid analyses using PandaPower. Results indicate that the current transmission system sets clear boundaries for the development of production and demand of electricity. The survey also shows that permission should not only be based on local conditions as reported by municipalities but should also factor in a spatial distribution of national targets. This thus calls for improved coordination between administrative levels – including the transmission system operator.

SDEWES2022.0284**Comparative Analysis of Solar-Driven Syngas-Based Process Configurations for Direct Iron Ore Reduction-Based Steel Making**

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Abstract

The production of iron and steel releases approximately 7% of global annual greenhouse gas (GHG) emissions, and is currently the focus of intensive decarbonization efforts. Direct reduction of iron (DRI) followed by electric arc furnace (EAF) smelting is typically the steel making route of choice in regions with abundant and affordable natural gas. Although less emission-intensive than blast furnace-based processes, conventional DRI-EAF processes still require substantial emissions reduction strategies to meet climate targets. As iron ore reduction is the most emission-intensive steel making process step, switching to low-carbon reducing agents has the potential to significantly reduce emissions in the industry. Pure hydrogen-based DRI (HDRI) via water electrolysis has been recently investigated in numerical modeling and pilot studies, and found to have the potential to abate emissions by up to 90% relative to conventional processes.

An alternative approach focusing on low-carbon syngas-based DRI-EAF processes, with syngas produced via either water electrolysis or methane reforming based routes, is explored in this work. By minimizing differences in composition relative to conventional reducing gas, low-carbon syngas has the potential to minimize changes in reduction equipment and process conditions, as compared to HDRI. In this study, a comparative analysis of energy demand and emissions for syngas production via low-temperature water electrolysis followed by reverse water gas shift, and steam methane reforming, is performed for different energy sourcing options using an energy process model. The energy and GHG emissions intensity of the syngas-based DRI-EAF processes are compared and benchmarked with conventional and alternative DRI-EAF routes.

SDEWES2022.0318

The Persian Gulf Offshore Wind Farm Layouts Design

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Abstract

Offshore Wind Energy (OWE) can be considered one of the Renewable Energy Sources (RESs) with high force potential installed in marine areas. To this aim, Offshore Wind (OW) potential analysis is essential to highlight the best sites for the Offshore Wind Farms (OWFs) installation and development. Secondly, the OWFs layouts analysis must be designed and developed based on the farm site key specifications of marine areas, and OWs accurate assessment can help identify previously untapped marine regions. In this regard, the Northwest Persian Gulf's marine areas can be considered the high potential of the windy areas (hot regions). The offshore in-situ buoys have been used for OWs accurate assessment and time-series analysis to identify site locations and potential installation. Finally, two OWFs layouts scenarios have been designed and tested based on two OW turbine types' on-site specifications of the Northwest Persian Gulf. Finally, the excavation results show that near and offshore Kuwaiti country has very suitable potential for developing OWFs in future installations.

SDEWES2022.0363

Analysis and Prediction of Building Electrical Consumption Patterns Using Deep Learning Models with Considering the Impact of the Covid-19 Pandemic

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Abstract

Nowadays, energy information systems play an important role in the operational optimization of smart buildings to provide such benefits as high efficiency, energy savings, and smart services. In addition, affected by the COVID-19 pandemic, the global energy consumption pattern has been changed. Therefore, the prediction of electrical consumption requires an intelligent estimation strategy considering the parameters affecting electrical consumption patterns in the pre-COVID-19 and during the COVID-19 pandemic. The aim of this paper is to propose an intelligent and accurate forecasting model in order to analyze and predict building electrical consumption based on dataset related to a real smart two-story house (located in Houston, Texas, USA) from 2019 to 2020. The proposed analysis and forecasting model consist of: analysis of the electrical usage pattern during the COVID-19 pandemic, decomposing of the original electrical consumption signal via the variational mode decomposition (VMD) model, mutual information-based feature selection model to select the best features as input variables, and deep learning time series forecasting model using Long Short Term Memory neural networks (LSTM) to predict the target value. The comprehensive comparison demonstrates that the combined model is more accurate than the single models. The achieved prediction performance indicates the superiority of the proposed intelligent application compared with other provided benchmark hybrid and single models.

SDEWES2022.0366

Energy and Exergy Analysis of the Ocean Thermal Energy Conversion Combined Cycle with a Two-Stage Turbine by Using Thermal Power Plant Condenser Output Water

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Abstract

In recent years, increasing energy needs, limited fossil fuel resources, global warming, and environmental pollution from fossil fuels have led to renewed attention to renewable sources. The Oceanic Thermal Energy Conversion System (OTEC) uses the temperature difference between warm sea surface water and deep cold water to generate electrical power. Due to the low-temperature difference between surface warm water and deep-sea cold water, the thermal efficiency of these systems is low compared to fossil fuel power plants. In the present study, as a proposed method to increase the output power and thermal efficiency of the OTEC cycle, a warm water outlet of the condenser of the thermal power plant was used instead of surface water in the OTEC basic cycle. The results showed that on average, 27.52 MW of pure electric power was generated in the OTEC cycle per month and the energy and exergy efficiencies were 3.34 and 17.2%, respectively. Then, the proposed and modified OTEC cycle was introduced using a two-stage turbine and reheating and was analyzed in terms of energy and exergy, and the results were compared with the basic cycle. The results showed that in the proposed cycle, compared to the basic cycle, the average output power has increased by 552 kW per month, and energy and exergy efficiencies increased by 0.048 and 0.31%, respectively.

SDEWES2022.0378

Analyzing the Impact of Demand Response and Reserves in Islands Energy Planning

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Abstract

Small Islands usually rely on fossil fuels for their energy supply and face common challenges such as high energy costs and carbon dioxide emissions. For these reasons they represent interesting cases for the transition towards a green, clean and secure energy system. Nevertheless, the integration of Variable Renewable Energy Sources (vRES) into the electricity grid are already causing technical problems to island grids thus making grid flexibility a key topic. Indeed, insular energy systems are particularly exposed to security issues given the small system inertia that makes them vulnerable to frequency instability. Such issue is not fully and thoroughly considered in long-term energy planning; indeed, this issue is usually taken into account through ramp constraints, partial load operation and decay of efficiency at partial load and start-up and ramp-up/down costs. Another important factor that should be considered in order to ensure the reliability of the grid are Reserves. There are different types of Reserves depending on the reactivity/response time and the duration of the service. Based on these characteristics they can be classified as primary reserve, fastest response and shortest duration, up to the tertiary reserve with the slowest reactivity and longest duration.

In this research paper, also primary reserves will be analysed in order to plan the long-term energy transition of the small island of Favignana, Italy. The analysis will be carried out by means of the new version of H2RES, a Linear Programming single-objective optimisation model able to provide a long-term capacity investment optimisation. The technologies that will be analysed are PV, fuel cell, diesel generators, electricity storage, hydrogen storage (electrolyser and storage) and heat pumps will be studied. Indeed, also demand response strategies will be considered as potentially enabled for providing ancillary services.

SDEWES2022.0383

Hydrogen for Building Stock Energy Flexibility

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Abstract

Applications of solar hydrogen are gaining more and more attention as many studies show competition with traditional electric batteries. Seasonal storage due to the current sharp change in output due to solar radiation and tourism consumption in many remote areas leads to Flexibility performance to be assessed. Energy and economic analysis are the instruments needed to determine the profitability of the flexible solutions, as well as the dimensioning and functioning of the energy system. Due to the availability of reported hourly load and output datasets, a building complex equipped with a total of 100 kWp of PV is being investigated together with Hydrogen Energy Storage Solutions. Over the course of the year, storage facilities ranging from 500 to 2000 kWh were simulated for both hydrogen and electric battery options from an ideal dispatch perspective and computing the flexible loads as energy services for the distributors. In addition, the investment and operating cost value of 2020, 2030 and 2040 was inserted as an input to search for improvements to the increased Technology Readiness Level of the storage medium listed as well as the potential economic contribution of the allowed Flexibility. Finally, for both hydrogen and battery solutions, the annual dispatch is compared to shifts in economic input accounting for the incentive schemes available for setting up a Renewable Energy Community and the foreseen establishment of a Flexibility Market. The study found that at the relatively increased CAPEX of the H₂ based storage solutions, ranging between 1.5M\$ in 2020 to 591M\$ in 2040, with the implementation of incentives the 2020 OPEX are reduced significantly, lowering down the value from 8.3k\$ to 2.7k\$, that represents a massive operating cost savings close to 70%.

SDEWES2022.0388

Parametric Analysis of a Reversible Solid Oxide Cell System in the Different Italian Climate Zones

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Abstract

Italy energy system depends mostly on imported fossil fuels, and the actual geopolitics scenario that is taking shape can challenge the once well-established import routes.

The most vulnerable of this forced transition could be the final users, especially in the domestic building sector, that could suffer from a possible lack of gas supply for energy purposes or in a wider way, they can see their electric and gas supply jeopardized.

Nonetheless, renewable energies are mature enough to sustain this transition, enhancing the local independency from external resources. Combined with the Renewable energy penetration and diffusion also at a small scale, hydrogen and especially green hydrogen is gaining momentum as a multipurpose energy vector.

The Italian government, in fact, is launching a series of unprecedented initiatives to foster hydrogen uptake, following the example of many other countries worldwide. Among the different hydrogen production solutions, the Solid Oxide technology, thanks to its reversibility (rSOC) and combined heat and power production (CHP) can be seen as an interesting solution to be adopted at the building level, especially in the aforementioned scenario.

The rSOC can offer different advantages such as i) high efficiencies, ii) high-grade heat, iii) fuel flexibility iv) no need for rare materials for catalyst v) a compact solution unifying in one device only a fuel cell and an electrolyser.

The proposed research focus is to analyse the rSOC application in building archetypes located in the recognized Italian climate zones. Each zone is established by law, and it is allowed to use heating systems just for fixed periods, accordingly to their degree days.

The simulation will be done dynamically in MATLAB Simulink, both for the buildings and the hydrogen system, i.e. the rSOC and its storage system. The aim of this research is to investigate how the different climate conditions will affect the outputs of the same technology, also considering that the building analysed will be based on archetypes reconstructed according to different energy classes, to obtain a complete picture of the proposed solution effectiveness, in all the possible scenarios, in Italy.

SDEWES2022.0391**A Multi-Node, Multi-Vector, and Multi-Sector Formulation of Integrated Energy System Models to Assess Net-Zero CO₂ Emission Scenarios**

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Abstract

The attention to decarbonization has reached high concern globally and most countries seek the goal of net zero CO₂ emissions by mid-century. The urgency for a substantial transformation of energy sources, conversion methods, and final uses is widely acknowledged, but the implemented measures and the achievements seem still slow for the target.

A crucial aspect in the transition of energy and industrial sectors is the need for integration, since the processes related to low-carbon energy vectors (electricity, hydrogen, biomethane, biofuels, ...) are highly interwoven (e.g., electrolysis, e-fuel production from H₂ and CO₂). Also, exploiting synergies is essential to optimize the use of renewable and biogenic sources, which are limited, unevenly distributed, and intermittent. Carbon capture technologies are critical and may be applied on residual fossil fuels, on biogenic sources, or for direct air capture. Finally, new infrastructure needs emerge in terms of energy vector exchange and long-term storage.

This work adopts a highly integrated modelling approach to represent the multi-sector national system by means of a multi-node spatial resolution, to study the cost-optimal configurations in a multi-vector scenario. The energy system model simulates the year-long behavior with hourly time resolution and regional spatial aggregation, considering the balances of all energy vectors. Tracking the CO₂ balance enables the introduction of a net zero emission constraint, including point-of-use and supply chain-related emissions, conversion, natural contributions, and permanent sequestration. The energy vectors demands comprise regular and new electric users, industry, and transport (road, air, sea). The analysis identifies the required system structure, taking into account domestic energy sources, conversion devices, and import/export exchange.

The case of Italy is investigated to assess a 2050 scenario with net zero CO₂ emissions. The required power generation and energy storage capacities are extremely high, but in general positively impacted by sector integration and energy vector multiplicity. Results show that most of the estimated photovoltaic and wind power potential is exploited, up to 400 GW and 150 GW, respectively, and that biogenic sources availability is saturated, competing between power generation with negative CO₂ capture and biofuel production. The impact of different import/export assumptions is studied (e.g., energy vector cost, max annual quantities).

SDEWES2022.0400

Dynamic vs. Stationary Approach for Heating and Cooling Loads Assessment Onboard Ships: a Novel Paradigm for HVAC System Design

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Abstract

Ships designers assess thermal loads according to a stationary calculation method for internal (lights, machinery, people) and external (climate) solicitations (ISO7547). However, this approach typically leads to an oversizing of HVAC systems with a resulting negative impact on capital costs as well as on energy consumptions of plants and thus on the ship pollutant emissions. Furthermore, higher weights and dimensions of plants are often obtained also with a consequent reduction of ship spaces potentially useful to extra payload.

To overcome these issues, a more accurate assessment of heating and cooling loads can be necessary to properly design ship HVAC systems. To this scope, in this paper a novel design methodology, based on 3D approach and dynamic energy performance simulations, is presented and described. Here, real cruise conditions are taken into account by actual profiles of ship loads and hourly weather conditions (for accounting the location and orientations of ships during the cruise). By this method, multi-objective optimization procedures as well as economic and environmental impact analyses can be carried out.

In order to show the capability of this novel design approach and to highlight the limitations of the standard stationary calculation method, a suitable case study regarding the HVAC system design of a modern large ship (with more than 2700 rooms) is presented. Here, the 3D ship geometrical model is implemented in TRNSYS environment for assessing the design heating and cooling loads as well as to dynamically calculate the energy performances for different system layouts. Comparisons between the results obtained with the dynamic simulation approach and the stationary one is also presented.

SDEWES2022.0409

Techno-Economic Analysis and Sustainable Development of Solar Still Farm for Irrigation in a Pistachio Orchard in Hot-Arid Climate

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Abstract

Lack of water to irrigate pistachio orchards has become one of the main problems for farmers. The presence of wells with high salinity allows farmers to use water for irrigation using desalination systems. High salinity is not suitable for irrigating pistachio orchards. However, the total dissolved solids of water used to irrigate pistachio orchards is 5,000 ppm. In this research, a solar still farm for producing suitable water for a pistachio orchard in Kerman city, Iran was designed and modeled. For this purpose, at first, meteorological information such as ambient temperature, wind speed, and solar radiation intensity was extracted experimentally. Then the amount of needed water reported by farmers for pistachio orchards during 2020-2021. The results showed that a pistachio orchard with an area of 10,000 m² needs 6,000 m³ of water per year. Modeling a still solar system showed that freshwater production equals 2400 liters in Kerman. Based on the mixing of fresh water and brine to obtain suitable water used for irrigation of pistachio orchard, it was determined that this solar still farm needs 1250 still solar systems. Economic analysis also showed that this case study's internal rate of return equals 17.43 %. In the end, this research could be helpful to provide a significant overview of the actual innovation of using the solar farm for the pistachio orchard in a hot arid region like this case study.

Special session: New challenges or necessity of bridging the technological gap - understanding material, energy and waste flows in the circular economy

The linear economic model based on the production, use, and disposal of products does not yet take into account the environmental, social, and economic impacts and consequences of the alarming growth rate of world consumption of materials and energy. The concept of a circular economy, although gaining in popularity, still does not have a technological perspective for effective implementation. Complex management systems are not configured to respond to the challenge they face. According to The Circularity Gap Report 2022, global circularity decreased in only two years from 9.1% in 2018 to 8.6% in 2020. Moreover, the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) cannot be met unless water and waste management are prioritized.

This special session focuses on identifying new challenges, bridging the technological gap, and developing an interdisciplinary approach to understanding material, energy and waste flows in the circular economy.

The special session is mainly dedicated (but not limited) to the following topics:

- material flows in the circular economy;
- new technological solutions for matter recovery;
- energy balances and energy efficiency;
- effects of COVID pandemic on the quantity and quality of specific waste groups;
- using the IoT for smart waste management.

Prof. Małgorzata Kacprzak, Warsaw University of Technology, Płock, Poland

Prof. Krzysztof Wołosz, Warsaw University of Technology, Płock, Poland

Dr. Sławomir Alabrudzinski, Warsaw University of Technology, Płock, Poland

Prof. Mariusz Markowski, Institute of Mechanical Engineering, Faculty of Civil Engineering, Mechanics and Petrochemistry, Warsaw University of Technology, Płock, Poland

Dr. Marian Trafczynski, Institute of Mechanical Engineering, Faculty of Civil Engineering, Mechanics and Petrochemistry, Warsaw University of Technology, Płock, Poland

Małgorzata Kacprzak - Full Professor at the Faculty of Civil Engineering, Mechanics and Petrochemistry, Warsaw University of Technology (WUT) in Poland. Her experience in research spreads from research planning to execution, co-ordination and administration. She received several international stipends/employment, including: Depart. of Forest Mycology and Pathology, Swedish University of Agricultural Sciences, Uppsala, Sweden (VISBY PROGRAMME); the Laboratory of Chemical and Environmental Engineering (LEQUIA), Depart. of Chemical and Agricultural Engineering and Agrofood Technology (EQATA), University of Girona, Spain; Depart. Of Environmental Health Sciences, Division of Environmental Health

Engineering, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA (OECD); Laboratoire Genie Civil et geoEnvironnement, University Lille, France. The main scientific interests concerning on: circular economy, smart city, soil and air mycology, biological quality of degraded soils; technology phytoextraction, phytostabilization, phytobioremediation; sewage sludge management, biowaste in circular economy. She is co-author of 92 papers published in journals with IF and 8 patents. She has participated or coordinated 15 big projects. Actually she is member of Management Committee of COST Action CA20133 - Cross-border transfer and development of sustainable resource recovery strategies towards zero waste (FULLRECO4US, 2021-2025) She is the author and co-author of 20 expert opinions for industrial partners, local governments and the Ministry of Environment

Krzysztof Wołosz - Prof. Krzysztof J. Wołosz (Member of Scientific Advisory Board of SDEWES Conferences) holds dr. habil. degree (equivalent to DSc.). He works currently at Warsaw University of Technology (WUT) where he is professor at WUT's Institute of Mechanical Engineering. He has reviewed a number of manuscripts submitted to Applied Thermal Engineering (Elsevier), Energies, Applied Sciences, Fluids and Symmetry (all of MDPI) and Journal of Mechanical and Energy Engineering. He has been co-editor of conference proceedings published by TransTech Publishing and Special Issue Editor in Sustainability MDPI Journal. His research interests include exergy analysis and local entropy sources especially in transient phenomena, energy utilization in industrial equipment, and computational fluid dynamics.

Slawomir Alabrudzinski - Since 2002, affiliated with Warsaw University of Technology and active in fundamental and applied research in the field of single- and multi-phase flows, heat transfer and phase change. Author and co-author of over 20 scientific publications. Co-investigator in over 12 research projects with experience including flow visualization, computational fluid dynamics, numerical modelling and code developing. Reviewer for high-impact journals published by Elsevier, Springer, and AIP Publishing. Since 2019, has been supporting SDEWES Conferences as a member of Scientific Advisory Board.

Mariusz Markowski - Professor at the Faculty of Civil Engineering, Mechanics and Petrochemistry, Warsaw University of Technology (WUT) in Poland, and head of Faculty's Department of Process Equipment. Before joining WUT in 1998, he has gained 12 years industrial experience as process designer in the engineering companies specialized in oil refining and petrochemical works, and heat and power systems. He has also served as industrial audit expert for The Polish National Energy Conservation Agency (KAPE) in Warsaw, and as a lecturer at continuing education courses organized by KAPE. His main research field is energy integration and efficient use of energy in process plants. He is author or co-author of articles published in, among others, Applied Energy, Applied Thermal Engineering, Energy, Energy Conversion & Management, Renewable & Sustainable Energy Reviews, and of papers presented at major international conferences including PRES and Int. Conf. Heat Exchangers Fouling and Cleaning. He has also contributed to the monograph Process Systems Engineering Vol. 5: Energy Systems Engineering published by Wiley-VCH.

Marian Trafczynski - Assistant Professor at the Faculty of Civil Engineering, Mechanics and Petrochemistry, Warsaw University of Technology (WUT) in Poland. Prior to joining regular WUT staff in 2013, he has gained industrial experience as a process engineer with engineering companies and has also served as an industrial audit expert for The Polish National Energy

Conservation Agency (KAPE) in Warsaw. His research interests include rational energy utilization in industrial equipment and mathematical modelling of heat and mass transfer equipment. He has been the lead author of several articles published in, among others, *Applied Energy*, *Applied Thermal Engineering*, *Energies*, *Energy*, *Energy Conversion & Management*, *Renewable & Sustainable Energy Reviews*, and several more papers presented at major international conference series including PRES, SDEWES and Int. Conf. Heat Exchangers Fouling and Cleaning. He is a reviewer of several high-impact research journals and of the above-mentioned conferences.

Invited submissions

SDEWES2022.0110

Minimization of Exergy Loss in the Turbine Condenser Operated in a Power Plant

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Abstract

This paper focusses on minimization of exergy loss in the condenser of a steam turbine operated in a thermal power plant. In the existing power plant units, the exergy losses in the condenser are rather low compared to the losses observed in boilers. Taking into account the total power plant exergy losses, these values are estimated to be respectively approx. 2-4% but sometimes even as high as 50% . In the presented work, in order to reduce exergy losses, a new approach to the problem of steam condensation in steam turbine condensers has been introduced. Evaluation of the new ap-proach has been carried out by introducing a mathematical model of the turbine-condenser system. In the scope of condenser thermal-flow calculations Ansys Fluent solver has been employed. The study has been concluded with an exemplary calculation considering a power plant with a capacity of 2000 MWe. As a result of the proposed steam condensation subsystem modification, exergy loss in the condenser was reduced by approx. 30%, which corresponds to an increase in the efficiency of the power plant by approx. 1%.

SDEWES2022.0354**Benchmark Study of the Energy Saving Potential Using Simple Heat Exchanger Network Control Strategies in the Presence of Fouling**

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Abstract

Heat exchangers – typically arranged in heat recovery networks – belong to the devices most widely used in industrial production systems. The control performance of Heat Exchanger Network (HEN) operation can be impaired by fouling which builds up on the heat-exchange surface. Fouling leads to burning extra fuel to compensate for reduced heat recovery and induces increased costs of cleaning interventions, etc. A real-life benchmark system comprising a HEN operated as part of a Crude Distillation Unit (CDU) is considered. In such systems, the crude oil stream is typically split into parallel branches and the oil mass flows through the branches are kept in constant proportion (at constant split ratio) by the process control system. In this work, the use of various simple control strategies (employing linear control systems with PID controllers) for HEN operation was studied. The aim is to enhance the energy efficiency of the system (maximize heat recovery and minimize greenhouse gas emissions). A mathematical model of the HEN was built and validated on the basis of real-life data recorded during the CDU operation. The simulations of closed-loop control were performed in MATLAB/Simulink environment and the results enabled a comparative evaluation of the studied simple strategies of PID control and its potential to achieve energy savings in CDU operation under fouling conditions.

SDEWES2022.0358

Selection of Fouling Characteristics for On-Line Cleaning Schedule of Heat Exchangers Basing on Previous Operation Periods

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Abstract

In process plants incorporating Heat Exchanger Networks (HENs) for heat recovery, fouling building up on heat transfer surfaces hinder correct operation and lead to economic losses. The immediate reasons of these losses are: increased energy consumption and, in certain cases, also undesirable plant stoppages for heat exchanger cleaning. During longer periods of network operation, monitoring of fouling growth based on measurement data makes it possible to on-line schedule and perform exchanger cleaning if needed for the mitigation of adverse effects of fouling. In the present work, the authors used the previously estimated characteristics of the thermal resistance of fouling, based on historical measurement data recorded during a five-year continuous operation of the real-life HEN in a Crude Distillation Unit (CDU). The scheduling of cleaning interventions, that is, planning the sequence of cleaning of the specified heat exchangers, could be based on the a-priori knowledge of the selected time behaviour of the thermal resistance of fouling $R_f(t)$ in individual exchangers. It was demonstrated that determination of the variations of thermal resistance of fouling is possible if operating parameters of the HEN have been measured and recorded during previous production periods. In this work, a case study on the cleaning schedule of HEN in a CDU processing 800 t/h of crude oil, is presented.

SDEWES2022.0416

Compact Trickle Bed Bioreactor Technology as an Effective Method for Odor and Voc Removal in Biological Wastewater Treatment Plants

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Abstract

Odorous air pollutants, such as volatile organic compounds (VOCs) and inorganic compounds - hydrogen sulfide (H₂S) or ammonia (NH₃) - are emitted from various sources in the municipal sector, including wastewater treatment plants (WWTPs) and waste management plants. The growing problem of odor emissions requires air pollution monitoring and abatement, while maintaining energy and economic efficiency. Research is underway on the effectiveness of Compact Trickle Bed Bioreactor (CTBB) technology applications in the municipal sector. The aims of this paper are to present the results of air bio-purification in a CTBB to remove odors and VOCs emitted from a municipal WWTP, and assess the potential of implementing the studied technology into biological WWTPs. A pilot-scale CTBB reactor was installed at a municipal WWTP for bio-treatment of the air discharged from a grease waste tank. Flame ionization detection (FID), photoionization detection (PID) and electrochemical detection were used to measure the variability of pollutant concentration over time, at CTBB reactor inlet and outlet. Based on the measurements, pollutant conversion factors (removal efficiencies) were determined. The factor of H₂S conversion was 95-99%, and that of NH₃ conversion was 99%, throughout the measurements at a gas phase flow rate of 20 m³/h and at pH=7 in the liquid phase. The VOC conversion was over 90% during 70% of the entire measurement period with the use of variable gas phase flow parameters of 20 m³/h and 10 m³/h and at pH=7 in the liquid phase. The results demonstrate the high implementation potential of the CTBB technology for air purification of odors and VOCs emitted by a municipal WWTP.

SDEWES2022.0419**Assumptions for the Energy and Material Balance in Municipal Wastewater Treatment Plants (MWWTPs) in Poland**

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Abstract

Recently, municipal wastewater treatment plants (MWWTPs) have undergone a rapid transformation from linear installations of wastewater process and waste disposal (mainly sewage sludge) to facilities generating energy and marketed products. The energy balance of the WWTPs is the result of energy input for sewage treatment and energy output mainly from biogas. The levels of energy and heat consumption/production cannot be key factors of energy efficiency. High energy demand may result from the use of advanced technologies for wastewater and sewage sludge treatment and divided for: inlet pumps (25%), wastewater treatment processes (60%), sewage sludge disposal (15%). In Poland, the number of MWWTPs has increased from 2,417 in 2000 to 3,281 in 2020. Mainly for wastewater treatment are used biological methods (75%) and methods increase of N,P removal (25%). The amount of generated sewage sludge (SS) is only about 1-3% of the total sewage volume, but its treatment is a significant part of technological processes. The 568.8 thousand Mg d.m. of sewage sludge was generated in 2020 in Polish WWTPs.

The wastewater processes are mainly divided for three stages: primary, secondary and tertiary treatment. The main parameters influencing the primary processes are: i) KWh/kg of total suspended solids (TSS) removed and ii) KWh/kg P chemically rem. In turn, energy efficiency indicators of the secondary treatment process are OCP (Oxygen Consumption Potential) and energy demand for aeration and mixing. Finally, the tertiary process: i) KWh/kg of TSS rem., ii) KWh/kg of NH₄ rem., iii) KWh/kg of TN rem., iv) KWh/kg of P rem. The key factors of SS energy balance are: sludge characterization, initial mass of volatile solids (VS), anaerobical digestion (AD) conversion efficiency, and the energy consumption for sludge drying.

The most common methods of SS management include AD, composting, lime stabilization, drying and incineration. In Poland in 2020 over 17% (98.6 thousand Mg of d.m.) of sludge from MWWTPs was thermally transformed (10 times more than in 2010). However, the greatest amount - 40%, is still used in agriculture. The AD, pyrolysis, supercritical water oxidation are not only more effective in energy balance or sludge final quality but also have lower potential for global warming and toxicity compared to other methods.

Further investigations are necessary for decision support system of wastewater and sewage sludge treatment due to effective energy and matter balance.

SDEWES2022.0429

Investments in Road Constructions According to Circular Economy and Climate Change Mitigation

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Abstract

Production focusing on the use of resources as long as possible, in line with the EU's aspirations, favours the idea of sustainable development, creating at the same time closed-loops of product life. A circular economy (CE) is characterized by the maximum use of all elements of the chain production while minimizing the waste generated. Road investments in progress as part of the circular economy concept, require a large base of materials used at different stages of road projects.

The main goal of road industry aims to reduce the carbon footprint and drastically reduce the emission of carbon monoxide (IV) to the atmosphere. This is done by engaging machines, tools and means of transport characterized by relatively low energy demand. In road construction, the idea of a circular economy is implemented by use of mixtures contain recycled material in pavements, strengthening and stabilizing the substrate, foundations and creating communication embankments. Some countries use recycled materials for 95% of road investments. Technologies enabling the achievement of such results in the future are being developed in Poland. There are many types of surfaces that fit the idea of circular economy through the use of production residues from coal power plants, cement plants, but also recycling aggregates from demolition. Recycled material commonly used in road construction is reclaimed asphalt, which, after appropriate technological treatment, can be re-incorporated into the pavement. In addition to presenting recycled materials used in road investments, the authors also indicated current development trends, in line with the concept of a circular economy, such as the use of rubber granulate obtained from tire recycling, which is an co-substrate to new-design components of asphalt.

The analysis of one of the newly designed streets of the city of Płock in terms of consistency with the assumptions of the circular economy, confirm the potential for use of post-production residues in road constructions in the city.

SDEWES2022.0430**Biosolid Use in Agricultural Lands: Long-Term Effects on Selected Soil Chemical and Physical Properties, Accumulation of Triclosan and Sulfamethoxazole in the Soil and Maize Plant**E. Tesfamariam^{*1}, M. Ngoetjana¹, J. Okonkwo²¹University of Pretoria, South Africa; ²Tshwane University of Technology, South Africa
(*eyob.tesfamariam@up.ac.za)**Abstract**

The benefits and drawbacks of using biosolids on soil chemical and physical properties as well as crop production have been investigated in several regions of the globe. Nonetheless, there is scant information on the fate of emerging contaminants from a long-term field scale. The aim of this study was to investigate the long-term (> 15 years) effects of biosolid use in contrasting cropping systems on a) selected soil chemical, b) sulfamethoxazole (SMX) and triclosan (TCS) accumulation in the soil, and c) uptake of SMX and TCS by maize crop (*Zea mays* L.) and their resulting risk to human. Soil and maize plant samples were collected at harvest from a long-term (>15 years) field trial, consisting of two contrasting cropping systems (rainfed and irrigated maize). Each cropping system was treated with three biosolid application rates (4, 8, and 16 t ha⁻¹), a commercial inorganic fertilizer, and a zero control. Soil organic carbon (SOC) was determined by the Walkley-Black method. Soil pH and EC were measured in the soil-water suspension of 1:2.5. Total nitrogen (TN) was analyzed by dry combustion method using Carlo Erba NA1500 C/N analyzer. Identification and quantification of TCS and SMX, were achieved with the aid of Shimadzu Liquid Chromatograph Mass Spectrometer (LC-MS/MS model 8030). Biosolid application significantly ($p \leq 0.0001$) improved SOC and TN in the uppermost 30 cm soil layer. However, it significantly ($p \leq 0.0001$) increased soil acidity and salinity though the increment was too low to cause negative impacts on soil productivity. TCS and SMX concentration in the top 30 cm soil layer was below instrument detection limits (1.963 ng/g for TCS and 0.64 ng/g for SMX). Similarly, SMX concentration in maize crops was below detection limits (i.e. 14.30 ng/g). However, TCS was detected on maize crops treated with 8 t ha⁻¹ sludge rates and above with the highest concentration recorded on the stems (666 - 892 ng/g dry weight) and lowest on the grain (35.5 - 42.8 ng/g dry weight). The estimated daily TCS intake for the current study (0.21 µg Kg⁻¹ day⁻¹ for adults; 1.25 µg Kg⁻¹ day⁻¹ for toddlers younger than 5 years) is well below the Acceptable Daily Intake (83 µg/Kg/day). Therefore, biosolids use in agricultural lands could contribute to the UNSDGs without significant negative impacts on soil and human health risks via dietary intake of TCS and SMX.

SDEWES2022.0438

Heat Transfer Calculations for Subcooled Boiling During Time-Dependent Fluid Flow in Minichannels with the Use of the Trefftz Functions and in Adina Program

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Abstract

This work deals with boiling heat transfer during fluid flow in minichannels. The essential element of the experimental stand was the test section with groups of parallel minichannels of 1 mm depth, while groups comprised 7, 15, 17, 19, 21 and 25 minichannels. The test section was vertically oriented with fluid up flow. For solving the heat transfer problem related to time-dependent flow boiling, two numerical methods based on the FEM were applied. One of them was based on the Trefftz functions. The calculations were also carried out in the commercial ADINA program. In both methods calculations of the heat transfer coefficient on the heated foil–fluid contact surface were obtained from the Robin boundary condition, in which knowing the foil and fluid temperatures and gradient of foil temperature were required. The results obtained from both numerical methods and a simple 1D approach based on Newton's law were satisfactory.

SDEWES2022.0439

Trefftz Functions Methods in Analysis of the Effect of Enhanced Heated Surface on Fc-72 Flow Boiling in Minichannels

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Abstract

This paper focuses on time-dependent flow boiling heat transfer. The main element of the research stand was the test section with 11 rectangular minichannels of 1 mm depth. The FC-72 was heated by a thin foil during upward flow. The temperature of the outer surface of the foil was measured by infrared thermography. Two types of foil surface were tested: smooth and enhanced with recesses produced using emery paper. The main objective was to verify whether the enhanced surface helps to obtain a better heat transfer efficiency compared to the smooth surface. The mathematical model of heat transfer was proposed, while methods with Trefftz functions were applied to solve the time-dependent problem of heat transfer. The Robin condition was used to determine heat transfer coefficients at the interface between the foil and the fluid. Results based on the calculated coefficients are provided and discussed. Boiling curves are presented.

SDEWES2022.0502**The Influence of Changing Industrial Conditions on the Dynamic Characteristics of Pid-Controlled Rectification Heat and Mass Exchanger**

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Abstract

The present work is an extension of the authors' previous research, where the dynamic model of the apparatus used for thermal rectification of mixtures was developed, where in a channel-type exchanger the thermal separation of substances is accompanied by diaphragm heat exchange. It should be added that exchangers of this type are not yet used in industry, as they are still in the research phase and their application in heat-integrated distillation columns, would allow reducing heat consumption by 40-60% compared to the existing industrial solutions. In the present work, the behavior of heat and mass exchanger (HME) unit is simulated using Simulink/MATLAB and the influence of industrial constraints (grow up of deposits on the heat transfer surface or hold up of liquid inside the channel of exchanger) on specific indices of quality of operation is investigated. The dynamic properties of the new apparatus should be taken into account already in the early stages of its design; if this is not the case, then process control may require the use of very complex control system. The transient characteristics, obtained from the simulations, show that the commonly used proportional–integral–derivative (PID) controller can be applied in the proposed technology under industrial constraints. In the present work, according to the obtained results, the authors observed that when the thermal resistance of fouling and/or hold up of liquid are increased, the thermal inertia of HME is changed leading to changes in the dynamic behaviour. Such changes were detected by studying the step responses simulated at the different stages of fouling build-up and hold up of liquid. Moreover, the variations induced by fouling build-up on the exchangers' heat transfer surfaces and hold up of liquid are visible in the values of gain, delay time and time constant. The changes in the delay time in most of the obtained step responses are insignificant but the increased/decreased time constants and reduced/increased gain values may degrade PID control quality. However, adverse changes in control quality can be prevented for example by periodic adjustments of the optimal values of PID gains. From the transient characteristics states that the HME is dynamically stable under industrial constraints, such as grow up of deposits on the heat transfer surface or hold up of liquid inside the channel of exchanger. Moreover, the model confirmed that the dynamic change of distillate purity was negligible from the point of view of industrial applications.

Special session: Planning and modelling of next generation district heating and cooling systems

District heating and cooling (DHC) systems will have a significant role in future energy systems. They can integrate renewable energy, couple power and heating sectors and utilise locally available urban waste heat sources. Although DHC networks are well-known technology they are constantly improving throughout the years by reducing temperature regimes and increasing energy efficiency. This enables integration of new supply and storage technologies, installation of novel substations and implementation of prosumer business schemes.

This special session invites researchers which would like to contribute to the planning and modelling of next generation district heating and cooling systems. Potential topics include:

- optimisation and modelling of next generation DHC systems
- DHC network expansion planning
- the role of DHC systems in renewable energy systems
- power-heating sector coupling via DHC systems
- waste heat utilisation
- low-temperature renewables in DHC systems
- thermal storage in new DHC systems
- heat planning of novel DHC systems
- novel prosumer business schemes
- novel heat market developments.

Dr. Tomislav Pukšec, University of Zagreb, Zagreb, Croatia

Dr. Hrvoje Dorotić, University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Zagreb, Croatia

Tomislav Pukšec - Tomislav Pukšec is an assistant professor at the Department of Energy, Power Engineering and Environment, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb. He is engaged in research in the field of energy planning, sustainable development, modelling of energy consumption and systems, energy efficiency and renewable energy sources. He participates in the organization of SDEWES conferences, as a member of the local organizational team from 2011. He is the author of 44 scientific articles, 32 of which are indexed in the Current Contents database. He acts a reviewer in several high-impact scientific journals. He has participated in the successful preparation and implementation of 8 completed Horizon 2020 projects, 7 CIP IEE projects (Competitiveness and Innovation, Intelligent Energy Europe), 1 FP7 and one IPA project, and 3 projects of the Croatian Science Foundation. He is currently working on the implementation of 2 Horizon 2020 projects

Hrvoje Dorotić - Hrvoje Dorotić is a postdoc at the University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture. His research topics include the optimisation of energy systems, integration of renewable energy sources and sector coupling while focusing on district heating systems. He is also participating in EU projects funded by different programmes Horizon2020, HorizonEU, Interreg, EUKI, COST, LIFE and national ones. He is the author or co-author of 10 journal papers. His current h-index is 6.

Invited submissions

SDEWES2022.0007

Effects of Coupling Combined Heat and Power Production with District Cooling

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Abstract

Combined heat and power production (CHP) has proven itself over the past decades to be an efficient way to meet both heat and power demands. However, high efficiency can be achieved at CHPs when the heat load is sufficient, while lower-priority CHPs must deal with the excess heat associated with power generation. This excess heat can be used for district cooling with absorption chillers. Although absorption chiller is an efficient technology for using waste heat for cooling generation, its efficiency is very sensitive to driving hot water temperature. This paper provides a detailed analysis of how cooling generation in CHPs using absorption chillers affects power generation and primary energy consumption. This study is based on the operational parameters of the Mustamäe CHP (Tallinn, Estonia) and the cooling demand of the Tehnopol science and business campus and proposes sufficient cooling production capacity based on the estimation of the campus' cooling demand.

SDEWES2022.0044

Optimal Heat Supply Solution for Combined Heat and Power Production with Climate-Neutral District Heating in Narva

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Abstract

The article discusses the evaluation of potential heat production options for the large-scale district heating system in Narva (Estonia). Heat is currently produced at the Balti Power Plant (CHP unit), using local oil shale mixed with biomass. The CHP unit consists of two circulating fluidized bed boilers, including one reheat steam turbine. According to the planned development strategy, the district heating system will become carbon neutral in the future.

Various options and parameter variations should be analysed. The following scenarios are compared: an existing CHP plant completely replacing fossil fuel with biomass, covering both base and peak loads (Scenario A), as well as scenarios where biomass-based CHP provides baseload, and is coupled with a heat pump recovering heat from cooling circulating water after the turbine condenser (Scenario B), heat pump recovering heat from a nearby water reservoir (Scenario C), or coupled with biomass peak boiler (Scenario D).

To evaluate the above scenarios, an energy/exergy complex analysis is performed and economic indicators have been calculated. Primary energy consumed and heat and electricity produced are also taken into account. The reduction in CO₂ emissions compared to the reference scenario is assessed. In addition, sensitivity analysis of scenarios is performed considering various supply and return temperatures and flow rates and temperature operating strategy is found to be beneficial in all scenarios.

Based on this analysis, the scenario that will improve energy efficiency and reliability of the system is determined using multi-criteria decision-making.

SDEWES2022.0312

District Heating Systems Modeling: a Gamification Approach

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Abstract

District heating (DH) is supposed to largely contribute to achievement of the climate goals in the near future. However, public awareness, understanding and acceptance of the technology are required. At the same time, gamification has been identified as a viable teaching and learning method in higher education, which might be also appealing to non-professionals and might bridge their knowledge gap in DH. Since literature review has shown that no game about DH exists, the concept of a serious game about a heat supply system and its transformation from a fossil fuel-based system to a renewable-based one is introduced in this work. The first results of the game development are presented, namely, initial conditions, gameplay, the model of heating sector and the model of the DH transformation. The game will allow players to explore interdependencies between technical, economic, ecological and sociopolitical aspects as well as among different stakeholders (producers, consumers, government) and develop strategies for a successful transformation. The flexibility of different transformation scenarios and the influence of boundary conditions on the transformation can be analyzed after playing the game multiple times.

SDEWES2022.0511

The Method of Determining the Radius of Techno-Economic Feasibility of Waste Heat for the Planning of the District Heating System

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Abstract

The heating sector is one of the most energy-intensive sectors, accounting for almost 50% of final energy consumption at the level of the European Union. Looking at where that energy comes from, it is noticeable that almost 70% of that energy comes from fossil fuels. In this context, the question arises as to how this dependence on fossil fuels can be reduced, and one of the answers to that question is the utilization of waste heat, not only from industry but also from urban heat sources. Urban heat sources such as the refrigeration system of supermarkets, cooling systems of supermarkets and shopping malls, data centres, and power substations are well known and recognized as systems that can be a reliable source of heat for the district heating system, but what represents a difficulty is their spatial dispersion and therefore spatial planning a district heating system is more demanding and requires considering many factors. In this paper, a methodology is offered that systematically helps in planning the integration of urban heat sources in district heating systems, considering several criteria. The criteria can be divided into criteria characteristic of heat sources: heat source temperature, waste heat potential, and criteria characteristic of the district heating system: temperature regime of the heat network, heat demand, and plot ratio. The main outcome of the paper is to determine the radius of techno-economic feasibility of waste heat, , at different temperature regimes of the district heating network (high-, medium-, low-, and neutral-temperature regimes), different heat demands (environments with the low and high demand), and different plot ratios (high and low population environments). The method has been implemented and tested in the case of the City of Zagreb.

SDEWES2022.0535

Comparison of Ultra-Low and Neutral Temperature Thermal Heating Networks with Traditional Solutions

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Abstract

According to EU, district heating and cooling systems are crucial in achieving energy and climate goals related to energy efficiency increase and integration of renewable energy sources. These systems are constantly evolving, while the latest 5th generation is characterised by even lower supply temperatures (20-40°C), decentralised heat pumps, large-scale integration of low-temperature renewable energy and waste heat sources, energy bidirectionality and involvement of prosumers. They are often referred, as ultra-low temperature, neutral temperature or low-exergy thermal networks. Although there are numerous benefits for their integration they should be carefully analysed and compared with traditional solutions in terms of cost, carbon emissions and primary energy. Most of the existing papers are providing detailed analysis of selected 5th generation thermal network topology, however they are not comparing obtained results with the status quo solution. Furthermore, most of the papers are usually focusing on the capital and operational cost of the system, while carbon emissions and primary energy efficiency are usually overlooked. Last two factors are directly correlated to integration of renewable energy and waste heat sources, which are crucial for achieving status of energy efficient district heating and cooling according to the Article 24 of EU Energy Efficiency Directive. For this purpose, we have developed hourly model which is capable of providing operation of a district heating and cooling system while considering various system topologies and boundary conditions such as temperature regimes, plot ratio, operational and investment costs, etc. Obtained results have shown that ultra-low and neutral temperature district heating networks are superior to traditional solutions for specific boundary conditions. Finally, sensitivity analysis has been carried out with the respect to investment and operational cost.

SDEWES2022.0570

Low-Temperature Waste Heat Recovery in a Conventional District Heating Network: a Case Study

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Abstract

Waste heat recovery can provide a crucial contribution to district heating sustainability, though its convenience is significantly affected by the temperature levels of both the source and the network.

In this work, a theoretical case study related to part of the Aalborg district heating network is presented. First, the current behaviour is modelled and discussed. The size of the considered network section is of the order of 35 MW, for an overall network length of about 8 km. Second, the integration of waste heat from a data centre is studied, for different source temperatures (related to different operating conditions of the servers and to different recovery technologies, including heat pumps), different network temperatures (related to different seasons), and different sizes of the recovery unit. This is used to discuss the performance of the heat recovery system and to analyse the impact on the network operation.

The present work is part of the LIFE4HeatRecovery project, funded by the LIFE Programme of the European Union under contract number LIFE17 CCM/IT/000085.

SDEWES2022.0576**Dynamically Distributed District Heating for an Existing System**

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Abstract

District heating (DH) sector in developed DH countries is undergoing a major transformation from 3rd generation DH to 4th generation (4GDH). The 3rd generation DH is often based on fossil fuels and almost always on centralised heat supply. 4GDH has a more distributed heat supply based on renewable energy sources and/or excess heat. Although thermal storages are present in current DH system, these new heat sources and corresponding systems almost always benefit greatly from increased storage capacity. Also, the flexibility of the system is improved by increased storage capacity.

This paper introduces the concept of dynamically distributed district heating. The concept addresses the challenges within systems in transition, offering a cost-efficient option for introducing low temperature distribution and new distributed heat supply while preserving the advantages of an efficient, more centralised system. The concept includes the identification of suitable areas within an existing system, ideally located on the outskirts of the network. The areas would have a limited heat supply and a large seasonal heat storage. They would be run part of the year in island-mode. The storages are charged during summer when low-cost heat is commonly available. During the heating season, the area is disconnected from the main network by utilising the local supply and storage.

The concept allows the temperature levels within local DH system to be managed more efficiently due to shorter distribution distances. It also enables the main network to be run at lower temperature levels and with a more favourable demand profile.

The paper studies the viability of the concept in the city of Helsinki and for its city-wide DH system. The city is divided into small areas with heat demands based on the building stock data and the open-data heat demand provided by local DH company Helen. The objective of the study is to find out the number of potentially suitable areas, propose an optimal design for them and evaluate the overall cost-efficiency of the concept. A secondary objective is to show how this concept would shape the operation of the main system.

The concept could be utilised as a cost-efficient steppingstone towards low temperature distribution and 4GDH for existing systems. The concept is also applicable for new systems or extensions for an existing one.

Special session: Renewable and innovative energy technologies for sustainable systems

The need to increase the sustainability and energy efficiency of systems has led to the development and implementation of innovative design criteria and standards with special attention to the integration of renewable energies, use of innovative HVAC systems and implementation of new envelope technologies, together with the use of integrated approaches for the sustainable design of buildings, communities and transportation systems towards the decarbonization of our economies.

The goal of this special session is to present new research results, case studies and practices aimed at reducing the energy demand of residential, commercial, public, and industrial buildings as well as transportation systems and infrastructures, by also decreasing the related environmental impact and improving the occupants' comfort and well-being. The special session is mainly dedicated to the following topics:

- Advanced envelope technologies and new materials
- Automation and innovative control for HVAC systems
- Building Information Modelling and integrated design approaches
- District heating and cooling
- Electrical storage systems
- E-mobility
- Energy efficient transportation systems
- Energy sustainability, resilience and climate adaptability of systems
- Heat pumps
- Heat recovery systems
- Innovative HVAC&R systems
- Life cycle energy efficiency of systems and embodied energy
- Natural, mechanical and hybrid ventilation
- Renewable energy systems and devices
- Smart buildings, districts and communities
- Solar heating and cooling
- Thermal energy storage technologies
- Vehicle-to-building and vehicle-to-grid

Prof. Annamaria Buonomano, University of Naples Federico II, Napoli, Italy

Prof. Soteris Kalogirou, Cyprus University of Technology, Limassol, Cyprus

Prof. Adolfo Palombo, University of Naples Federico II, Naples, Italy

Dr. Rafaela Agathokleous, Cyprus University of Technology, Limassol, Cyprus

Dr. Giovanni Barone, University of Naples Federico II, Naples, Italy

Dr. Cesare Forzano, Università di Napoli Federico II, Napoli, Italy

Dr. Constantinos Vassiliades, Neapolis University Pafos, Pafos, Cyprus

Annamaria Buonomano - Annamaria Buonomano obtained a B.Sc. and a M.Sc. in Engineering Management summa cum laude in 2004 and 2006 from University of Naples Federico II and a Ph.D. in Energetics from University of Palermo in 2010. She was visiting scholar at the Energy Performance of Buildings Group of the Lawrence Berkeley National Laboratory (Berkeley, USA) in 2009, researcher at the Ben Gurion National Solar Energy Center of the Jacob Blaustein Institutes for Desert Research of University of Ben-Gurion (Sde Boqer, Israel) in 2011, and several times visiting scientist at Concordia University (Montreal, Canada), where she was appointed as Affiliate Assistant Professor in the Department of Building, Civil and Environmental Engineering in 2017. She is actively involved in research topics regarding building energy efficiency, with a particular focus on the development of performance simulation models and investigation of innovative building-plant solutions, based on integrated construction techniques, innovative HVAC systems and novel renewable energy technologies including solar heating and cooling systems, concentrating photovoltaic solar thermal systems, polygeneration, vehicle-to-grid, vehicle-to-buildig and related advances concepts (B2V2B or V2B2). She is also involved in collaborative research activities relative to the design of net zero energy buildings and communities through the integration of passive solar thermal systems in buildings and the use of electric vehicles to add flexibility to buildings.

Soteris Kalogirou - Professor Soteris Kalogirou is at the Department of Mechanical Engineering and Materials Sciences and Engineering of the Cyprus University of Technology, Limassol, Cyprus. He is currently the Dean of the School of Engineering and Technology. In addition to his Ph.D., he holds the title of D.Sc. He is a Fellow of the European Academy of Sciences and Founding Member of the Cyprus Academy of Sciences, Letters and Arts. For more than 35 years, he is actively involved in research in the area of solar energy and particularly in flat plate and concentrating collectors, solar water heating, solar steam generating systems, desalination, photovoltaics, and absorption cooling. He has a large number of publications as books, book chapters, international scientific journals and refereed conference proceedings. He is Editor-in-Chief of Renewable Energy and Deputy Editor-in-Chief of Energy, and Editorial Board Member of another seventeen journals. He is the editor of the book Artificial Intelligence in Energy and Renewable Energy Systems, published by Nova Science Inc., co-editor of the book Soft Computing in Green and Renewable Energy Systems, published by Springer, editor of the book McEvoy's Handbook of Photovoltaics, published by Academic Press of Elsevier and author of the books Solar Energy Engineering: Processes and Systems, and Thermal Solar Desalination: Methods and Systems, published by Academic Press of Elsevier. He is a member of World Renewable Energy Network (WREN), American Society of Heating Refrigeration and Air-conditioning Engineers (ASHRAE), Institute of Refrigeration (IoR) and International Solar Energy Society (ISES).

Adolfo Palombo - Adolfo Palombo obtained a M.Sc. in Mechanical Engineering summa cum laude in 1992 and a Ph.D. in Thermo-Mechanical Systems in 1997 from University of Naples Federico II. He was visiting scholar in the Energy and Analysis Program, Energy and Environment Division, at the LBNL, Berkeley, U.S.A. in 1995. He is actively involved in research fields concerning energy technologies for civil, hospital and industrial applications, such as heating and cooling of buildings, thermo-fluid dynamic measurements, power systems, renewable energies, innovative HVAC systems for energy efficiency and NZEBs. He is also involved in the development of dynamic building energy simulation tools for the assessment of energy, economic, and environmental performances of the investigated innovative systems. He is responsible of several MoUs with European, USA and Canadian universities and research institutes with the aim to further collaborative research and teaching activities on energy applications. He is also responsible of several funded research projects regarding the energy efficiency of systems. He is member of: Experts committee for reviewing and evaluating research projects funded by Italian Ministry for Industry (CSEA); Management Committee of the national technological cluster Blue Italian Growth (BIG); Management Committee of the IBPSA-Italy. He was member of: Board of experts in the permanent supervisory committee of the Italian Regulatory Authority for Energy, Networks and Environment (AREERA); Analysis committees at the direction for audits of Italian Energy Services Management (GSE SpA); Management Committee of Action TU1205 (Building Integration of Solar Thermal Systems, BISTS) of the European COST (Cooperation in Science and Technology).

Rafaela Agathokleous - Rafaela Agathokleous has accomplished her BSc. graduation in Mechanical Engineering and Materials Science Engineering in 2012 at the Cyprus University of Technology, Limassol, Cyprus. She got her MSc. graduation in Sustainable Energy Technologies and Management in 2013 at the Brunel University London, London, UK. Furthermore, Rafaela has accomplished her PhD in 2017 at the Cyprus University of Technology, with a thesis titled: Thermal analysis of Building Integrated Photovoltaic/Thermal (BIPV/T) systems. Presently, Rafaela Agathokleous is Post-Doctoral Researcher, while before Research Associate at the Cyprus University of Technology, Mechanical Engineering Department. Her research fields are mainly focused on renewable energies and in particular on solar energy systems and technologies. In these fields she also accomplished international research collaborations. Additionally, she is involved in editorial, holding the position of assistant editor at the Energy the International Journal of Elsevier, and she is a reviewer in Renewable Energy and Solar Energy journals as well. Rafaela is a member at the Chartered Institution of Building Services Engineers (CIBSE), member of the International Solar Energy Society (ISES) and member at the Cyprus Scientific and Technical Chamber (ETEK). Rafaela also had different teaching experiences and student supervisions at the Cyprus University of Technology, Mechanical Engineering Department. She was also visiting lecturer at Ulster University, Belfast School of Architecture, and the Built Environment, UK.

Giovanni Barone - Giovanni Barone obtained a B.Sc. and a M.Sc. in Mechanical Engineering in 2013 and 2016 from University of Naples Federico II and a Ph.D. in Industrial Engineering at the same university in 2020. He was visiting scholar at the Cyprus University of Technology (Cyprus) in 2019. He is actively involved in research topics regarding building energy efficiency, with a particular focus on the development of performance simulation models and investigation of innovative building-plant solutions, based on integrated construction techniques, innovative HVAC systems and novel renewable energy technologies including solar heating and cooling systems, concentrating photovoltaic solar thermal systems, polygeneration. He is also involved in

collaborative research activities relative to the design of net zero energy buildings and the integration of passive solar thermal systems in buildings.

Cesare Forzano - Cesare Forzano achieved the M.Sc. in Mechanical Engineering for Energy and Environment in 2016 at the University of Naples Federico II (Italy). He was visiting student at the Cyprus University of Technology (Cyprus) in 2017 where he started his research activity on Building Integrated Solar Systems. In 2020 he got his Ph.D. on Sustainable Energy and Technologies at the Free University of Bozen (Italy). During his Ph.D. he focused his research activities on diverse renewable energy systems, being also visiting student at the University of Ulster (UK). Currently, he is Assistant Professor at the University of Naples Federico II focusing his research activities on building energy efficiency, district heating and cooling, polygeneration systems, renewable energy devices, and especially on sustainability and energy efficiency of transportation systems (railway sector, etc.). In these fields he had different international research collaborations being also reviewer of diverse international journals. Cesare had many supervisions of students and different teaching experiences on Applied Thermodynamics, Heat Transfer, Advanced Energy Systems, and HVAC system design in BIM environment. He is also a member at the IBPSA-Italy.

Constantinos Vassiliades - Dr. Constantinos Vassiliades is an Assistant Professor at the Department of Architecture, Land and Environmental Sciences, Neapolis University of Pafos. He studied with a scholarship at the Aristotle University of Thessaloniki, where in 2012 got the Diploma of Architect Engineer with an excellent performance and was awarded as the best graduate. In 2018 he completed his Doctoral Dissertation at the Department of Architecture of the University of Cyprus, which deals with the building integration of photovoltaic and solar thermal systems. He is a Research Associate of the University of Cyprus and the Cyprus University of Technology, a Visiting Researcher at the Department of Industrial Engineering of the University of Naples “Federico II” and a Visiting Lecturer at the Division of Architecture and Water of Luleå University of Technology (LTU), as well as a partner at “Vassiliades Architects”. Constantinos deals extensively with the sustainability, technology, and energy efficiency of buildings on the architectural side, both professionally and within his research. He participated in relevant research projects, where he made publications, participated in conferences, taught in training schools in Barcelona and Warsaw, and he is selected as one of the 26 Rising Researchers of the ACU British Council Commonwealth Futures Climate Research Cohort. Several of his studies have been published in architectural and research journals and he is one of the authors and contributors of the book “Building Integrated Solar Thermal Systems – Design and Applications Handbook”. He is a Qualified Building Energy Efficiency Expert for Buildings Used as Houses of the Cyprus’ Ministry of Commerce, Energy, Industry and Tourism, member of ETEK (Technical Chamber of Cyprus) and of the Cyprus Architects Association.

Invited submissions

SDEWES2022.0009

Critique Review of Renewable Generation Technologies and Their Impact on Dynamic Grid Stability in Power Systems with 100% Renewable Generation

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Abstract

Most power systems throughout the world are making a transition to renewable energy a core target of their energy roadmaps. However, wind and solar power are not without their challenges. Battery storage is playing a role in this transition, but it is not silver bullet solution. This is because switching from synchronous to variable inverter-based renewable energy sources raises a number of technical concerns. The first key challenge is the intermittent nature or variability of renewable generation due to the weather dependency, which has prompted questions regarding the reliability and flexibility of a power network. The second challenge is that many of these new resources are interfaced to the grid via power electronic inverters rather by spinning electromechanical machinery. When compared to synchronous generators, inverter-based resources have very distinct characteristics, including a lack of physically coupled inertial response and, traditionally, a limited ability to produce large amounts of current during fault events. The progressive drop in both system inertia and short circuit current results in significant deviation in frequency and terminal voltage even during small active power imbalances. This issue is particularly important in islanded electricity networks with few synchronous interconnections, such as Ireland, the UK, and Australia, and even in the USA and China which has interconnected regions. Hence the main objective of this paper is to provide a comprehensive review of power system stability issues with integrating a high share of converter based renewable generation (i.e., wind power, solar photovoltaic, energy storage and smart appliances). This study examines the main implication of the transformation of global power system to 100% renewable electricity. The potential technology solutions, challenges, and limitations including energy storage, electric vehicles, demand response, synchronous condenser, and enhanced converter control strategy are assessed. This review further details the role of grid codes and international standards in maintaining dynamic stability in grids with very high to full penetration of variable renewable generation especially during severe grid faults. Finally, recommendations on potential technology pathways are presented in order to inform industry and accelerate this 100% renewable power system transformation.

SDEWES2022.0016**Comparative Techno-Economic Investigation of Hybrid Renewable Energy System Configurations for Power, Heating and Cooling**

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Abstract

The utilisation of renewables is acknowledged as a core element of solutions aimed at alleviating the energy (fossil fuels) shortage and environmental deterioration challenges that the world is currently facing. Hybrid renewable energy systems (HRESs) are suitable for addressing the intermittency of separate, individual renewable resources, and for their more reliable and flexible energy provision. They are thus expected to play a vital role in promoting the wider use of renewables. In this paper, a list of renewable energy technologies, specifically photovoltaic (PV) panels, solar thermal collectors (STCs), PV-thermal (PV-T) collectors, wind turbines (WTs) and biomass boilers are considered within selected HRES configurations based on different combinations of these technologies. Detailed techno-economic assessments of these HRESs are performed with Fayoum, in Egypt, as a case study. Local weather data and demand profiles are used, along with scale analysis considering the systems' sizes, to determine optimal systems for power, heating and cooling provision to a hotel, which is selected here as a building of interest given the growing importance of the tourism sector in Fayoum, as well as similar regions around the world. The results show that PV panels, especially the low-cost ones, enable the HRESs to deliver favourable performance, of which the levelised cost of equivalent electricity (LCOEeq) ranges from 0.05 \$/kWh to 0.10 \$/kWh, and the payback time (PBT) ranges from 14.1 years to 35.7 years for various system sizes. PV-T based systems are also promising, of which the LCOEeq is slightly (~ 0.01 \$/kWh) higher than PV based systems. A modified HRES layout that splits the heating provision into hot water and space heating satisfied by renewables (solar and biomass) and the hotel's existing air-conditioning system, respectively, is also proposed, and a decrease of ~ 0.02 \$/kWh in LCOEeq and a decrease of ~ 9 years in PBT relative to the original HRES are achieved, as it benefits from a smaller biomass boiler, lower biomass consumption and less electricity fed/sold to the grid. The results and conclusions from this work provide valuable guidance for the design and establishment of HRESs in practical applications, thus facilitating the wider deployment of such technologies.

SDEWES2022.0061

A Comparison Analysis Between Total Equivalent Warming Impact and Expanded Total Equivalent Warming Impact Index in an Air Conditioning Application for a Real University Building

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Abstract

Heating, Ventilation, Air Conditioning and Refrigeration sectors cause 7.8% of greenhouse gas emissions worldwide. The environmental impact of the energy conversion devices involved in these sectors have been analysed by considering both indirect and direct greenhouse gas emissions by using the well-known Total Equivalent Warming Impact index, TEWI. The direct effect is calculated by considering the refrigerant leakages into the system while the indirect emissions depend on electric energy consumption and emission factors associated to electricity power plants mix. Recently an innovative environmental index so called Extended Total Equivalent Warming Impact (ETEWI) method that represents and upgrade of TEWI, is proposed to scientific community with aim to improve the environmental emission of Heating, Ventilation, Air Conditioning and Refrigeration sectors. This index allows to revisit the traditional terms of TEWI and also to introduce innovative terms. The traditional direct term is detailed by considering the dynamic evaluation of refrigerant charge in the system while the indirect one is calculated by assuming the hourly variation of energy consumptions and emission factors. Four innovative terms are introduced in order to take into account Urban Heat Island effects, gas leakages on pipeline and fuel combustion-based devices. ETEWI is applied in this work to an electric air-to-air heat pump that supply heating and cooling demand of a real university building in South of Italy. A comparison between traditional TEWI and innovative ETEWI have been proposed to evidence the possibility to energy policy update for environmental indexes. The results demonstrate that the electric device shows a reduction equal to 29.7% in emissions evaluation by using ETEWI method with respect to traditional TEWI evaluation.

SDEWES2022.0066

A Simultaneous Energy and Transport Poverty Alleviation Analysis for a Just Transition

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Abstract

Despite increasing policy emphasis on creating a more equitable society as a key component of the energy transition, there is still a dearth of assessments investigating the equity outcomes of decarbonisation scenarios and community scale Just Transition case studies. This work seeks to fill this gap by examining how we could alleviate energy and transport poverty by studying Fermanagh and Omagh District Council as a case study in Northern Ireland. We examine total costs of ownership of mode shifting and car sharing in transport, and investment needs for domestic retrofit for energy poverty alleviation. We find that eBikes for suitable commutes bring substantial economic and environmental benefits compared to cars. For car sharing, the economic and environmental benefits are also substantial, with electric vehicles becoming cost effective at all occupancy rates from 2025. Regarding the alleviation of energy poverty, we find that the mean cost to retrofit energy poor dwellings ranges from £2,143 depending on dwelling type. However, up to 3.5% of residents of each dwelling type will find the consequent debt burden causes significant financial stress, particularly the elderly and those claiming benefits. We conclude that current support for energy and transport poverty alleviation are insufficient and too narrowly targeted, with their expansion being a requisite component of any hopes of achieving a Just Transition in Northern Ireland.

SDEWES2022.0070**Hydrogen Supply Chain Optimization for the Railway Sector: a Sicilian Case Study**

E. Cutore, A. Fichera, G. Inturri, M. Le Pira, R. Volpe*

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Abstract

The European Union (EU) is committed to reach climate-neutrality by 2050 and, to this scope, strategies and solutions should be proposed to address the energetic and environmental sustainability across different hard-to-abate sectors, as is the case of the transport sector. Railway transport is the backbone of the EU vision of a sustainable, seamless and integrated transport system. However, it faces many challenges. In Europe, almost half of the railway fleets are not electrified and constituted by diesel-powered trains used for cargo and passenger transport. As an alternative fuel, pure hydrogen represents a suitable candidate to foster the decarbonization of the transport sector and can be used to feed a fuel cell, a cleaner, flexible, carbon- and noise-free technology. As an energy carrier, hydrogen is produced using a wide range of energy sources, both renewable and non-renewable, with capabilities of being stored with minimal energy losses. Although advisable, the deployment of hydrogen fuel cell trains is still in its early development stage, due to the difficulties in building adequate infrastructures, such as electrolyzers and refueling stations, as well as in managing the decisional process for the optimal positioning and dimensioning of the entire supply chain. Under these premises, the modeling and optimization of a hydrogen supply chain is crucial to address the above-mentioned sustainability targets. In this work, the production, transmission, separation/purification, distribution, and fueling stages of the hydrogen supply chain are taken into account to model the optimal combination of technologies, their location and capacities, and the transport flows characterizing the railway sector. The different stages of the hydrogen supply chain are modelled as mixed-integer linear programming (MILP) problem aiming at defining the optimal technologies, operations and investments needed to allow the introduction of hydrogen into the railway sector. The Sicilian railway lines (Italy) have been chosen as case study to evaluate the viability of the technology for different decarbonization scenarios. Finally, a Well-to-Tank (WtT) analysis is carried out to assess the environmental, economic, and energetic performances of the entire railway network. Results confirm that the proposed model can be considered as a reliable tool for the decision-making process in the hydrogen railway sector. They allow the identification of critical aspects in each stage of the hydrogen supply chain and a detailed analysis of the impact of the proposed solutions on emission reduction.

SDEWES2022.0071

A New Multi-Step Approach to Modelling District Heating Systems Using Plexos

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Abstract

A reduction in the use of fossil fuel heating systems is essential to meet global net zero targets. District heating networks are becoming more widespread, and the number of buildings connected to a network is expected to grow steadily over the coming years. Heat networks do not undergo the same degree of regulation as electricity networks therefore there is a variation in pricing models among different suppliers. Furthermore, modelling of the system is more complex due to the presence of transients, thermal losses, and time delays. A common pricing structure is needed to allow transparency for consumers and incentivise a change in their consumption patterns for example conserving energy during times of high demand when expensive peak load production is required. This research explores a new techno-economic approach which can be used on both existing networks and new network proposals to forecast the heat load, considering building typology and seasonal variations, then uses PLEXOS to compute the most economic heat plant dispatch to meet demand.

SDEWES2022.0077

Techno-Economic Analysis to Identify the Optimal Conditions for Green Hydrogen Production

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Abstract

Green hydrogen can be utilised as an energy carrier to overcome the intermittency of renewable energy. This study investigates the production of hydrogen from wind using commercially available desalination and electrolysis units. Additionally, the intermittency of wind is examined, with comparison against grid bought electricity. A model was developed to determine the hydrogen selling price required to ensure profitability over a 10-year period. Firstly, where hydrogen is produced using energy from the grid, with electricity purchased when below a specified price point or between specified hours. In the second scenario a wind turbine is owned by the user and the electricity price is not considered, while the turbine CAPEX is. This study demonstrated an economy of scale with hydrogen prices found to be comparable in the scenarios at larger scale. Hydrogen prices are also closely linked to the CAPEX, with the equipment size, space and safety identified as limiting factors.

SDEWES2022.0083**An Experimental Evaluation on the Optical Properties and Transmissivity of a Novel Photovoltaic Glazing Daylighting Control Technology**

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Abstract

In this paper, experimental work has been carried out to evaluate the transmissivity of a novel daylighting control technology used on glazing. This systems' concept is derived from the novel glazing system Concentrated Photovoltaic Glazing (CoPVG) which uses total internal reflection to control solar gain and harness electrical energy onto the stationary photovoltaic cells placed onto the prismatic glazing module. During winter and fall months, the transmissivity and solar gain will be higher due to lower solar altitude angle. As a result of the inclination of the photovoltaic cells and glazing configuration, this allows a high percentage of solar irradiance into the building, with a maximum transmissivity value of 58% in a dynamic modelling tool. For summer and spring months, the transmissivity and solar gain in the building will be lower with high solar altitude. The work consisted of a small-scale wire frame box, to represent a room, the front of which incorporates the glazing element fixed to a timber frame arrangement. The wire frame box is set onto a rotatable board, to represent the sun's azimuth angles. This configuration in its entirety is placed on a vertical moving pneumatic lift. A lamp is used, to represent the sun. The combination of moving the vertical lift up or down and tilting the lamp, represents the altitude angles of the sun. Previous computational modelling and ray tracing work has been carried out to produce a schedule for the azimuth and altitude angles to indicate the time of the year with an associated transmissivity of the system. The purpose of the wire frame configuration is to enable the pyranometer to be placed into each square opening to record lumens levels at different points on the frame, at the corresponding azimuth and altitude angles. From these recordings, a transmissivity is denoted using the pyranometer at varying azimuth and altitude angles, representing the sun's path throughout the year. The measurements were taken on each face of the box and a cumulative total was taken and compared to the measurements taken on the front face. For the purpose of this study, the switching angles were the focus. This experimental methodology was used to validate the previous computational work carried out in IESVE, which looked at the systems' transmissivity throughout the year. The results from the experimental work shows a maximum transmissivity of 63%. The close proximity in transmissivity are a validation of using the commercial tool IESVE when defining the CoPVG's operation principle to allow further research to be carried out in various geographical locations. This dynamic model will also be furthered used to analyse solar gain, heating and cooling loads within a room and compare these to a room using standard glazing against the same room integrating the CoPVG.

SDEWES2022.0091

Indirect Evaporative Cooling as an Alternative or a Complement to Vapor Compression Systems

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Abstract

Indirect evaporative cooling exploits the saturation of an air flow with water to cool, through a heat exchanger, another air flow whose absolute humidity remains unchanged. A recent improvement in indirect evaporative cooling is provided by the so-called Maisotsenko cycle (M-cycle). In this, the air flow to be saturated consists of a part of the air flow that has been cooled, which is reintroduced into the heat exchanger. As a result, the limit temperature to which the remainder of the cooled air flow can theoretically be brought is not the wet bulb temperature but the dew point temperature. A 0D/1D mathematical model of an indirect evaporative cooling system based on the M-cycle is built and used to analyse the thermal behaviour of the cooling system. The aim is to support the implementation of the technology in full-scale applications, where the M-cycle is used alone or to complement a vapour compression system. A laboratory prototype of the M-cycle is also built, in order to explore key aspects of the technology and allow the validation of the mathematical model.

SDEWES2022.0094

Design and Development of a Novel Customer-Centric Retail Electricity Trading and Analysis Platform

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Abstract

The traditional structure and operations of retail electricity markets are being challenged with the proliferation of decentralised technologies, increasing customer engagement and the necessity of retail-wholesale market harmonisation. Retail electricity markets act as essential intermediaries between consumers, emerging prosumers and large-scale generators of electricity. On this basis, this study explores the conceptual design of a novel customer-centric retail electricity trading and analysis platform. The proposed platform provides an innovative web and mobile based application which consolidates customer engagement strategies, for electricity customers, retail electricity suppliers and utility regulators. Customer engagement strategies which are integrated in the proposed platform are as follows: 1. demand response and dynamic pricing, 2. analysis and provision of real-time energy consumption and monetary data and 3. a peer-to-peer electricity trading framework to flourish prosumer activity. The study concludes with the role of energy system stakeholders and policy makers have in enabling the commercialisation and technical implementation of this novel platform to support regional and global net zero targets.

SDEWES2022.0102

Study of Optimal Sizing for Various Hybrid Power Plants Including Hydrogen Vector as Storage System. A Case of Study in Corsica Island

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Abstract

The present paper aims to determine the optimal configuration of several hybrid power plants composed of renewable electricity production and various storage systems such as hydrogen storage systems. The sizing optimization problem is solved by using a Multi-Objective Particle Swarm Optimization (MOPSO). The multi-objective function consists in the minimization of the Annual System Cost and the share of Imported Energy from the grid or other non-renewable sources. The results show that configurations including hybrid storage systems are more reliable and economic than the one with only hydrogen storage systems. A power station with only hydrogen storage is three times more expensive than one with two storages. In addition, the current costs of hydrogen equipment do not appear competitive compared to the battery storage system costs. To mitigate this effect, some economic forecasts such as national subsidies, allowing the decrease prices of hydrogen components have been added. Actually, if the prices of hydrogen components decrease from 50%, a power plant containing both electrochemical and chemical storages becomes viable. That suits well to the European Union's policy in this area of Hydrogen. Considering a configuration with 10% of imported energy from the grid and 60% of reduction costs on hydrogen storage system, with the addition of a 535 kW PEMEL and a 335kW PEMFC, the batteries bank decreases from 7MWh to 5.6 MWh.

SDEWES2022.0116

Performance Assessment of a Microfluidic Glazing: Preliminary Results from a Winter Experimental Campaign

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Abstract

The use of large glazing façades allows to maximise the daylight and the visual connection with the external environment increasing the occupant comfort and the winter solar gains, but can result in high winter thermal energy losses and summer overheating. Microfluidic glazing (MFG) is a transparent technology which works as a heat exchanger controlling the fluxes through the component and, when integrated with a PV system, avoiding overheating risks and thus helping in maintaining a good efficiency of the solar cells. Nevertheless, the design and operation of this technology must be carefully managed in order to obtain the expected outcomes. This study presents the preliminary results of an experimental campaign set up to evaluate the energy performance of the MFG. Surface temperature control and distribution, and heat exchange through the component depending on different flow rates and circulating fluids, is here presented.

SDEWES2022.0123

The Application of En Iso 52016-1 to Assess Building Cost-Optimal Energy Performance Levels in Italy

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Abstract

In Italy, the cost-optimal calculation procedure, based on the comparative methodology framework established by the Commission Delegated Regulation 244/2012, was firstly applied by means of a monthly quasi steady-state calculation method of the building energy performance. The introduction of the EN ISO 52016-1 new simplified hourly calculation method created the necessity of new procedures. The aim of this work is to analyse the variation of the cost-optimal results by applying the different calculation method of the building energy need for space heating and cooling mentioned before to reference buildings. The cost-optimal analysis was hence performed on a group of buildings representative of the Italian building stock. The differences in terms of cost-optimal levels and packages of energy efficiency measures were assessed in the application of monthly and hourly methods. The results show limited variations in the resulting global cost, while the differences in the cost-optimal package of energy efficiency measures are not negligible.

SDEWES2022.0130

Design and Application of a Decentralized Ventilation System with a Heat Recovery Unit Adapting to Nordic Climates: a Case Study in Norway

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Abstract

This study evaluates the performance of decentralized ventilation (DV) system with a heat recovery unit (HRU) adapting to Nordic climates. Selected Norway local conditions were used to determine a HRU efficiency and acceptable weather condition for using the DV system without thermal loads. Around 4-20 % per year in the local conditions can use a fan-assisted natural ventilation system, and DV system with 0.7 HRU efficiency saves 14.5 % of total HVAC energy. An HRU efficiency highly dominated thermal ventilation energy demands in cold climates; however, the cooling efficiency did not significantly affect the energy demands. If the HRU efficiency is lower than 50%, the energy-saving rate is significantly decreased; therefore, it has no benefit for energy saving compared to using the centralized ventilation (CV) system; however, the DV system can be utilized in various working conditions to save energy with different occupancy ratios, individual room space zoning, and indoor air pollution rates.

SDEWES2022.0132

Experimental Assessment of a Novel Bio-Based Latent Thermal Energy Storage for Air Conditioning

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Abstract

This work experimentally investigates a novel 20 kWh LTES which uses the roll-bond technology to efficiently store and release the energy exploiting the solid/liquid phase change process of a bio-based PCM, CRODATA THERM 9.5. The thermal storage object of this work is made of a double wall insulated aluminum container with external sizes of 650 x 710 mm and a height of 1400 mm. The container thickness is 50 mm filled with an insulation material to limit as much as possible the thermal losses to the surroundings. Inside the internal tank, sixteen aluminum heat exchangers based on the well-known roll-bond technology specifically designed for this application are positioned vertically and connected in parallel to allow for the charging and discharging of the LTES. The heat transfer fluid (in this case water) circulates into this circuit, and it activates immediately the whole aluminum flat panel that assumes an average temperature similar to the one of the fluid. The fast heat transfer (commonly less than 2 minutes) makes this solution smart, efficient, and promising for the LTES application. The aluminum panels are light and can be easily positioned as a battery into the container internal volume. The aluminum heat exchangers are connected in parallel to two distribution manifolds made of stainless steel. The inlet and return manifolds are connected directly to the experimental setup that provides the cold/hot water to charge/discharge the LTES.

The heat exchangers are embedded in 300 kg of bio-based PCM that presents a nominal melting temperature of 9.5°C with a latent heat of this PCM is 186 kJ/kg.

The LTES is fed with a constant water flow rate coming from a chiller. The inlet water temperature can be set in range between 5°C and 20°C. The water temperature difference between inlet and outlet of the LTES is measured by a T-type thermopile (uncertainty ± 0.03 K, $k=2$) while the water flow rate is measured using a magnetic volumetric flowmeter (uncertainty $\pm 0.2\%$ of FS = $0.33 \cdot 10^{-3}$ m³/s). 39 calibrated T-type thermocouples (uncertainty ± 0.05 K, $k=2$) are inserted inside the LTES at 5 different heights to monitor the solid/liquid phase change process during the charging/discharging processes. The LTES is located inside a climatic chamber and the effects of the ambient temperature are evaluated by varying the air temperature 20°C to 35°C.

SDEWES2022.0133

Building Integration of a BIPV and a BIPV/T System on a Double Skin Façade: Design Optimization and Energy Analysis of a One-Bedroom Studio Apartment and its Semi-Open Space

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Abstract

The improvement of the energy performance of buildings, alongside with the utilization of alternative energy sources is imperative these days since the building sector in Europe accounts for 24% of greenhouse gas GHG emissions and 40% of the primary energy needs. Thus, building integration of passive techniques and active solar systems emerge as an energy-saving solution and a green construction practice, which is directly linked to the reduction of the environmental impact.

This research performed herein, investigates the contribution of three proposed double façade systems, a Conventional Double Façade (DF) system, a BIPV DF system and a BIPV/T DF system, on a one-bedroom studio housing module in terms of energy production, thermal loads and primary energy demands for heating and cooling. The cavity space of the DF system is treated as a “veranda”, a semi-open space which acts as an extension of the living space. Each scenario is parametrically investigated in terms of its cavity depth, to find out under which cavity depth each DF system is the most efficient in terms of thermal loads and primary energy consumptions. The scenarios were investigated using EnergyPlus dynamic simulation software through the platform DesignBuilder. The module was examined under Nicosia’s, Cyprus, climatic conditions, aiming to represent the South-Eastern Mediterranean region as well, to add into the existing knowledge of BPIVs and BIPV/Ts under these climatic conditions.

The aim of the research is to investigate the passive and active contribution of a DF with integrated active solar systems, on a typical studio apartment. The intermediate semi-open space’s viability in terms of thermal and visual comfort for the users, is planned to be thoroughly examined in the future, thus focusing to propose a design strategy and analysis that leads to the creation of nearly zero energy building modules, with DFs and cavities that can be used as extensions of the living space.

SDEWES2022.0135

An Innovative Hybrid Ac-Dc Distribution System for Efficient Use of Solar Systems

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Abstract

One of the main concerns globally is the phenomenon of climate change - which is mainly caused by human activities. The only solution to deal with this phenomenon, is to move to a cleaner, greener and more sustainable development in various sectors such as electricity, transports, industry, etc. An important step in this direction is the penetration of more and more renewable energy sources in the electricity grid. Therefore, with the increasing penetration of apparatus and equipment operating on direct current (DC) the concept of DC and hybrid AC-DC distribution systems attract more and more attention nowadays. The present study proposes a novel concept in the development of an innovative compact hybrid electrical-thermal storage system for buildings, in combination with an efficient DC driven heat pump using harnessed thermal energy through a separate solar thermal system, the installation of a hybrid AC-DC distribution system for the interconnection of the photovoltaic system, the electric storage and electrical loads of the building. Photovoltaic system, battery energy storage system and all the DC devices (such as DC Heat Pump serving the heating and cooling needs of the building) are directly connected to the DC part of the system, avoiding losses from unnecessary conversion stages, while AC loads and the AC utility grid are connected to the AC part of the system. The proposed configuration is expected to increase the overall energy efficiency of the system and will allow for energy savings around 20% on an annual basis based on efficient heating – cooling systems, less inversion losses etc. In addition, the overall system is controlled through a programmable logic controller (PLC), which decides and implements the optimal operation of the system. The proposed hybrid solution has been tested in near-life operation in a demo-site in Cyprus. This paper aims to describe the innovative system and assess its performance in real conditions through field measurements with regards to energy consumption, the energy production, indoor comfort conditions, and battery status and behavior. The concept presented herein is part of the ongoing research project HYBUILD, which is funded by the European Union through HORIZON 2020.

SDEWES2022.0139

Distributed Energy Resources for Resilience the Energy/Health Nexus

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Abstract

In the past, residential battery storage was only cost justified for off-grid households. Recently however, the lower costs and longer life of battery storage has created a market segment for photovoltaic (PV)+storage systems among some grid tied households used primarily for power bill reductions via self-consumption and time of use schemes. The increasing frequency of power outages along with a concern for energy equity has led to the need to determine the full value of behind the meter storage including the value of resilience in the residential sector.

Reliable access to electrical power is required to maintain normal functions of many critical systems and services such as refrigeration, well water supply, communications, medical devices, lighting, ventilation and thermal comfort systems. Sheridan et al found that there is a significant increase in emergency department (ED) visits, lengths of stay and cost of injuries during wind events coupled with power outages, especially among older individuals and Medicaid holders.

There have been previous attempts to identify and estimate vulnerable populations and their risk factors and to examine the impacts of specific storm events. In this study, we use the Empower Initiative Emergency Planning de-identified dataset to identify at-risk Medicare beneficiaries from the Medicare Fee-For-Service (FFS/Parts A& B) and Medicare Advantage (CMS' HMO plans/Part C) Programs that rely upon electricity-dependent durable medical equipment (DME) and cardiac implantable devices and healthcare services that include ESRD (dialysis), oxygen tank services, and home health visits. This medical data is combined with the US Energy Information Administration's Annual Electric Power Industry Report, Form EIA-861 detailed data on utility reliability.

Key Contributions of the Paper

- Explore additional value streams of PV+storage systems for behind the meter residential application
- Provide detailed economic analysis of the value of increased household resilience, for households with DME, through the implementation of PV+storage systems with a focus on rural settings

SDEWES2022.0141

Façade Renovation Using Building Integration of Active Solar Systems and Effects on Thermal Comfort in Public Spaces: a Case Study for Luleå, Sweden and Limassol, Cyprus

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Abstract

Climate change has brought up changes in energy management strategies in the urban landscape. This is based on the fact that the building sector is responsible for over 40% of the total primary energy consumption in the world and for 24% of the greenhouse gas emissions. This is exacerbated by the fact that the building stock in Europe is aging, in the need for energy renovation. Solutions such as the building integration of active solar systems are to the forefront of discussions, especially at a time when 50% of the world's population lives in cities, with this number becoming 80% by 2030, explaining the fact that cities are responsible for over 70% of global carbon dioxide emissions.

But how does building integration of active solar systems affect the built environment? The research performed here, investigates how the building integration of active solar energy systems in the facades of the neighbouring buildings affects the thermal comfort conditions in the public space, in two coastal cities, one at the northern end, and one at the southern end of Europe, Luleå, Sweden and Limassol, Cyprus, respectively. A typical example of the urban system of each city is chosen, and active solar systems are integrated on the facades of the buildings, according to each case. The thermal conditions on the street level are then simulated, using Envi-MET.

The research compares the thermal conditions in the public space, before and after the integration, aiming to assess the differences between low and high insolation conditions, using the Physiological Equivalent Temperature (PET).

SDEWES2022.0146

A Bim-Based Data Extraction Technology Framework to Serve a Novel Building Energy Reduced Order Model (Rom)

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Abstract

Energy consumption in buildings comprises in excess of 36% of global energy usage which in turn represents 28% of global energy-related CO₂ emissions in 2018. Building Information Modeling (BIM) is aimed at facilitating cooperation between stakeholders of the construction industry when designing, constructing, and maintaining new and existing buildings. A particular aim of these stakeholders is to develop energy resilient infrastructure with the least climatic impact. However, the extensive data/information exchange that exists throughout the Building Life Cycle presents one of the major challenges in the construction industry in achieving energy resilient buildings. Building energy performance simulation currently requires labor-intensive, error-prone, manual data transformations aimed at providing energy-efficient buildings. Providing a technology-based framework that enables the coupling of fit-for-purpose Building Information Model together with low-cost energy performance evaluation Reduced Order Models (ROMs) can play a key role in reducing economic costs and improving the energy resilience of new and existing buildings. ModSCO is a web-based ROM that supports systematic energy performance evaluation using grey-box computational methods, designed to simulate scenarios with incomplete or uncertain building information with low-order execution times. BIM data can be stored in an ISO standard IFC object-based open BIM file format. This paper presents an API-based workflow that extracts information from the BIM model to generate the essential parameters for the ModSCO ROM, thus simulated monthly energy profiles of a building. The workflow proposed in this paper has been successfully applied to a residential building in the Netherlands, within the H2020 project SPHERE. The paper describes the workflow, benefits, and limitations of its application in a real case study and future next steps.

SDEWES2022.0150

Analysis of Epcs: Impact of the Epcbd on Changes in the Energy Performance of Buildings

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Abstract

The fundamental characteristics of residential multi-storey apartment buildings in Lithuania that determine the energy performance class within the context of energy performance are discussed and analysed in the article. Summarizing the results of the analysis of energy consumption in buildings allow to make the conclusion that the Lithuanian government has implemented the requirements of energy performance directives to move to class A++ (nearly zero energy buildings - NZEB) by 2021. This was achieved by significantly reducing thermal energy used for heating and domestic hot water systems. In order to increase overall energy performance and to move to the construction of zero-emission buildings, it is necessary to prioritize the reduction of energy needed for domestic hot water preparation systems for buildings, electricity for lighting, electricity consumption for electric appliances.

SDEWES2022.0151

Thermal and Electrical Storage for the Energy Self-Sufficiency of Residential Buildings

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Abstract

To reach the EU 2030 goal of reducing greenhouse gas emissions targets, many apartments within residential buildings can be equipped with roofs top or building-integrated PV systems.

However, as non-programmable renewable energy sources (solar, wind) are characterized by uncertainty, and fluctuation, it is very difficult to resolve the mismatches between the production and demand for energy. In this regard, thermal and electric energy storage systems are crucial for maximizing self-consumption, reducing the difference between peaks and valleys, and for improving the flexibility of the electrical system. In this paper, the analysis of an energy system composed of a heat pump feed by a photovoltaic plant with thermal or electrical, as well as both storage is carried out for a reference building located in Catania (Mediterranean climate). The energy systems studied were simulated by a project created in TRNSYS. The results show that the use of both thermal and electric storage makes it possible to ensure both very high self-consumption and self-sufficiency of more than 80% and very low power exchange with the grid. The results of this study are useful to provide indications for the design of the storage in combination with a solar-assisted heat pump system avoiding the recurrent praxis of oversizing, in particular for the electric storage

SDEWES2022.0155

From Zero Energy to Zero Power Buildings: a New Framework to Define High-Energy Performance Future-Proof Buildings

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Abstract

The definition of Zero Energy Building (ZEB) has often been controversial both in regulation and research. A universal and shared definition of ZEB would allow a potential comparison between high-energy performance buildings. Currently, the same ZEB evaluated with an annual, monthly or hourly energy balance leads to misleading results. Energy flows should be reconsidered focusing on their time evolution (analysis timespan), their physical origin (boundary conditions) and their source of generation and distribution (primary resources).

This work aims to explore a new evaluation framework defining the Zero Power Building, a building whose energy performance is assessed at short timesteps, ideally tending to zero. The results of this work can find both research and regulatory applications, allowing fair comparison between buildings belonging to different contexts. A first demonstration is the application of the proposed framework on an ASHRAE reference building, evaluating its performance applying the conditions of the Zero Power framework. The results generated underline the importance of an accurate assessment of the building's performance and the need for an update of the current regulations.

SDEWES2022.0159

Effective Pre-Training of a Drl Agent by Means of Lstm Models for Thermal Energy Management in Buildings

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Abstract

Recently Deep Reinforcement Learning has gained popularity among advanced control strategies for building systems due to its model-free nature. However, DRL generally requires a considerable amount of time to converge to the optimal control policy. To overcome this issue, DRL controllers are commonly pre-trained offline in simulation environments based on engineering models of the real building. Despite their effectiveness, physics-based models require significant effort and expertise to be developed. The present paper aims at evaluating the applicability of data-driven models to pre-train DRL agents before their effective deployment in real-world case studies. In this context, an automatic procedure was designed to assess the minimum amount of monitoring data required to train a robust data-driven model to mimic the building dynamics and a DRL agent with acceptable performance. The proposed process was conceived to emulate the real-world implementation of the DRL control agent. The results show that the DRL agent was capable to ensure up to 90% of the time the desired indoor air temperature levels despite it was trained on a simplified data-driven model of the analyzed system while consuming the same amount of energy compared to a baseline rule-based controller.

SDEWES2022.0160

Evaluation of Indoor Comfort and Visual Conditions and Analysis of Energy Intervention Solutions in a Public Building in Cyprus

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Abstract

The energy efficiency of the public buildings is a key policy element to increase public awareness of the effectiveness of the energy renovation measures and the associated impact of the ongoing decarbonization regulations concerning the current building stock. This study aims to analyze the current indoor thermal and visual comfort conditions of a public building located in the warmer climatic area of Southeast Mediterranean and their impact on energy consumption. The methodology applied in this analysis combines analytical and computational simulation methods, primarily based on the 'sites' real operation data. More specifically, dynamic simulations are carried out with the plugin Climate Studio in Rhinoceros software which uses the EnergyPlus and the Radiance to analyze the indoor thermal and lighting conditions accordingly. Considering the results of this analysis, selected renovation measures are proposed to reduce energy consumption and increase thermal and visual comfort conditions. The results confirm the high energy upgrade potential of the public buildings while at the same time improving the thermal and visual comfort.

SDEWES2022.0163

Feasibility Study on Combined Heat and Power Systems for Hotels in the Maltese Islands

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Abstract

In Europe the energy consumed by the non-residential building sector, specifically the hospitality sector is one of the highest, with a study commissioned by the European Commission estimating that hotels in the European Union annually consume around 8TWh of energy for heating and cooling purposes. This amount is significant, especially in island economies such as that of the Mediterranean Island of Malta, where Tourism is often essential for the local economy.

To counter the requirement for the considerable amount of energy necessary to produce the heating and cooling required in such buildings, energy-efficient systems or the use of renewable energy are often listed as possible solutions. Based on this premise, the research contained in this paper presents an investigation on the feasibility of using Combined Heat and Power and Combined Cooling, Heating and Power systems for the hospitality sector in Malta. The financial and environmental impacts of such systems on the hospitality sector was therefore explored.

Using a supply-demand design methodology, the research made use of the software package RETScreen, to model the demand of a number of hotels ranging from 3-star to 5-star hotels. In total the electrical and thermal demands of six hotels were modelled using measured data collected from measurements done in these six representative hotels as part of a benchmarking study which had been done by the sectoral association, the Malta Hotels and Restaurants Association. Based on these modelled hotels, different scenarios were simulated to gauge the sensitivity of a number of parametric variables, including technical aspects such as thermal size matching (rated, over or underrated), (the presence of) financial grants, electricity tariffs, feed-in tariffs, and fuel prices. A total of 144 simulations were carried out.

Using the results obtained from the simulations the technical and financial feasibility of such systems in these representative hotels was evaluated. The energy results included the total amount of cogenerated electricity used by the hotel, the cogenerated electricity exported to grid, the net electricity grid imports, the heat recovered, the heat required, and the fuel used. The financial results used the calculated simple payback period and the net present value, amongst others, as the main key indicators.

The study showed that the variables having the highest impact were the financial incentives, the electricity tariffs, and the size matching of the system. Specifically, the study showed that the 4-star hotels considered were the entities which would benefit the most from having such systems implemented, and that even with minor changes in the electricity tariff structure it would still be financially feasible to install a Combined Heat and Power system for these hotels.

SDEWES2022.0164

Energy and Infection Risk Analysis of Ventilation Systems in Different Building Types

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Abstract

Ventilation is fundamental for providing a good Indoor Air Quality (IAQ) in buildings. In fact, the effect of supplying fresh air is the dilution and removal of pollutants, leading to higher levels of salubrity. The topic has achieved even more relevance during the current COVID-19 pandemic, as it represents a mitigation strategy against the airborne transmission of respiratory diseases. Nevertheless, ventilation involves considerable economic costs and energy consumptions, related to air handling and filtration.

In this paper, a comparison between different ventilation systems is carried out both in terms of energy demand and infection risk control. Three case-studies are analysed: a residential building and an educational building, both provided with a hybrid ventilation system, and a mechanically ventilated office building. For each case, thermal energy is generated by an air-to-air heat pump. A dynamic building energy simulation is performed in order to calculate the yearly primary energy consumptions, taking into account the electrical absorptions of the heat pump and auxiliary equipment. The analysis is carried out in two climates: Venice and Rome.

On the other hand, the airborne infection risk is evaluated through a model that couples a ventilation zonal modelling approach with the infection probability calculation. The former defines how the air moves within a space, subdividing it into well-mixed cells with a macro-discretisation grid. The latter is based on the well-know Wells-Riley model, which considers the infectious aerosols in terms of quanta. The integrated model provides an insight on the spatial variation of infection risk, evaluating whether the distance between susceptible and infected subjects is relevant. In the case of mechanical ventilation system, the trend of infection risk and energy consumptions are analysed at different ventilation flowrates. Finally, for educational and office buildings, the effect of wearing protective masks on the reduction of infection transmission is examined, as well.

SDEWES2022.0165

Energetic and Economic Advantages of Energy Communities: a Case Study Referred to a Southern Italian Town

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Abstract

The energy transition, i.e. the construction of a new energy and social model based on renewable energy sources production and consumption, with a view to distributed generation, cannot be further postponed. A high-carbon society has generated global warming, climate change, environmental and social inequity, requiring a profound rethinking of governments', businesses', financial systems' and individuals' interaction with the planet. But the transition also becomes an opportunity to generate new production and distribution models and eco-sustainable behaviours. New collective and collaborative actions, such as energy districts and communities, with new production/consumption exchange systems, combined with digital technologies, are at the heart of EU programs on green economy models. In this scenario the work arises, aimed to analyse electricity needs satisfaction of a condominium in Reggio Calabria (Italy), comparing users' photovoltaic electric supply as grid-connected separate users or as members of an energy community in terms of energy and economic benefits.

SDEWES2022.0168**Thermo-Economic Optimisation of Grid-Scale Compressed-Air Energy Storage Systems with Solid and Liquid Thermal Storage**M. Mersch¹, P. Sapin¹, A. Olympios¹, Y. Ding², N. Mac Dowell¹, C.N. Markides^{*1}¹Imperial College London, United Kingdom; ²University of Birmingham, United Kingdom (*c.markides@imperial.ac.uk)**Abstract**

Increased deployment of intermittent renewable energy technologies combined with a reduction in firm generation capacity from conventional power plants results in an increasing demand for large-scale, long-duration energy storage. Compressed-air energy storage (CAES) is a proven technology for storing multiple gigawatt hours of electricity for hours, days and even weeks. New developments, especially integrating thermal energy storage (TES) to retain some of the thermal energy generated during air compression, promise higher roundtrip efficiencies and lower levelised costs of storage. This makes CAES an attractive option for satisfying the storage demands of energy systems with high renewables shares. However, CAES plants need to be designed carefully to deliver these benefits, and many different configurations have been proposed. In this work, we apply a consistent thermo-economic modelling framework to assess the performance and costs of different CAES configurations with a nominal discharge power of 50 MW and a charging/discharging duration of 6 h. Special attention is paid to the TES options, with both solid packed-bed TES (PB-TESs) and liquid TES (L-TESs) examined as viable options for advanced CAES plants and different storage materials proposed for both options. The comprehensive thermo-economic optimisation, considering different system layouts, TES technologies and storage materials, is a key novelty of the presented work. A configuration with two PB-TESs using Basalt as the storage material is found to perform best, achieving an energy capital cost of 166 \$/kWh and a roundtrip efficiency of 69 %. Systems with PB-TESs perform better than systems with L-TESs both in terms of energy capital cost and roundtrip efficiency. The optimal energy capital cost of systems with one PB-TES are 19 % lower than those of systems with one L-TES, while achieving a roundtrip efficiency of 59 % compared to 38 % for the cost-optimal system with one L-TES. The best-performing PB-TES material achieves 15 % lower energy capital cost than the worst-performing, while for L-TES materials the difference is 43 %. For the latter, the performance depends significantly on the upper temperature limit of the material. The turbomachinery, as well as the pressure vessel in systems with PB-TESs and the storage material as well as the heat exchangers in systems with L-TESs, account for the largest share of investment cost, making them attractive targets for future cost reductions.

SDEWES2022.0169

Energy Assessment of a Dish-Stirling System Powering a Reverse Osmosis Plant for Seawater Desalination

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Abstract

Water scarcity in many regions of the world and the global demographic growth make the desalination of seawater and/or brackish an effective solution to meet the growing demand for freshwater. Nowadays, reverse osmosis has the largest share of the global installed desalination capacity. The impelling need to reduce greenhouse gas emissions has been pushing the search for sustainable technologies to produce the electricity needed to power reverse osmosis plants. Among solar technologies, little attention has been paid to the possibility of powering reverse osmosis with electricity from the dish-Stirling concentrator. To fill this knowledge gap, this paper assesses the energy-saving potential of a reverse osmosis plant coupled with a cogenerative dish-Stirling concentrator on a small island in the Mediterranean Sea. A model of the integrated systems was developed based on data measured on a real dish-Stirling concentrator, and variation of the energy consumption of the reverse osmosis plant with the temperature of the feedwater solution was also accounted for. Hourly simulations showed that almost 36% of the annual water demand could be covered by driving the plant using electricity from the concentrator, and the solar fraction of the electricity consumed by the reverse osmosis plant accounted for 57%. Finally, the analysis revealed that only a 1% decrease in solar fraction resulted when the heat recovered from the concentrator is not used for the feedwater preheating.

SDEWES2022.0173

Perspectives on Sustainable Energy Hub: a Transformation from Fuel Based Power Plant to Multi Energy Storage Plant

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Abstract

In response to the global climate change crisis, carbon neutrality strategies have been implemented around the world. Large amounts of sustainable electricity connected to the power grid requires large-scale energy storage. This paper recommends the strategy of multi energy storage including electric energy, thermal energy, and fuel storage instead of single electrochemical energy storage on the energy consumption side corresponding to the diverse energy demands. Transforming fuel based power plants to multi energy storage plants, i.e., sustainable energy hubs, is the prospect of achieving this strategy. The methods of constructing the sustainable energy hub are discussed. Combined with the existing power grids, heating and gas supply networks, multi energy storage plants can reduce the economic and social costs of the energy transition. The supporting conditions of fuel based power plants are analysed, and a preliminary layout of the multi energy storage plant is provided. The bottlenecks of the appropriate multi energy storage technologies are evaluated and prospected.

SDEWES2022.0178

Performance Assessment of a Hybrid PV-Thermal (PV-T) Collector: Detailed CFD Modelling of Flow and Heat Transfer

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Abstract

In recent years, new materials and absorber configurations have been proposed to improve the performance of hybrid photovoltaic-thermal (PV-T) collectors. This work analyses the fluid flow and the energy performance of an uncovered water-based PV-T collector with a roll-bond aluminium thermal absorber. A detailed computational fluid dynamics (CFD) model was developed in ANSYS Fluent and the results were compared with the experimental performance features provided by the PV-T manufacturer. The fluid flow results show uneven flow distribution among the roll-bond microchannels which might cause temperature hot spots in some regions of the PV cells. The several PV-T collector layers were also modelled using the energy transfer equations layer-by-layer. The model was run for several inlet water temperatures and water flow rates to obtain the thermal performance curve. The electrical efficiencies of the PV-T collector were also calculated. The results show that the developed CFD model reproduces accurately the thermal performance of the PV-T collector, with a maximum error of 6.5% for inlet water temperatures of 20-60 °C. Therefore, this model can be used with confidence to propose alternative designs that achieve a homogeneous temperature distribution in the PV layer and improve the overall PV-T collector performance.

SDEWES2022.0180

Innovative Hybrid Condensing Radiant Heating System for Industrial Buildings: an Energy and Economic Analysis

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Abstract

In this paper, an innovative hybrid condensing radiant tubes heating system for a typical industrial building was modelled in three very different climatic zones of Italy using a dynamic simulation software. The radiant tubes were coupled with an air heating system with terminals placed in the building: the latter were supplied by hot water produced by the condensation of the exhausted of the radiant tubes and by a heat pump with external air heat source. The energy performance of the hybrid heating system was evaluated by optimizing the main parameters: nominal power of the heat pump, bivalent temperature in alternative bivalent operation, cut-off temperature in parallel bivalent operation, and peak power of the photovoltaic system on the building roof. The analysis was performed considering the variation of the performance of the heat pump with the outside air temperature. The optimal configuration of the hybrid heating system that minimizes the annual amount of total non-renewable primary energy and maximizes the non-renewable primary energy ratio was compared to some more traditional heating systems for industrial buildings. The energy savings of this innovative solution vary in the range 40%-80% depending on the climate and the configuration of the system. An economic analysis allows also to evaluate the interesting economic advantages of the hybrid heating system for industrial buildings.

SDEWES2022.0183

Role of Neighborhood Spatial and Energy Design in Enhancing Energy Resilience During Power Disruption

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Abstract

Energy resilience is critical for survival during disasters and extreme events, as it is a key component in fulfilling various basic needs, such as providing indoor thermal comfort (heating and cooling), food preparation, hot water, and others. Urban developments can become more resilient by establishing reliable and affordable energy systems and resources. This paper discusses the role of neighborhoods' design in enhancing their energy resilience during power disruptions. Neighborhoods' design includes building types existing within these neighborhoods and their role and function, land use and spatial design, the architectural design and energy characteristics of specific buildings to act as local shelters in case of evacuations, and available renewable and alternative energy sources that can assist during power outage, including electrical and thermal energy disruption /blackout. The neighborhoods considered in this study are designed according to sustainable practices while reflecting north American urban developments. Several scenarios are designed and analyzed to account for the duration of disruptions, scenarios of evacuations, and type of temporary shelters. The role of community design will be highlighted under each of these scenarios, and recommendations on practices to enhance resilience will be discussed.

Preliminary results indicate that in general, employing local evacuation buildings during an electrical crisis, is less energy vulnerable than leaving the population in their residences. Electrical energy can be fulfilled by onsite energy generation for under 24 hours, for some of the neighborhoods considered in the study. For longer power outage scenarios (1-3 weeks), the type and design of evacuation buildings should be carefully designed to allow proper accommodation of the whole population. Regarding thermal energy outage crisis, while original neighborhood designs cannot meet their thermal requirements during the wintertime, neighborhoods that have higher density population are especially vulnerable. Better energy resilience can be achieved by appropriately designing onsite energy resources to eliminate electrical and thermal energy vulnerabilities. For instance, employing 8.8% to 15.4% of the neighborhood land to accommodate solar thermal collectors can eliminate the thermal energy vulnerabilities during the energy outage scenarios.

SDEWES2022.0188

Energetic and Photosynthetic Performance Investigation of a Semitransparent Photovoltaic Rooftop Greenhouse (Stpvrg) for Building Integration

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Abstract

Semitransparent photovoltaic rooftop greenhouses offer advantages in terms of water-energy-food-ecosystems nexus in an urban context. Over the last decade, multifunctionality in urban planning has attracted increased attention. In order to tackle this challenge, the present study aims to evaluate semitransparent photovoltaic rooftop greenhouses based on organic photovoltaics and ethylene-tetrafluoroethylene films. The goals of the study are as follows: 1) to investigate the effects on plant growth, 2) to evaluate the impacts on the energy balance of the greenhouse/building. In order to meet these goals, a RADIANCE/TRNSYS model has been developed. Two cities have been examined: Barcelona and Paris. The results show that these systems are promising and can cover part of the electricity demands of a building: around 15% and 17% for Barcelona and Paris, respectively. Additional parameters such as Daily Light Integral and External Quantum Efficiency have been investigated. Different scenarios have been examined.

SDEWES2022.0189

Life Cycle Assessment (LCA) of Building-Integrated Solar Systems Based on Organic Photovoltaics and Ethylene Tetrafluoroethylene

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Abstract

Taking into account the importance of Organic Photovoltaic (OPV) modules and Ethylene Tetrafluoroethylene (ETFE) foils to building-integrated applications, the present study aims at evaluating two OPV-ETFE façade-integrated systems that have been developed and tested at the University of Lleida, in Spain. An environmental Life Cycle Assessment (LCA) has been conducted. The majority of the calculations have been based upon SimaPro software and ecoinvent database. The environmental profiles of the OPV-ETFE systems for Barcelona and Paris have been examined. The calculations involve two electricity mixes with notably different compositions: the electricity mix of Spain and the one of France. The results reveal that the energy payback times are: i) around 1-2 years (in most cases), ii) lower in comparison to the lifespans of the systems. Except for energy payback time, the study also involves other kinds of environmental indicators and different types of life-cycle impact assessment methods. Considering certain impact categories, it has been found that there are striking differences between the results of Barcelona and those of Paris. These remarkable differences are mainly due to the specific characteristics of the French electricity mix (high share of nuclear-generated electricity; low carbon emissions). Comparisons with traditional Si-based photovoltaic systems are also presented. Finally, it should be noted that the main components that have been investigated (OPV cells; ETFE foils) are used not only for façade-integrated systems but also for a wider range of applications (for instance, for long-span membrane structures and greenhouses). Therefore, the results of the present study would also be useful for other types of systems/applications.

SDEWES2022.0195

Coupling a Road Solar Thermal Collector and Borehole Thermal Energy Storage for Building Heating: First Experimental Results

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Abstract

The combined use of solar energy and seasonal thermal energy storage systems allows the maximisation of the renewable fraction of energy used for heating non-residential buildings.. This paper presents the results of the experimentation and numerical simulations used to design a new pilot plant consisting of road solar thermal collectors connected to a borehole thermal energy storage. For this purpose, a 30 m long pilot borehole, equipped with 10 thermal sensors, was realised on facility test site. Through a series of different unconventional thermal tests and using more than one year of thermal measurements, it was possible to characterise both the undisturbed thermal profile of the soil and the thermophysical characteristics of its different strata. This data was used to calibrate a detailed three-dimensional multi-physical finite element model coupling the road thermal collector and the seasonal thermal energy storage. Using climate input data from a typical meteorological year of the facility test area, hourly-based dynamic simulations were performed to assess one year of plant operation. Numerical results show how the solar thermal energy stored in the soil during the summer season, can be recovered to heat a building during the winter months.

SDEWES2022.0198

Exploring Analytical Tools to Support the Energy Transition Towards Decarbonized Public Buildings

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Abstract

The decarbonization of the building sector is one of the main challenges that Europe is facing and the large-scale deployment of nearly Zero Energy Buildings is seen as one of the essential means. The recast Energy Performance of Buildings Directive EPBD 2010/31/EU (European Union, 2010) makes nZEBs a standard for new buildings by end of 2020. However, for Europe to be climate neutral by 2050 requires commitments beyond nZEBs level. As a consequence, in December 2021 the European Commission (EU) aligned the requirements of the energy performance of buildings with the European Green Deal and sets out the decarbonisation of the EU's building stock by 2050 in the context of the new revised directive, EPBD2021/0426. The revised EPBD proposes as of 2030, all new buildings must be zero-carbon emission. Moreover, regarding public sector, all new public buildings must be zero-carbon emission already as of 2027. To make public buildings more energy efficient requires tailored solutions but also decisions and planning involving Local Public Administration.

In this context, the authors of this paper, who are participants in the Interreg MED Project, PrioritEE Plus, are willing to share the initial findings from the use of a Decision Support Tool in the Portuguese context. The use of the DSTool is used in 3 building clusters belonging to different public entities and located in different climatic zones in Portugal. The users of the DSTool can simulate several renovation scenarios corresponding to different packages of energy efficient measures, compare the results and prioritize according with the level of intervention and related costs. It is expected that this tool can support the Public Administration actions, decision and local plans towards the decarbonization of the Public Buildings.

SDEWES2022.0201

Evaluation of the Potential of Data-Base Centers to Reduce the Heating Demand in University Buildings

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Abstract

The European Union aims to be climate neutral by 2050. To do this, and as an intermediate objective, a first key mission consisting of cities being climate neutral by 2030 is appointed, since they currently produce 72% of global emissions and, in 2050, they will have 80% of the world's population.

This research work is developed within the framework of "Missions Valencia 2030", an initiative promoted by the Valencia City Council and integrated into the "Urban Strategy of Valencia 2030". In this context, the Polytechnical University of Valencia (UPV) is an ambassador entity of these "Missions" and, as such, it can be an example of good practices acting as a sandbox environment, where those solutions for decarbonization of UPV campus, might later be transferred to the city and vice-versa.

The main objective of this research work is the proposal of measures that support the decarbonization of the UPV Vera campus, in the city of Valencia. Special focus is dedicated to waste heat recovery of the ASIC data center located at UPV campus which has an approximately constant cooling demand all over the year, which amounts to a yearly 1,661,020 kWh. To recover that heat, a polyvalent 300 kW heat pump (able to easily switch from water-to-water to air-to-water working modes) was selected for a simultaneous contribution of cold and heat in a set of strategically identified buildings at campus: UPV data center, and three buildings located nearby using natural gas boilers central system at UPV for heating. A thermal storage was designed to balance the cooling and heating needs.

First, a big data management was done where the electrical consumption registered was analyzed. Second, the buildings thermal energy demand was obtained through building simulation models developed in CYPE software and experimentally validated, as no individual gas consumption data was available per building. Finally, a technoeconomic assessment was carried out for two different scenarios considered corresponding to different ways of waste heat recovery. Results conclude that savings higher than 254,106 thermal kWh, and a consequent reduction in CO₂ emissions of at least 64,035 kg can be obtained. Therefore, it is concluded that this project is beneficial for the environment, supporting the decarbonization of the Vera campus to become climate neutral in 2030.

SDEWES2022.0206

Evaluation of Multiobjective Model Predictive Control for Commercial Building Indoor Air Quality and Energy Performance

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Abstract

Despite a slow adoption for several decades, technological advancements, political pressure and lower costs are now fostering the deployment of advanced building control. The availability of advanced control methods is motivating the consideration of alternative objectives that could render buildings not only energy efficient, but also allow them to participate in energy markets or become more resilient structures of refuge in case of emergencies. Driven by the pandemic, a growing concern is occupant health and indoor environmental quality taken as a whole, motivating the focus to indoor air quality in addition to thermal, visual, and acoustic comfort. Multiobjective control allows devising algorithms that simultaneously meet multiple objectives of energy efficiency, energy cost, indoor air quality, and thermal comfort in ways that are not achievable with conventional rule-based controllers. Recently developed building simulation test beds enable us to design, test and finetune such multiobjective controllers methods, where virtual buildings can be exposed to a variety of design and boundary conditions.

This paper demonstrates the usage of a novel virtual test bed, the Advanced Controls Test Bed (ACTB), for the design of a model predictive controller (MPC) that controls the HVAC system of a high-fidelity Spawn of EnergyPlus model of the U.S. DOE Reference Small Office Building. This MPC monitors indoor temperature, CO₂ levels, weather forecasts that include the air quality index, and the current and forecasted cost of electricity in Chicago, IL, U.S.A. This test case demonstrates the design of an advanced controller that balances HVAC system energy usage and energy cost with indoor air quality and thermal comfort. The ACTB is based on the Building Optimization Testing Framework (BOPTEST), and its capabilities include the comparison of controller performance based on several key performance indicators. The MPC controller performance is compared to a conventional rule-based controller based on ASHRAE Guideline 36-2018 in terms of energy use and cost, thermal comfort, and indoor air quality.

SDEWES2022.0225

HVAC Systems Configurations in Post-Pandemic Era: Cost-Benefit Analysis to Support Energy Investment Decision-Making

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Abstract

The COVID-19 pandemic has put a strain on HVAC systems, highlighting the shortcomings of existing air handling technologies and systems management. During the pandemic, attention was entirely devoted to guaranteeing proper indoor conditions not to affect occupants' health; therefore, the main prevention measures undertaken were the increment of the outdoor air rate in air handling units (AHU), reducing the share of recirculating air, the use of auxiliary filtering equipment, and the extension of systems operation hours. If these actions allow to reduce the risk of airborne transmission, they have a non-negligible impact in terms of energy consumption, unsustainable in the long-term.

To gradually return to normal HVAC systems operations, there is the need to find solutions and innovative technologies able to represent a good trade-off between energy consumption, indoor air quality and occupants' health. To do so, HVAC systems considerations must be guided by proper methodological approaches, able to make these benefits quantifiable and evident to consumers, to support energy investment decisions.

These considerations are fundamental for public spaces since the risk of infection is higher in crowded and poorly ventilated spaces. Specifically, in Italy, attention is currently devoted to schools, which are recognized as critical hotspots for SARS-COV-2 virus transmission, due to the high occupancy density, the seating arrangement and the frequent contact between occupants, the extended time spent indoor, as well as the inadequate indoor air conditions of Italian existing schools.

In the light of the above, the research aims to develop a cost-benefit analysis (CBA) for estimating the impacts of diverse AHU configurations installed in Italian schools, according to different scenarios: during COVID-19 and post COVID-19. The different configurations are compared according to the diverse air filtering technologies installed in the AHUs, as well as accounting the different operation strategies undertaken in the considered scenarios, in line with the guidelines and recommendations in force during the COVID-19 emergency. The work aims to demonstrate the need to move from a more financially driven analysis of the different solutions to an integrated approach, able to include, quantify and monetize the individual and social benefits that the compared configurations could guarantee in terms of energy cost savings and reduced health-related costs.

SDEWES2022.0290

Compound Parabolic Concentrator System with Two Storage Tanks for the Domestic Hot Water Production in Hospitals: Transient and Energy Evaluations

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Abstract

The objective of this research work is to study the energy performance of a compound parabolic concentrator (CPC) system with two storage tanks for the production of domestic hot water (DHW) used for two different users; the first requires high temperatures while the second requires lower temperatures. The system investigated consists of CPC systems, connected to two heat exchangers arranged in series, in turn, connected to two storage tanks that supply DHW to the users. The user considered is typical of a hospital building that requires DHW at a temperature of 50 °C and 80 °C. The hourly DHW demands for the two hospital users were calculated by starting from reference standards applied to a hospital user.

A calculation scheme was created in a transient simulation environment that provides dynamically all temperatures at different points of the three circuits, in addition to calculating all thermal exchanges through each component. The outcomes of this work are the study of the influence of the CPC size on the system transient behaviour, a qualitative-quantitative determination of the monthly and yearly system performance and the definition of some performance indicators on a monthly and yearly basis. Finally, some empirical correlations are proposed to rapidly verify the system performance without using any transient simulation tool.

SDEWES2022.0330

A Dynamic Programming Based Method for Optimal Control of a Cascaded Heat Pump System with Thermal Energy and Battery Storage

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Abstract

More and more residential heating and cooling (H&C) systems are being electrified, with most of them using heat pumps (HP) in combination with electrical and/or thermal energy storage systems.

Innovative system configurations are reaching the market with HPs coupled in a temperature cascade: a central HP maintains a low-temperature water-loop where thermal storage tanks (TES) are installed; the water loop provides thermal energy to the evaporators of distributed booster HPs, located in the apartment or in each room of the apartment.

Such a system configuration may cope with variable outdoor air temperatures and with the availability of intermittent renewable electricity. When the latter is readily available and/or operational variables are favourable for the efficient use of the central HP operation, the TES is charged; excess renewable electricity is eventually stored in batteries. In meeting the thermal building loads, stored thermal and/or electrical energy can then be used by the booster HPs to function under optimal conditions.

However, with ever changing operating objectives to consider, finding an optimal control is a complex endeavour. Model predictive control (MPC) is an established approach for solving the problem of optimally managing energy systems and has been used in a multitude of cases in the research community. Due to the large solution space (5-10 operational parameters for each of the time steps), any exhaustive search approach is computationally infeasible.

The presented solution approaches this MPC problem by developing a dynamic programming (DP) based strategy, where for each point in time, the state of the system is characterized by the state-of-charge of the storage. With the help of this DP framework, it is then possible to find a globally optimal control solution at acceptable computational effort, as detailed modelling of the system concerned is avoided.

In this paper, we will first show a performance comparison between a detailed, physics based model validated through laboratory tests, and the reduced order model, which is the foundation of the DP optimization. Second, for a representative multi-family house in a southern continental climate, we will show how the DP approach implemented can result in meaningful electricity savings vs. a conventional rule based controller, or in remarkable load shifts to favourable hours of the day, depending on weather conditions, grid operator reward signals and/or availability of local renewable electricity.

SDEWES2022.0393

Novel Planar Liquid-Vapour Thermal Diode: Mathematical Modelling and Experimental Validation

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Abstract

Increasing attention of the scientific community is focused on the development of innovative building Integrated Collector-Storage Solar Water Heaters (ICSSWH) to be adopted in buildings. Such devices can in fact permit catching the solar energy and storing it into the device itself without needing centralized storage systems (saving on installation and running costs). Nevertheless, several issues exist in terms of the heat retention capacity of ICSSWH. In this framework, increasing interest is paid to thermal diode technology whose adoption enhances the heat transfer between two sides of the device, while obstructing it in the opposite direction. These systems can revolutionise ICSSWH devices by enhancing both heat collection and retention performance. In this framework, this paper presents a dynamic mathematical model of an innovative liquid/vapour planar thermal diode (LVPTD) prototype. The model, developed at the University of Naples Federico II, is suitably validated through experimental data of the actual device, developed and experimentally tested at the Centre for Sustainable Technologies (CST) at the Ulster University of Belfast. By the developed model, the collection and retention efficiencies of the proposed thermal diode prototype under diverse boundary conditions can be tested, achieving interesting results from both heat collection and retention points of view.

SDEWES2022.0401

Comparative Energy and Economic Analyses for a Novel High-Vacuum Integrated Collector Storage Solar Water Prototype

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Abstract

This paper investigates the energy and economic performance of an innovative Integrated Collector-Storage Solar Water Heaters (ICSSWH) prototype by assessing the influence of weather conditions and local energy market prices on the related energy and economic performances.

As it is well known, standard ICSSWH devices are typically affected by thermal losses which significantly reduce their economic profitability. Convective and radiative losses account for approximately 80% of the overall. To reduce these heat losses, a novel high-vacuum flat-plate ICSSWH prototype, featured by a very high-vacuum gap (up to 10^{-8} mbar), is developed. By this evacuated space (where the absorber serpentine water storage is located) the convective thermal losses are practically nullified. In addition, the serpentine absorber system is suitably painted with a special low-e coating for also significantly reducing the radiative thermal losses. Therefore, by the presented prototype a hot water storage with very low temperature drops during time intervals with no or low solar radiation can be achieved.

To analyse the energy performance of the above mentioned innovative high-vacuum ICSSWH prototype, a suitable dynamic simulation model was developed and implemented in a computer tool written in MatLab. This tool, based on a detailed 3D transient finite-difference thermal network, was experimentally validated. The energy performance and economic profitability of the proposed system are highly dependent on weather conditions and natural gas or electricity purchasing prices (of backup systems). For assessing the energy and economic convenience of such a device a comprehensive parametric analysis is here developed. Specifically, for 10 different weather zones, for diverse use profiles, and by varying the main system design and operating parameters a complete energy, economic and environmental performance analysis is conducted by comparing the innovative system performances to those of traditional ones. In general, promising outcomes are achieved in terms of energy saving and paybacks. Of course, a remarkable dependence on the climate zones is detected.

SDEWES2022.0402

Guidelines to Reach the Goal of Positive Energy Airport Terminals

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Abstract

This study has the scope of identifying valuable solutions to reduce energy consumption of airport terminals, and providing guidelines to stakeholders to implement important efficiency measures to make airport facilities zero impact and face the challenges that national legislations and international directives impose for energy saving.

A comprehensive study of a wide range of energy-saving actions was carried out by means of a detailed building energy simulation model of a two-story terminal building comprising 91 thermal zones. Specifically, the Naples International Airport was modelled accounting for real information gathered from previous energy audits on the facility. Several energy-saving strategies such as envelope improvement, HVAC systems enhancement and renewable energy adoption were analysed. The carried out analyses highlight a significant savings potential and show how airports can become important green hubs for the production of energy from renewable sources. Design criteria can be obtained by the achieved simulation results and exported to airports in Mediterranean area.

Special session: Safe Use of Wastewater in Agriculture; a Water-Food-Energy Nexus

The agriculture sector has been heavily dependent on freshwater for thousands of years. Currently, in some arid regions with freshwater scarcity, 80- 95% of available freshwater is used for agriculture, while the global average is 70%. In other areas, freshwater scarcity and the cost of energy and fertilisers have driven millions of farmers to use wastewater. Globally, over 20 million hectares of agricultural land is being irrigated using wastewater, however, not all wastewater used for irrigation is safe. Therefore, now more than ever, with our better understanding of the effects of climate change, the importance of preserving freshwater resources and biodiversity, and in light of the rapidly growing demand for food, water and energy, the agriculture sector needs an improved and scientific approach to make better and safer use of wastewater. WHO has published guidelines for safe water reuse; however, the adaptability of these guidelines remains challenging. To address the technical and institutional challenges of safe water reuse, developing countries need precise institutional arrangements and skilled professionals with a sound understanding of wastewater reuse's risks and opportunities.

To promote the Safe Use of Wastewater in Agriculture (SUWA), this research proposes to realize the potential for wastewater as a source of water, nutrients, and energy. Hence, by applying a 'nexus' approach, project partners will utilise their interdisciplinary expertise to demonstrate the value of wastewater and highlight the interdependence of water, energy and food security and potential for enhancing their combined significance in Iran and Tunisia as case studies. Research partners will also engage private and public sectors' stakeholders to evaluate SUWA strategies. Importantly, this project will deliver scientific, user friendly and fit for purpose guidelines for the safe use of wastewater in agriculture, particularly in developing countries.

This session will be focused on:

- The water-food-energy nexus, which is central to sustainable development. The demand for safeguarding the sustainable supply of water, food and energy is increasing, driven by a rising global population, rapid urbanization, changing diets and economic growth. Agriculture is the largest consumer of the world's freshwater resources, and more than one-quarter of the energy used globally is expended on food production and supply. The inextricable linkages between these critical domains require a suitably integrated approach to ensure water and food security, and sustainable agriculture and energy production worldwide.
- More specifically, this project is directly linked to SDG6: Clean Water and Sanitation. It focuses on recycling and recirculating water within an industry, and safe reuse. Safe reuse of wastewater in agriculture is complementary to the focus of SDG target 6.4 on reducing freshwater withdrawals and improving the efficiency of use. There will be specific focus on case studies in relevant environments, where needs for safe use of wastewater in agriculture have been identified, which can be used to holistically consider technological solutions, whilst at the same time influencing local policy for wider implementation

Papers focused on the aforementioned aspects, possibly integrated and applied to any context (marginal lands, wastewaters, degraded urban landscape, etc.) with focus on relevant topics such as stakeholders, policy making, end-users (e.g. farmers, householders), technical feasibility, health and safety and sustainability (environmental, social and economic aspects) are welcome.

Dr. Serena Caucci, United Nations University, FLORES, Dresden, Germany

Dr. Kourosh Behzadian, University of West London, London, United Kingdom

Prof. Ioannis Ieropoulos, University of Southampton, Southampton, United Kingdom

Serena Caucci - Serena Caucci is an Associate Programme Officer at UNU-FLORES. Prior to joining UNU-FLORES, Serena served as a researcher and scientific project manager at the Technische Universität Dresden, Germany and at the Helmholtz-Centre for Environmental Research – UFZ in Leipzig, Germany where she elaborated and coordinated efforts on water sanitation and the impact of contaminants of emerging concern in anthropogenic-driven environments. Serena has also worked as consultant for the EIT Climate KIC where she developed curricula for innovation trainings and knowledge transition in bioeconomy. She began her career as Environmental Science Fellow at the University of Florence, Italy where her work on carbon storage mechanism by microbial community in soils was part of a LIFE project Natura 2000. Serena's current research is geared towards sustainable development with a special interest in the impact that anthropogenic activities have on natural resources. Focusing on the sustainable management of wastewater and organic waste, Serena is working towards the development of a transdisciplinary framework that could make use of socioeconomic and environmental interlinkages to enhance sustainable natural resource management. The final goal of her activities leads to knowledge translation for evidence-based decision-making processes and its implementation at various scales.

Kourosh Behzadian - Dr Kourosh Behzadian (BSc, MSc, PhD, FHEA, FICE, FCIWEM, CEng, C.WEM) is Associate Professor and Course Leader of BEng (Hons) Civil Engineering and MSc Civil Engineering in the University of West London. He is expert in Hydro-systems Engineering and Management and Operations Research, a Chartered Civil Engineer by the Engineering Council, Fellow of ICE, Fellow of CIWEM, Chartered Water and Environmental Manager by the Chartered Institution of Water & Environmental Management (CIWEM), Fellow of the Higher Education Academy in the UK, Editor of the Journal of Cogent Environmental Science, Taylor & Francis Group, Honorary Research Fellow at the University of Exeter, Brown International Advanced Research Institutes (BIARI) Alumni at Brown University. He has worked on several research projects in the UK, Europe, America and the Middle East. He has (co)authored over 120 peer-reviewed journal papers, conference papers and technical reports. He has also supervised over 40 postgraduate research students in various fields of civil engineering (water engineering, hydraulic structures, environmental engineering and construction management).

Ioannis Ieropoulos - Ioannis A. Ieropoulos is Professor of Bioenergy & Self-Sustainable Systems and co-founder and Director of the Bristol BioEnergy Centre, Bristol Robotics Laboratory, UWE. He has an interest in waste utilisation and energy autonomy and produced the EcoBot family of robots and RowBot, which have their own MFC microbiome and operate completely devoid of conventional power sources. He has been an EPSRC Career Acceleration Fellow (2010-2015) and is currently a Bill & Melinda Gates Foundation grantee on the "Urine-tricity/PEE POWER®" project, advancing the MFC technology for sanitation improvement in Developing World Countries. He leads projects, focusing on robotics, biodegradable & functional materials, funded by the Leverhulme Trust, and the European Commission (FP-6, FP-7 and H2020) with a focus on living architecture. He has published >100 peer reviewed journal papers, generated >£10M of research income in the last 10 years and holds 2 patents on MFC stack development, configuration, modulation and control.

Invited submissions

SDEWES2022.0556**Safe Use of Activated Sawdust Treated Aquaculture Effluent for Agricultural Purposes**O.K. Olanlokun¹, M.O. Jimoh*²¹University of Strathclyde, United Kingdom; ²University of Warwick, Coventry, United Kingdom, United Kingdom (*Modupe.Jimoh@warwick.ac.uk)**Abstract**

Aquaculture is a fast-growing industry and an area of agriculture with substantial water use. Unfortunately, in most places, it is discharged without treatment for irrigation or directly on land, into drains or other water bodies. If treated, this substantial volume of water would come in handy as a helpful resource safe for other agricultural purposes. Sawdust is a common by product of woodwork. It is often disposed of in landfills or burnt to reclaim working space. The use of sawdust for the removal of heavy metal ions from synthesized wastewater has been established by other researchers. It, therefore, lends credence to its being a potential material for aquaculture wastewater treatment. This study intends to investigate sustainable ways to re-use two different forms of agricultural waste product (sawdust and aquaculture effluent) towards circularity and environmental management. For this study, two different types of sawdust: homogenous (Isoberlina Doka wood specie) and heterogeneous mix (Daniella ogea, Anogesus olivera, Isoberlina doka, Afzelia bipinensis and Gmelina arborea) were converted into Activated Sawdust (AS). Catfish farm (CF) wastewater was collected from the National Centre for Agriculture Mechanization (NCAM), Idofian, Nigeria. The AS was employed to treat Catfish Farming Effluent (CFE) using adsorption via a batch process in the laboratory. The effluents were tested to determine the efficiency of the treatment process. The efficiency of AS treatment for phosphorus, BOD, TDS and nitrite removal in the CFE was 12 %, 44 %, 60 %, and 83 %, respectively. This paper further examines the possible areas of agriculture where an aquaculture effluent treated with sawdust waste and the sludge produced can be useful by benchmarking the treated effluent quality against standards for agricultural water use.

SDEWES2022.0558**Preliminary Investigation of the Electroactivity of a Newly Isolated *Pseudomonas Citronellolis* Strain in a Double Chamber Microbial Fuel Cell**C. Varnava¹, P. Persianis¹, I. Ieropoulos², A. Tsipa*¹¹University of Cyprus, Cyprus; ²University of Southampton, United Kingdom
(*tsipa.argyro@ucy.ac.cy)**Abstract**

To date, many studies have shown a significant progress in MFCs applications, with the scaling-up to industrial MFCs being, now, the challenge. The latter, in some cases, is restricted due to the limited known number of electrogenic microorganisms and the materials of electrodes. Investigation of new microorganisms with exceptional electrocatalytic activity to improve the MFCs performance is necessary¹⁻³.

Pseudomonas has been effectively used in various biotechnological applications, and has successfully been applied in MFCs as an anode biocatalyst. Pure cultures in MFCs should be used to lead us to a better understanding of the molecular mechanisms employed, gene regulation and metabolic pathways activated for bioremediation, electron transfer and electricity generation. Thus, allowing the employment of optimization strategies. However, the most common *Pseudomonas* species used is *P. aeruginosa*¹, an opportunistic pathogen, which significantly limits its use in MFCs applications.

Therefore, to overcome the latter limitation, we preliminarily investigated the electroactivity of a *P. citronellolis* strain, isolated in our lab⁴ in a medium-sized double chamber MFC. Oily wastewater (OW) and M9 minimal salts media (Na_2HPO_4 , KH_2PO_4 , NaCl , NH_4Cl , MgSO_4) were used in the anodic chamber, and a 0.5 M potassium ferricyanide solution as a cathode. Polarization curve experiments were carried out. The optimum load was, then, used for maximum potential difference generation. Based on our preliminary studies, the maximum potential difference generated was 543 mV in a 14-days period. In addition, SEM, and COD and GC/MS analyses are planned to reveal strain's biofilm to the anode electrode, and OW biodegradation efficiency. The results of this preliminary study let us be particularly optimistic about strain's electrochemical activity. Further targeted studies need to be done for technology performance optimization, in terms of its operation in the anodic and cathodic chamber.

SDEWES2022.0559**Understanding Sustainability of Water Reuse in Agriculture: a Global Review on the Dimensionality of Indicator-Based Assessments**S. Caucci^{*1}, I. Georgiou², H. hettiarachchi³, G. Edeltraud³, A.K. Hüske⁴¹United Nations University, FLORES, Germany; ²United Nations University UNU-FLORES, Germany; ³United Nations University Unu-FLORES, Germany; ⁴Copenhagen Business School, Denmark (*caucci@unu.edu)**Abstract**

The need for a sustainable development that integrates the environmental, social and economic dimension has been the pillar for the introduction of the Sustainable Development Goals (SDGs) for prompt and targeted policy actions. SDG 6 and 12 (clean water & sanitation and responsible consumption & production) have emphasized the importance of a sustainability assessment of water reuse in circular economy especially in agriculture where its activities are responsible for more than 70% of the worldwide water abstraction and thus natural resource depletion. Sustainability assessments provide a powerful tool for translating knowledge into policies and practices. Indeed the concept of sustainability is well established but its interpretation and application vary in practice, especially when it comes to indicators. Despite indicators provide a powerful qualitative and quantitative way of measuring different aspects of sustainability. With this paper we aim at identifying the gap between theory and practice of assessments on water reuse in agriculture. In detail, we conducted a systematic review of studies assessing the sustainability of water reuse in agriculture. The systematic review revealed a rather complex relationship between the dimensions with underlying interlinkages, as many indicators cannot be categorized as one-dimensional, but multi-dimensional. The analysis is thus conducted at the indicator-variable level, here referred as indicator factors rather than indicators. Factors forming the sustainability indicators are classified either as economic, environmental or social factors according to their measured impact within the indicator as a whole.

In this paper we focus on the dimensionality of the assessments, the indicator factors, the boundary levels in which they are applied and the demographic and geographic characteristics of the areas studied. Interlinkages between multidimension of the factors were also considered to propose the next steps towards a holistic sustainability assessment. Overall, 664 indicator factors were identified in the 132 researched scientific publications assessing sustainability of water reuse in agriculture and allocated in regards to how many dimensions they simultaneously assess. The results also provide a global overview of the drivers for sustainability assessment in water reuse and seeks to highlight the main gaps in the current practices towards a more holistic sustainability assessment.

SDEWES2022.0566

A New Empirical Approach for Modelling Fate and Transport of Chromium Bioaccumulation in Irrigated Crops: a Water-Food-Pollution Nexus

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Abstract

Discharge of chromium (Cr) into receiving water bodies is a serious problem in water resources worldwide that inevitably gets taken up by agricultural crops and hence threatens both the environment and human health. This study investigates the fate and transport modelling of Cr discharged into the Kashaf River by leather industries in Mashhad city, Iran and the bio magnification effects on agricultural crops irrigated by the river. The accumulative concentration of Cr in tomato in the present case study from the time of planting until harvest day shows an increasing trend of up to 126 µg/L. The sensitivity analysis illustrates that the accumulated chromium ions in tomato are affected by time in growth cycle, chromium dosage in water, and total hardness of water more than any other factors. This study adopts an empirical approach by developing statistical modelling for bio-accumulated Cr in tomato during the growth period and evaluates different 3D mathematical distribution such as Polynomial, Interpolant, and Lowest models. The results demonstrate Polynomial with x and y more than four-degree model has the best efficiency for the measurement of accumulated chromium ion in tomato as per qualitative factors. The outputs in this study can be viewed in the context of water-food-pollution nexus and how the pollution discharged from the industry into the water resources can have a major impact on the safety of food that is dependent on irrigation from freshwater resources.

SDEWES2022.0573

Safe Use of Wastewater in Agriculture; the Challenges in Implementation and Opportunities Through a Water- Food- Energy NEXUS Approach

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Abstract

Irrigation is presumably the most significant example of showcasing the safe use potential of wastewater. For thousands of years, agriculture has been heavily dependent on freshwater resources for irrigation. However, water scarcity, energy costs, the costs of fertilisers, and the pressures for food security have all been drivers in persuading farmers and other entrepreneurs to utilise wastewater as an available and stable resource. On a global scale, more than 20 million hectares of agricultural land is irrigated using wastewater, and it is not all treated wastewater, in order words, safe for irrigation In order to address the technical, institutional, and policy challenges of safe water reuse, countries need to adhere to clear institutional arrangements and more skilled human resources with a sound understanding of the potential risks of wastewater reuse. In order to address the capacity development needs, the United Nations Decade Programme on Capacity Development (UNW-DPC), together with the World Health Organization (WHO), Food and Agricultural Organization (FAO), United Nations Environment Programm (UNEP), and other UN members and partners initiated a series of capacity development workshops around the world. These workshops included representatives from 73 UN member states from Asia, Africa and Latin America. This review paper looks at the outcomes of those workshops where the safe use of wastewater was implemented in the participating countries. It looks at the opportunities versus risks, the treatment technologies that were successful or failed, the policy and governance frameworks that were put in place, and public acceptance surrounding the implementation of safe use of wastewater in agriculture. It then draws upon where the Nexus of water- food, and energy can improve usage efficiency and the overall governance of wastewater reuse in agriculture for those countries by exposing the interrelatedness and interdependencies of these resources and their management.

SDEWES2022.0574**Treated Wastewater Reuse for Agricultural Irrigation in the EU and Current Challenges: Regulation of Contaminants of Emerging Concern in Groundwater**S. Caucci¹, Z. Ozkul², A. Ardakanian³, R. Ardakanian*⁴¹United Nations University, FLORES, Germany; ²United Nations University, Germany;³University of West London, United Kingdom; ⁴UNU-FLORES, Germany

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Abstract

Treated wastewater reuse is a common practice in Southern European countries and MENA to meet water demand for agricultural irrigation given the competing water demands and limited availability of water. The use of treated wastewater in agriculture is endorsed in the EU and other states due to its economic and environmental benefits. However, there are growing concerns regarding the presence of new contaminants of emerging concern (CECs) such as pharmaceuticals and antibiotic residues that are not completely removed during conventional wastewater treatment processes. The Water Framework Directive (WFD) which is recognized as the most substantial and ambitious piece of European environmental legislation to date has not assessed water reuse sufficiently. Water reuse, indeed, is only defined as a supplementary measure and the regulatory framework for water reuse for irrigation purposes has been still patchy across the EU. To fill the gap in the European frameworks and ensure that minimum requirements are in place for the safe use of treated wastewater, the European Commission has put forward legislative minimum requirements for water reuse for agricultural irrigation in line with the key European directives. Although the recent regulation is expected to improve and encourage efficient use of water, the ongoing discussion in the EU often gives little weight to the release of contaminants of emerging concern and wastewater-borne antibiotics in groundwater and transboundary aquifers. From the policy perspective, the challenge is how to control the potential transport and accumulation of contaminants of emerging concern in the environment and their introduction to the water cycle. While there are efforts to enhance the regulations and guidelines for wastewater reuse in the EU, questions remain whether the current discussion has sufficiently considered the presence of contaminants of emerging concern in view of the protection of transboundary groundwater bodies and aquifers. The study is therefore set to identify alternative governance strategies that can be appropriate to regulate wastewater reuse for agricultural irrigation in the European Union and offer new perspectives to address the risks posed by the CECs to transboundary groundwater bodies of the EU. After introducing the concept of wastewater reuse, the text briefly summarizes the European policy context on treated wastewater reuse for agricultural irrigation in line with CECs and groundwater protection. Finally, an appropriate risk management system based on a solution-focused approach for safe water reuse is proposed to minimize hazards from chemical pollution.

SDEWES2022.0578**Free Surface Constructed Wetland with Recirculation Using Photovoltaic Pump for Domestic Wastewater Treatment: the First Full-Scale System in Cyprus and its Potential in the Mediterranean**I. Vyrides^{*1}, M. Vasquez¹, C. Samanides¹, P. Photiou¹, P. Pissaridou¹, G. Dialynas²¹Cyprus University of Technology, Cyprus; ²Smart Environmental Solutions Ltd, Cyprus (*ioannis.vyrides@cut.ac.cy)**Abstract**

The first constructed wetland in Cyprus was re-designed and started its operation in July 2020 at Choletria Paphos. This sustainable system consists of a septic tank followed by a free-surface constructed wetland. Constructed wetlands for wastewater treatment are systems for treating wastewater by natural–biological processes, similar to those in the natural environment, through soil, vegetation such as reeds and microorganisms, where pollutants from wastewater are metabolized and removed. The wetland's surface is sealed with a plastic liner to prevent the diffusion of the wastewater to the ground. In the Choletria community, a wastewater treatment plant with a septic tank was built in 1985 as an artificial wetland of horizontal sub-surface flow. This system did not function properly, in the first years of its operation, due to a combination of reasons. Following relevant studies, the Cyprus University of Technology, within the framework of the INTERREG BALKAN-MED European Program, reconstructed the Wastewater Treatment Plant (WWTP) of Choletria Community completely as a septic tank – free water surface constructed wetland with recirculation using a photovoltaic pump. Several system parameters were monitored, such as COD, BOD, TN, NH₄, NO₃ NO₂, TP, pH, conductivity and ecotoxicological analysis. In addition, the microbial profile in various places on the free water surface was monitored along with the antibiotic resistance genes over time. Apart from the operational parameters, the present study examined and evaluated the possible "added value" of this system to the ecology and the biological environment of the area. This evaluation was elaborated through the inventory of the flora and fauna species of the wetland, based on specialized field visits and the review of the ecosystem services provided by the wetland. This study showed that the new, improved system at Choletria can achieve 65-90% COD, around 65% TN and 45% TP removal. The toxicity of the sewage products of the village and, therefore, the water returned to the environment has no significant harm to the surrounding vegetation, which includes trees and bamboo. Additionally, we can confirm that even though antibiotic-resistant genes can be detected in the inlet sewage products, these are eliminated through the process. As a result, the tested antibiotic-resistant genes cannot be detected in the effluent. The results of this study pointed out that this system can be an effective, sustainable, low-cost solution for the treatment and recycling of domestic wastewater in small remote communities. Apart from this, this system can add ecological benefits to the semi-arid isolated communities in the Mediterranean.

SDEWES2022.0579**Microbial Fuel Cells: Practical Implementation, Robotics and Pee Power®**I. Ieropoulos^{*1}, J. Greenman²¹University of Southampton, United Kingdom; ²University of the West of England, United Kingdom (*i.ieropoulos@soton.ac.uk)**Abstract**

Microbial fuel cells (MFCs) is a promising platform technology for a number of applications. MFCs work on anaerobic/electroactive microbial metabolism, which results in electricity being produced whilst organic matter (consumed as fuel) is being treated. MFCs usually consist of two half-cells, separated by an ion exchange membrane and electrons flow from the bacterial (negative) half-cell, to the positive half-cell, through a circuit. Amongst a plethora of organic waste products and materials tested in MFCs, human urine has been reported as an effective fuel for electricity generation. Urine is responsible for 10% of organics, 75% of nitrogen and 50% of phosphorous found in domestic wastewater, and yet volumetrically, it only constitutes less than 5% at municipal level. It is therefore of significantly advantageous if waste separation was implemented at source, for more efficient downstream wastewater treatment.

This talk will present results from the practical implementation perspective of MFCs in a range of applications, thereby making the case for a platform technology that can be used in off-grid and citywide inclusive environments. The talk will show the chronological development of the technology, from the early robotics implementation to the most recent application in sanitation. Work from the Urine-tricity programme that has been running for 10 years, showing the potential of MFCs in treating human urine will be presented. Different MFC designs, including ceramic-based with power generation and organics degradation are being discussed. When ceramics are appropriately exploited, this results in the generation of an electrochemically activated solution, known as the catholyte, which is a valuable by-product that can be used as a disinfectant. This catholyte is an alkaline, high in salt (thus high in conductivity) liquid that is produced due to the electro-osmotic drag and has been shown to achieve pathogen killing. MFCs can also be generally used as a biosensor to monitor the organics in an aqueous medium, through the analogue signal produced. The MFC technology has also been successfully scaled up and implemented as a power source for lighting, in remote, previously unsafe toilet environments, and for this reason, has been named Pee Power®. More recently, emphasis has been given on the pathogen killing properties of MFCs, whilst generating electricity and results from this work will also be presented for different pathogenic species.

The talk concludes with the case for microbial fuel cells as a platform technology for multiple a range of environments including sanitation, renewable energy generation, production of value-added products via elemental recycling and wastewater treatment.

Special session: Smart Energy Networks

The current worldwide energy system is undergoing a deep transition, aiming at reducing the energy-related emissions of carbon dioxide and other pollutants. Such transition also includes the development of smart energy networks, combining several energy technologies for energy production, storage and utilization, and including a plurality of energy producers, users and prosumers (i.e., producers and users at the same time). The concept of smart energy networks requires “system-of-system thinking”, that means looking at the energy demands of a district with a unified approach, considering simultaneously all the energy demands (electricity, heat and cool). In smart energy networks, any type of energy can be converted to another type of energy, according to the user demands. In particular, the smartness of a smart energy grid may lie in: i) the integration of several energy technologies; ii) the integration of several energy end users, in order to exploit the synergies among them, iii) the use of advanced control strategies able to optimize network performance.

In this framework, another critical issue regards the excess of renewable electricity production, which leads to several severe issues in the grid management. Such issues must be mandatory addressed to increase the renewable energy penetration.

On the other hand, the increasing use of electric vehicles is further increasing the grid stress, due to dramatically high peak power required for charging their batteries. Therefore, the development of smart charging strategies is crucial to promote the penetration of the electric vehicle is dramatically limited.

In this context, this Special Session aims at collecting the most significant and recent studies dealing with the following topics not limited to:

- Polygeneration plants serving micro-grids or energy networks
- Energy planning
- 4th generation district heating and cooling networks fed by renewables or coupled with innovative technologies
- 5th generation district heating and cooling networks fed by renewables or coupled with innovative technologies
- Electric vehicles
- Control strategies or solutions for peak shaving and peak shifting with the aim of avoid grid unbalancing and overvoltage
- Optimal coupling of several renewable energy sources for addressing the issue of peak power production and peak of power demand
- Innovative technology for energy storage
- Novel and advanced strategies and technologies able to reduce the electric grid stress due to the peak of power demand and power production.
- Geothermal power plants
- Advanced thermal storage

- Thermally and Electrically driven water desalination
- Use of biofuels in transport sector
- Integration of renewables for biomethane production
- Integration of renewables for hydrogen production
- Renewable Hydrogen as an energy storage system
- System dynamic simulation
- Energy efficiency and integration of renewables in HVAC systems
- Optimal integration of different renewable energy sources

Prof. Francesco Calise, University of Naples Federico II, Naples, Italy

Dr. Maria Vicidomini, University of Naples Federico II, Naples, Italy

Dr. Francesco Liberato Cappiello, University of Naples Federico II, Napoli, Italy

Francesco Calise - Francesco Calise was born in 1978 and graduated cum laude in mechanical engineering from the University of Naples Federico II, Italy in 2002. He obtained the Ph.D. degree in Mechanical and Thermal Engineering in 2006. From 2006 to 2014, he is a Researcher and Assistant Professor of applied thermodynamics at the University of Naples Federico II. In 2014 he has been entitled as Associate Professor at the University of Naples Federico II. His research activity has been mainly focused on the following topics: fuel cells, advanced optimization techniques, solar thermal systems, concentrating photovoltaic/thermal photovoltaic systems, energy saving in buildings, solar heating and cooling, Organic Rankine Cycles, geothermal energy, dynamic simulations of energy systems, renewable Polygeneration systems and many others. He was invited lecturer for some courses or Conferences (UK and Finland). He teaches several courses of energy management and applied thermodynamics at the University of Naples Federico II for BsC, MS and PhD students. He was a supervisor of several Ph.D. degree theses. He is a reviewer of about 30 international Journals. He was involved in several Research Projects funded by EU and Italian Government. He is Member of the Editorial Board of 10 International Journals. He was a Conference Chair and/or member of Scientific Committee in several session of International Conferences. He is Vice-Chair Cross Reader for the FET OPEN Projects funded by EU

Maria Vicidomini - Maria Vicidomini was born in 1988 and graduated cum laude in Environmental engineering at the University of Naples Federico II, Italy in 2013. From 2013 to 2014, she was a fellow researcher at the University of Naples Federico II. She obtained the Ph.D. degree in Industrial Engineering in 2018. In 2019 she has been entitled as Researcher at the University of Naples Federico II. Her research activity has been mainly focused on the development of dynamic simulation models for the energy, exergy, economic and environmental analysis and impact of innovative systems for distributed polygeneration systems, supplied by renewable energy (geothermal, solar, wind energy) and natural gas. Building Integrated Solar

Thermal Systems and internal combustion engines for the production of heat, cool and power. Solar heating and cooling systems. Solar desalination systems. Hybrid renewable system based on wind, solar and geothermal energy. Electrical storage. Electric vehicles. Her research activity is also developed in cooperation with several international institutions (Portugal, Iran, Turkey, Denmark, China, Croatia, Poland, Germany, Canada). She was a supervisor of several BsC, MS and PhD students at the University of Naples Federico II. She is a reviewer of about 15 international Journals. She was guest editor in special issues on International Journals. She is a member of the scientific committee of several international conferences and she is also involved in the organizing committee of the CEER 2020 Conferences. She was a conference chair and presenter in several sessions of International Conferences.

Francesco Liberato Cappiello - Francesco L. Cappiello was graduated cum laude in Aerospace and Astronautical Engineering at the University of Naples Federico II, Italy in 2017. He obtained the Ph.D. degree in Industrial Engineering in 2021. In 2021 he has been entitled as Researcher at the University of Naples Federico II. His research activity mainly deals with renewable smart energy grids. In particular, he focused on the following topics: sustainable mobility; electric vehicles fed by renewables; polygeneration plants; district heating/cooling networks (4th and 5th gen); cogeneration/trigeneration; hydrogen as electric energy storage; reduction of primary energy consumption of residential districts, energy measure for reducing the primary energy consumption of hospitals and healthcare facilities, reverse osmosis coupled with renewable energy sources, dynamic simulations of energy systems, energy saving in buildings and many others. He spent six months at Hochschule für Technik Stuttgart, developing dynamic models of several modular trigeneration layouts for a big hospital of Stuttgart. This analysis also included the hybridization of the trigeneration plant with photovoltaic technology. His research activity is also developed in cooperation with several international institutions (Spain and Germany). He is a reviewer of about 7 international Journals. He was topic editor for 2 International Journals. He is guest editor in a special issue on two International Journals. He was a supervisor of several BsC, MS, and PhD students at the University of Naples Federico II. He was a conference presenter in several sessions of International Conferences. He was a conference chair and presenter in several sessions of International Conferences.

Invited submissions

SDEWES2022.0239

Exploiting the Ocean Thermal Energy Conversion Technology for Green Hydrogen Production and Storage: Exergo-Economic Analysis

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Abstract

Ocean Thermal Energy Conversion (OTEC) is a renewable energy technology that produces electrical energy from the temperature gradient between shallow and deep ocean waters. The most suitable locations for harvesting this phenomenon are the tropical regions. Energy storage and transportation are challenging as these places are far from electric grids. This led to the idea of using OTEC systems to obtain hydrogen through an electrolyzer and then compress and store it. In the present study, three different plant configurations are analyzed. In the first and second layouts, a Rankine cycle with ammonia or a mixture of water and ethanol is used as working fluid, respectively; in the third layout, a Kalina cycle utilizing a mixture of water and ammonia is considered. The OTEC cycle is connected with a polymer electrolyte membrane (PEM) electrolyzer and the compression and storage system. The water entering the electrolyzer is pre-heated to 80°C by a solar collector. Energy, exergy, and exergo-economic studies were conducted to evaluate the cost of producing, compressing, and storing hydrogen. A parametric analysis examining the main design constraints is performed considering the temperature range of the condenser, the mass flow ratio of hot and cold resource flows, and the mass fraction. The maximum value of the overall exergy efficiency equal to 93.5% was obtained with the Kalina cycle and 0.52 €/kWh is the minimum cost of hydrogen production achieved. The results were compared with typical data of other hydrogen production systems.

SDEWES2022.0241

Experimental and Numerical Analysis of a Dual-Source Heat Pump with PV-T Evaporators for Residential Heating Applications

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Abstract

Solar assisted heat pumps exploit solar energy as the heat source. However, the efficiency of the solar source is strictly related to weather conditions, location and time. Thus, to maximize the exploitation of the solar source and guarantee the continuous operations of the system with adequate performance, the use of dual-source heat pumps should be considered. This paper presents an experimental and numerical investigation on the performance of a dual-source heat pump operating with CO₂ as the refrigerant. The considered heat pump is a solar-air dual-source unit capable of working with an air finned coil or, alternatively, with photovoltaic-thermal (PV-T) solar collectors as the evaporator. When operating with the solar source, the refrigerant directly flows and evaporates in three PV-T panels: each collector is composed of a sheet-and-tube heat exchanger made of an aluminum plate and a copper serpentine positioned below the PV module. This allows to both exploit the energy coming from the solar radiation for evaporating the refrigerant and to improve the PV electricity production due to the cooling of the cells. A specific numerical model of the heat pump has been developed and implemented as a TRNSYS type. The model has been validated with measurements obtained during the operation of the heat pump throughout the short-time. The validated model can be used as a useful tool to assess the heat pump performance over long-time, showing the potential of the investigated dual-source system.

SDEWES2022.0283

Achieving Flexibility in the Energy Transition: Opportunities and Challenges of Multi-Energy Systems

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Abstract

The transition towards the decarbonization of the energy sector, in progress for years, requires a rapid acceleration in the entire energy chain, from production, using more and more decentralized renewable energy sources, to a more rational and conscious use of energy by final users. This increasing deployment of distributed generation technologies has an impact on the whole energy chain involving supply, transmission, conversion, and demand sides. Therefore, in response to the uncertainty and volatility arising from renewable sources, much more flexibility is required to the energy system, to continuously ensure the power balance between generation and demand.

In this context, interest is arising around the so-called Multi-Energy Systems (MESs), which are systems where different energy vectors, such as electricity, heating and gas (or hydrogen), coexist and optimally interact. In fact, MESs enable to fully exploit the flexibility potential of multiple resources (e.g. batteries, renewable sources, storage tanks and heat pumps), interconnected through coupled energy networks, and to maximize their efficiency. However, the synergetic operation of different energy domains implies an increased complexity from the simulation and control standpoints, and it introduces additional physical and regulatory constraints in the way energy is transmitted through the interfaced networks and converted between the different energy vectors.

In line with the above, the work aims to investigate the main challenges and opportunities that MESs can offer to the power system, also exploring a procedure to properly quantify their flexibility potential. Moreover, an innovative method for the dynamic simulation of MESs will be described in detail, considering a reference case study of a district heating network interfaced with the power grid, with the aim of providing an effective tool to support MESs optimal management and flexibility evaluation. Finally, the main results regarding the simulation and flexibility analysis, as well as the introduced benefits, will be discussed.

SDEWES2022.0292**Solar and Wind Based Green Hydrogen Production Systems: Trends and Standardization**

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Abstract

Experts have suggested possible solutions for the decarbonization of various sectors to decrease carbon dioxide emissions. One of the most promising decarbonization solutions is to use hydrogen as an energy carrier for different applications. Hydrogen can be used for the decarbonization of various sectors, and there is no real alternative to decarbonize certain sectors; these sectors include fertilizer, hydrogenation, hydrocracking and desulphurization. Studies regarding green hydrogen production have recently become very popular because hydrogen should be produced from clean sources for the decarbonization of various sectors. In this review, solar and wind based green hydrogen production systems are presented to investigate the trends and efforts for green hydrogen production systems based on solar and wind sources. Solar and wind based hydrogen production systems have been selected because coupling water electrolyzers with solar and wind sources can be a promising solution in the near future for the utilization of surplus power from these sources. Indeed, many research groups, researchers, and institutions have completed and investigated different green hydrogen production systems; however, a systematic approach should be developed to compare different green hydrogen production systems. One of the most important novelties of this review is to suggest a pathway and standardization strategy to compare different green hydrogen production systems based on solar and wind sources. Furthermore, a database based on the most relevant publications was built, which includes information regarding green hydrogen production. In particular, different data and information are extracted from the most relevant papers in this field, such as renewable systems investigated, location of the studied system, connection with the electrical grid (off-grid or on-grid), research type (homemade algorithm or simulation software, experimental, optimization, energy, economic, environmental and life cycle assessment analysis) developed, final utilization of hydrogen considered and performance indicators employed. With the unique and novel approaches of this work, the extended version of this conference review will be an important guide for the editors, reviewers, researchers and other stakeholders who are interested in green hydrogen production systems.

SDEWES2022.0304

Techno-Economic Optimization and System Integration of Power-to-Gas at Different Geographical Scale in Europe

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Abstract

Decarbonization targets and global political instabilities push the European Commission to elaborate strategies to ensure more affordable and secure energy. Within these strategies, e.g., RePowerEU, Power to Gas (P2G) and Power to X (P2X) are foreseen to become a key play for the successful transition towards a sustainable energy system. A rigorous methodology to investigate P2G and P2X plants' potential and optimize the techno-economic performances is therefore essential for an effective scale up and implementation of these plants. Therefore, this study aims to show how energy modelling tools can be used to support decision-makers to identify potential locations of the plants and furthermore estimate the techno-economic performance of the plants. In this study, three energy modelling tools were developed and adapted to investigate the plants' design and planning at different levels of detail in the Apulia region (Italy), considering the integration with the energy system in order to ensure a complete assessment.

SDEWES2022.0327

Energy-Economic Assessment of Self-Sufficient Microgrid Based on Wind Turbine, Photovoltaic Field, Wood Gasifier, Battery, and Hydrogen Energy Storage

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Abstract

Designing self-sufficient renewable energy systems is becoming a key issue in the energy sector due to modern energy goals based on limiting the use of fossil fuels and the need to ensure energy security at the national and local levels. Despite the increasing penetration of renewable energy sources around the world, the use of hybrid systems, i.e. systems containing more than one energy source, is relatively scarce. Therefore, the scope of the paper is to improve the knowledge regarding hybrid renewable energy systems on the basis of the system composed of the wind turbine, photovoltaic field, gasifier, battery, and fuel cell for purposes of energy balance.

In the proposed system, renewable energy produced by the wind turbine and photovoltaic panels is used to match the energy load of a tourist resort. Energy exceeding the load is directed to the energy storage system based on the battery and hydrogen tank. When needed, energy from the battery and hydrogen may be recovered directly (battery) or by means of a fuel cell (hydrogen). If the load exceeds the production of energy from a wind turbine, photovoltaic field, and energy storage, the system uses a wood gasifier as a backup energy source.

The described system is modeled and dynamically simulated by means of TRNSYS software. The parameters obtained from the simulation serve as the basis for further energy and economic assessment. The operation of the system is presented on a daily and monthly basis, while the key performance indicators of the system are reported considering the period of one year. Simulations were carried out for Thessaloniki, Greece. The goal achieved during the simulation of the system was to ensure at least 98% of energy demand from renewable sources.

SDEWES2022.0331

The Accumulation Heat Exchanger for Preheating Supply Air in Ventilation Systems – an Example of a Sustainable Approach to Reducing Energy Consumption and Greenhouse Gas Emissions

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Abstract

Heating, ventilation, and air conditioning systems play an important role in ensuring the comfort and safety of indoor air quality. However, these systems account for 40–60% of the energy usage in buildings and are primarily responsible for greenhouse gas emissions and operating costs. The high energy share of heating, ventilation, and air conditioning systems in buildings motivates to study of the various parameters related to reducing energy consumption and finding sustainable solutions. This paper focuses on evaluating the contribution of the accumulation air heat exchanger system to decreasing the energy consumption of air conditioning and ventilation systems for residential and office buildings in the Polish climate conditions. The theoretical part of the work deals with methods of building ventilation, supply air preheating, and heat recovery solutions, as well as their joint impact on thermal performance. The novel concept of a heat exchanger composed of accumulation material was proposed and discussed. The proposed accumulation heat exchanger can heat the supply of ventilation air using thermal energy from solar radiation. Using solar radiation, it is possible to heat the accumulation layer during the day and use the accumulated heat to preheat the supply air both day and night. The prototypical version of the accumulation heat exchanger was tested in laboratory conditions using an especially developed experimental rig. This rig was equipped with temperature sensors, anemometers, an infrared camera, air fans, an electric heater, and a control and measurement system based on the programmable logic controller. The results confirm the possibility of increasing the temperature of the supply air using solar energy. The further development of the proposed solution may be important from the point of view of reducing greenhouse gas emissions and the operating costs of buildings.

SDEWES2022.0454

Renewable Smart Energy Network: a Thermoeconomic Comparison Between Conventional Lithium-Ion Batteries and Reversible Solid Oxide Fuel Cells

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Abstract

Smart energy networks based on renewables and electric energy storage systems are a promising technology for reducing the primary energy demand for residential districts and private mobility. The design of a smart energy network based on photovoltaic panels, electric energy storage systems, heat pumps and electric vehicles is presented in this work. The proposed smart energy network consists of a fully electric residential district based on air-to-air heat pumps for building space heating and cooling and air-to-water heat pumps for domestic hot water production. The proposed renewable smart energy network consists of a photovoltaic field which meets the power load of the residential district, for building space heating, cooling, domestic hot water and for charging the electric vehicles included in such district. The peak of renewable power and of power demand are shaved by means of a district electric energy storage system. Two technologies are considered and compared into this work, namely a lithium-ion electric energy storage system and a reversible solid oxide fuel cell.

The proposed systems are modelled and dynamically simulated in TRNSYS 18. The proposed systems achieve promising results in terms of avoided primary energy consumption, i.e. a primary energy saving index of 84% for both the analyzed technologies. Therefore, both lithium-ion batteries and reversible solid oxide fuel cells are able to play a crucial role as electric energy storage systems in order to increase the use of renewables, shaving both the peaks of power demand and production. However, the technology based on lithium-ion batteries achieves better economic results due its commercial maturity, lower capital cost, and lower plant complexity

SDEWES2022.0456**Dynamic Simulation and Thermoeconomic Analysis of a Plug Flow Reactor Integrated with a Biogas Upgrading Unit and Renewables for Clean Biomethane Production**

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Abstract

Biogas production from the organic fraction of municipal solid waste is becoming an increasingly attractive solution in the field of renewables. In particular, the upgrading process of biogas into biomethane can simultaneously address the issues dealing with decarbonization of the transport sector and urban waste management. In this work, the production of biogas obtained from the organic fraction of municipal solid wastes in a plug-flow reactor is analyzed. In order to steer the chemical reactions, the temperature of the process must be kept under control. A simulation model, developed in MatLab®, is developed to predict the temperature field within the reactor, in order to assess how the temperature affects the growth and the decay of the main microbial species. A thermal model, based on two equilibrium equations, is implemented to describe the heat transfer between the digester and the environment and the digester and the internal heat exchanger. A biological model, based on the differential equations, is also included for the calculation of the biological processes occurring in the reactor. The in-house developed model is also integrated in TRNSYS environment to perform a yearly dynamic simulation of the reactor in combination with other renewable technologies. In the developed system layout, the thermal energy required to control the temperature of the reactor is matched by solar thermal source. The biogas upgrading process, converting biogas in biomethane, is extremely energy demanding, requiring huge amounts of electricity. This electrical demand is met by means of a photovoltaic field. In this work, a detailed thermoeconomic analysis is proposed to compare the environmental impact and economic feasibility of a biomethane production plant based on a plug flow reactor and fed by renewables. Several economic incentives are considered and compared to determine the optimal solution both in terms of energy and economic savings. The biomethane produced, about 850 tonsyears, is injected in the national gas grid or supplied to gas stations. In the proposed plant, about 35% of the thermal energy demand and over the 50% of the electric one was satisfied by removable sources. A promising payback time of about 5 years was estimated.

SDEWES2022.0457

A Comparative Thermo-economic Analysis of Fourth Generation and Fifth Generation District Heating and Cooling Networks

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Abstract

The energy refurbishment of domestic heating and cooling systems is crucial to achieve the goals of decarbonization expected by 2050. Recent advancements led to the development of urban-scale district heating and cooling systems, operating with low temperature loops, and integrated with renewable technologies. In particular, fourth generation district heating and cooling systems are largely used and a number of these systems were installed in the last few years. This is due to the wide use of heat pumps and low temperature heating terminals such as radiant floors and fan coils. Fifth generation district heating and cooling systems represent a significant advancement in district heating and cooling network technology. This research proposes a thermo-economic comparison between a fourth generation and fifth generation district heating cooling network coupled with ground heat pumps, serving a residential district located in Leganes, Madrid. The thermal load of the residential district network is simulated by means of accurate models of the buildings located in the area. The electric load in the proposed systems is partially matched by a photovoltaic field of 3 MW. The dynamic simulation model of such districts is developed in TRNSYS18 environment and both models are developed in detail in each component of the systems. Both the analyzed technologies achieve very promising results from the economic and the energy point of view. The Primary Energy Saving for the 4th and 5th generation districts are equal to 78% and 58%, respectively. Finally, 4th and 5th generation are able to reduce the CO₂ emissions by 85% and the 72%, respectively. Innovative district heating and cooling systems are dramatically effective in the reduction of the environmental impact of buildings sector.

Special session: Sustainable production and the role of industry in the energy transition

Industry and manufacturing play a major role in our current energy system. A significant portion of the world's energy consumption is needed to meet the needs of industry. Due to increased efforts to limit the effects of climate change, industrial and commercial consumers are also changing their behaviour. In addition to environmental and technological factors, economic factors are also driving the trend. Starting with low-hanging fruit such as simple energy efficiency measures, current developments aim at holistic strategies to realise a climate-neutral company. However, there are still many open research questions to be answered.

This special session will bring together experts in the field of sustainable production and the role of industry in the energy transition. The contributions will present new results from case studies, technological developments and holistic approaches to greenhouse gas accounting and energy planning. The aim is to highlight innovative approaches to systematically improve energy efficiency, to further develop strategies for climate-neutral companies and related greenhouse gas accounting, and to understand industry and its energy needs as an integral part of renewable energy systems. For the latter, industry can offer potential for flexibility and waste heat. The special session therefore aims to highlight current research and development, particularly in the following areas:

- Energy efficiency in industry: measures and benchmarks
- Heat recovery and process integration
- Electrification of process heat
- Industrial heat pumps
- Hydrogen in industrial processes
- Waste heat utilisation in district heating
- Sector coupling
- Demand side management and flexible energy demand
- Life cycle assessment
- Corporate carbon footprint
- Carbon accounting and controlling
- Strategies for climate-neutral business
- Energy monitoring and Industry 4.0
- Energy planning with regard to industrial energy demand

Prof. Henning Meschede, University Paderborn, Paderborn, Germany

Dr. Florian Schlosser, Paderborn University, Paderborn, Germany

Dr. Ron-Hendrik Hechelmann, University of Kassel, Kassel, Germany

Henning Meschede - Henning Meschede is Professor of Energy Systems Technologies at Paderborn University. The focus of his professorship is on the research and application of methods for the design and construction of decentralised, intelligent, renewable energy systems, in particular on the integration of the various sectors of electricity, heat and mobility. In particular, he analysis conceptualisation of sector coupling and the role of industry and commerce in renewable energy systems as well as the sensitivity of energy modelling through probabilistic input time series and future energy data-based business models. Previously, he worked at the University of Kassel in the field of commercial sector coupling concepts as a component of regional energy systems. In particular, he analysed island energy systems and energy efficiency as well as load management potentials in the tourism industry. He was a visiting researcher at the School for Solar Economy at Lappeenranta University of Technology, Finland, analysing transition pathways for 100% renewable energy systems on islands. After his work at the University of Kassel, he moved to an energy utility in Dortmund, where he continued to work as a Data Scientist on the introduction of digital, data-based value-added services in the energy industry. The results of his work have been published in several papers and at scientific and economic conferences. He reviews papers for several journals. In addition to his teaching at Paderborn University, he has a lectureship in Energy Efficiency in Industrial Processes for the MENA Region at the University of Kassel in cooperation with Cairo University and in Energy Data Analysis in Industry and Commerce at the University of Kassel.

Florian Schlosser - Florian Schlosser is currently working as a senior researcher at the department of Energy System Technologies at Paderborn University. There he leads the specialist group Energy Transition in Industry. The focus of this group is the transition of industries in regional renewable energy systems. Energy efficiency by Process Integration and the integration of renewable energy by industrial sector coupling technologies like (high-temperature) heat pumps are the main research activities. For this purpose, he is exchanging knowledge and experiences in international working groups about High-Temperature Heat Pumps (Annex 58) and Industrial Electrification (Annex XIX). Previously, he worked as a PhD student at the department Sustainable Products and Processes at University of Kassel. There he focussed on Process Integration methods and the intergation of heat pumps for decarbonisation of industrial heat supply. This was also the objective of his doctoral thesis. During his PhD, he was a visiting researcher at the Energy Group at the University of Waikato. His work also focuses on supporting planning practice. Therefore, the results of his work are incorporated into the development of the German Engineering Guideline 4646 for the application of large-scale heat pumps. The results of his work have been published in several papers and presented at scientific and economic conferences. In addition to his teaching at Paderborn University, he holds a lectureship in Energy Efficiency in Industrial Processes for the MENA Region at the University of Kassel in cooperation with Cairo University.

Ron-Hendrik Hechelmann - Ron-Hendrik Hechelmann is currently working as a senior researcher at the institute sustainable products and processes at the University of Kassel, Germany. His current research focus is the transformation of companies and energy suppliers to align their business activities with the 1,5 °C target. The interplay of energy efficiency measures, the integration of renewable energies inside and outside their own operational boundaries, and carbon insetting plays an essential role in a holistic climate strategy. His research group is working

on the automation and digitalization of climate strategies for companies, around information barriers and the lack energy consultants in sufficient numbers. His doctoral research focused on energy efficiency, sustainable energy and refrigeration systems in the industry with mathematical optimization and self-learning energy models. During his PhD, he was a visiting researcher at the Energy Planning group at Aalborg University and at the Industrial Energy Efficiency Division at the University of Waikato in New Zealand. His work has been published in several papers and at scientific and business conferences. He reviews papers for several journals. He also teaches at the University of Kassel and holds a lectureship in Energy Efficiency in Industrial Processes for the MENA Region at the University of Kassel in collaboration with Cairo University.

Invited submissions

SDEWES2022.0219

Studying the Impact of Industrial Policymaking on the Business Model of Low-Emission Technologies: the Transid Model

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Abstract

Basic materials like steel, cement, aluminium and (petro)chemicals are the building blocks of our industrialised societies, but today their production is highly energy and emission-intensive. Hence, these industries need to decarbonise over the next decades to keep global warming at least below 2°C. However, low-emission industrial-scale production processes are not commercially available to date for any of these basic materials and require policy support to ensure their large-scale diffusion over the upcoming decades. This paper introduces the novel TRANSid (Transition to industry decarbonisation) model to study the framework conditions that enable large-scale investment decisions in climate-friendly basic material options. We use a simplified case study of the cement sector to show how the model optimises investment and operational cost until 2050 by opting for the installation of carbon capture technology. Furthermore, we demonstrate how an extension of the model to other sectors allows us to study the industry and sector-specific policy options.

SDEWES2022.0328

Using Flexibility to Utilize Varying Grid Emission Factor to Reduce Greenhouse Gas Emissions of Cold Storage Warehouses

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Abstract

One of Germany's goals during the "energy transition" is to deliver at least 80 % of electricity by renewable energies before 2050. Therefore, many new wind and photovoltaic (PV) power plants will be built to replace nuclear and fossil fuel power plants. Wind and PV power are variable renewable energies (VRE) since there are not controllable. The amount of power provided varies throughout the day and year. The difference between minimal power provided by sun and wind and the maximum power will increase by installing more sun and wind power plants.

An energy system should be able to react to the varying amount of clean energy provided. One way to react to the varying amount is to reduce power consumption during times with little VRE and to increase power consumption during times with high amount of wind and sun. To be able to react to VRE, industrial consumers need to introduce flexibility in their processes.

Storing and cooling goods in cold storage warehouses can be used to react to VRE. The goods in a cold storage warehouse often provide an inherent energy storage. The inherent energy storage can be utilized by introducing a lower and an upper temperature for the goods. The temperature difference in combination with specific heat capacity and the mass of the goods is the thermal capacity of the energy storage.

In this work the flexibilization of a cold storage warehouse for dairy products was modelled and simulated. In times with low specific emissions for electricity (grid emission factor, GEF) the power consumption of the cold storage was increased by setting the air temperature in the cold storage below the typical temperature for a cold storage. The temperature of the goods decreases compared to the typical temperature. If current GEF is high, the power consumption is turned off and the temperature of goods and air will increase. In this case, "cold" is stored in the dairy products. Since times with high GEF can occur over a long time, an upper threshold for the maximum temperature of goods need to be set. If the temperature exceeds this temperature, power consumption will be turned on regardless of GEF since high quality of dairy products needs to be maintained.

This study shows that by utilizing a varying GEF, the greenhouse gas emissions of a cold storage warehouse can be reduced even though in some cases the amount of electricity consumed increases. Emissions decreases while energy demand increases is a suitable example for "System Efficiency".

SDEWES2022.0332**Opportunities for Cement Decarbonization**M. Pisciotta^{*1}, H. Pilorgé¹, J. Davids², P. Psarras¹¹University of Pennsylvania, United States; ²Carbon Direct, United States
(*mpisciot@seas.upenn.edu)**Abstract**

In the most recent IPCC assessment report, it is recommended to decarbonize the economy to avoid global average temperature increase of 1.5°C by 2100 to avoid some of the most catastrophic effects of climate change. Today, the production of cement makes up roughly 5-8% (~2.3 GtCO₂/yr) of all global carbon dioxide (CO₂) emissions. Of these emissions, nearly 67 MtCO₂/yr come from the United States. The cement sector faces a unique challenge in decarbonizing operations because the CO₂ emitted originates both from the use fossil fuels in the high-temperature calcination step and from the chemistry of limestone (CaCO₃) breaking down into lime (CaO) and CO₂. In addition, the cement industry has small profit margins, so expensive changes to the process or product can be very detrimental to profitability. This study provides an overview of the incumbent methodology for cement production as well as details specific pathways towards decarbonization that are available to the cement industry. A technology-agnostic cost model is used to estimate the cost of carbon capture and storage (CCS) for all the cement plants in Texas and Florida, two of the highest capacity cement producers in the United States. Further, geospatial case studies for these states are presented to illustrate how the co-location of resources, such as CO₂ storage opportunities, can inform and dictate the most promising pathways to decarbonize.

SDEWES2022.0333**Towards Defossilised Steel: Supply Chain Options for a Green European Steel Industry**G. Lopez^{*1}, T. Galimova¹, M. Fasihi², D. Bogdanov², C. Breyer¹¹LUT University, Finland; ²Lappeenranta University of Technology, Finland
(*gabriel.lopez@lut.fi)**Abstract**

As the European Union intensifies its response to the climate emergency, increased focus has been placed on the hard-to-abate energy-intensive industries. Primary among these is the steel industry, a cornerstone of the European economy and industry. With the emergence of new hydrogen-based steelmaking options, particularly through hydrogen direct reduction, the structure of global steel production and supply chains will transition from being based on low-cost coal resources to that based on low-cost electricity and therefore hydrogen production. This study examines the techno-economic options for three European countries of Germany, Spain, and Finland under five different steel supply chain configurations compared to domestic production. Results suggest that the high costs of hydrogen transportation make a European steelmaking supply chain cost competitive to steel produced with imported hydrogen, with domestic production costs ranging from 440-524 €/t_{cs} and 392-470 €/t_{cs} for 2030 and 2040, respectively. Hydrogen imports only reach cost-parity using large-scale pipelines in the next two decades, where levelised costs of crude steel based on imported hydrogen are 98-106% of domestic production costs. Conversely, the import of hot briquetted iron from Morocco will become economically competitive with a domestic supply chain, especially for Finland and Germany, and the import of crude steel from Morocco consistently emerges as the least cost option for Europe ranging from 429-459 €/t_{cs} in 2030 and 357-384 €/t_{cs} in 2040. These results suggest that European production of steel in a 100% renewable energy system may be economically competitive to using intermediate or steel product imports. Given the capital and energy intensive nature of the steel industry, critical investment decisions are required in this decade, and this research serves to provide a deeper understanding of supply chain options for Europe.

SDEWES2022.0426

Ecological and Economical Feasibility of Inductive Heating for Sustainable Press Hardening Processes

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Abstract

Press hardening is an established process for the production of high-strength lightweight structural automotive parts, like the B-pillar. While lightweight design is an important aspect of emission reduction during the use phase, emissions arising in other phases of the automotive lifecycle also need to be considered. Roller-hearth-furnaces, as used during the press hardening process, present a non-negligible source of greenhouse gas emissions in part production processes. Alternative heating methods, such as inductive heating, may pose a possibility to reduce emissions during the manufacturing process, while also offering additional advantages in high process flexibility, high energy efficiency and low space requirements. However, there are multiple challenges when it comes to inductive heating of sheet metal for industrial processes, such as homogeneity of heating and resulting material properties. Therefore, various investigation on the usability of inductive heating for press hardening process have been conducted. Recently, an inductive heating process utilizing a longitudinal field inductor for industrial press hardening has been developed, showing good results in regard to process homogeneity, heating times and material properties. This process is used as a baseline for an ecological and economical assessment of inductive heating for industrial press hardening processes in comparison to traditional gas-fired furnaces. The reference values for a comparison on cost and emission are based on a gas-fired conveyor furnace with constant speed used for the heating of sheet metal for press hardening. The share of furnace operation modes, like standby and production with varying good-mass flows, as well as resulting natural gas demands are provided. From this data, specific energy requirements of heated sheet metal can be derived for various material mass flows and utilization scenarios, which serve as a baseline for the cost and emission comparison.

The objective of this study is to determine the emissions and costs for inductive heating compared to conventional gas-fired roller-hearth furnaces for different parameter-set of boundary conditions like product mass flow, energy prices, emission factors depending on energy transition scenarios. Based on this evaluation matrix, break-even conditions favoring inductive heating can be identified.

SDEWES2022.0436

Carbon Neutrality for Companies - Comparing Carbon Neutrality Strategies of Different Branches

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Abstract

The growing social, economic, and political significance of climate change means that more and more companies are looking at developing their own climate strategies.

To this end, comparative strategies are developed for nine companies in different sectors (electrical, chemical, beverage, insurance, mechanical engineering, automotive, plastics processing and energy supply companies). Following an inventory of operational measures to reduce emissions, further potential measures are examined for their greenhouse gas reduction potential and cost-effectiveness. The climate strategies are outlined and evaluated.

The results show that the abatement potential and feasibility of measures depend to a large extent on certain preconditions and dynamic effects. These include the development of the emission intensity of electricity generation in the company's country.

For example, the climate strategies developed lead to a reduction in the corporate carbon footprint of 72 % between 2019 and 2030 for company A, while 79 % can be achieved for company B. The results show that measures to expand the company's own renewable energy plants and energy efficiency measures are particularly cost-effective, while the substitution of natural gas results in the highest abatement costs. Decarbonizing electricity procurement and switching from natural gas to biomethane have the highest GHG abatement potential. Company A has a wide range of electricity substitution measures available, while Company B can substitute a large portion of its natural gas demand with a district heating connection. It is also clear that climate protection strategies in industry are only partially economical under the given conditions. This is shown by the fact that both strategies lead to negative cash flows of about 14.5 million euros for company A and 5.1 million euros for company B.

The novelty of this work is the linking of the economic and ecological consideration of the CO_{2e} measures in the context of a company-specific target setting and implementation period of the climate strategy. Using CO_{2e} marginal abatement cost curves, the different options for emission reduction are discussed and general conclusions for the development of climate strategies for companies are drawn.

SDEWES2022.0441

Optimization-Based Integration of High-Temperature Heat Pumps in Industrial Energy Supply Systems of the Pulp and Paper Industry

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Abstract

Efficiency increase is a crucial measure for industrial energy supply systems, not only due to regulatory frameworks and requirements regarding climate protection measures but also to maintain economic competitiveness. As (high-temperature) heat pumps reduce primary energy consumption, they pose a promising opportunity. Their relevance in the energy transition and to mitigate industrial climate-damaging greenhouse gas emissions is also highlighted in the report on "Net zero emissions" by the International Energy Agency. According to the pathway net zero emissions until 2050 heat pumps with a monthly capacity of 500 MW heating power need to be installed. Thus, technically and economically viable integration concepts for heat pumps and especially high temperature heat pumps need to be highlighted since they are crucial to meet this ambitious goal.

As the production of pulp and paper accounted for approximately 6% of global industrial energy consumption in 2017, it is crucial to identify economic pathways to carbon neutral paper products. Steam up to 200°C is the most relevant energy carrier in this sector and thus, high temperature steam generation heat pumps provide a significant potential for decarbonization and efficiency increase in this sector.

To address this potential the authors developed a mixed-integer linear programming formulation for cost-optimal energy supply systems including high-temperature heat pumps for steam supply. Within this work sector-typical excess heat streams and steam demand characteristics are considered. The objective function includes operational and capital expenditures. Potentials for high temperature heat pump integration are identified and the resulting economic and environmental impacts are evaluated.

SDEWES2022.0442**Techno-Economic Potential of High-Temperature Heat Pump Integration**F. Schlosser^{*1}, T. Walmsley², L. Kong², B. Zühlsdorf³, H. Meschede⁴

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Abstract

Increasing energy costs, dependence on fossil energies from crisis regions and increasing requirements on product carbon footprint are drivers for companies developing strategies for decarbonisation of process heat. Heat pumps are a particularly great lever for reducing greenhouse gas emissions of process heat supply, as they harness environmental or waste heat and can make use of renewable electricity. Technologically, temperatures up to 160 °C can already be realised with heat pumps available on the market. Heat pumps achieving temperatures up to 250 °C are under development. While rising target temperatures lead to larger temperature differences between heat sources and sinks, the Coefficients of Performance (COP) is decreasing at the same time. To achieve economic feasible COPs, especially high-temperature heat pumps (> 100 °C) must match the process requirements in terms of temperature-load-profile as close as possible. Therefore, this paper aims to screen process requirements of promising high-temperature processes and match them with promising heat pump concepts. The study will thereby distinguish between the techno-economic potential of market-available heat pumps, prototypes from R&D project as well as conceptional heat pump designs from simulation studies. For this purpose, processes such as drying, galvanisation, thermal separation or preservation are represented using the Grand Composite Curve or the Modified Energy Transfer Diagram. The difference between the two methods is that the latter enables direct heat recovery potential to be tapped by the heat pump. With the help of a regression-based COP targeting algorithm, the economic break-even for different energy transition scenarios and the technical limit of the corresponding heat pump types are identified. In this way, the economic and technical possible Heat Pumping Recovery Rate (HPRR) can be identified for the processes mentioned. Heat pumps available on the market show promising results as the economic and technical HPRR for an electricity-to-gas price ratio of 3.5 are 6 % or 37 % for spray tower drying of milk powder with heat recovery, and 28 % or 55 % without heat recovery.

SDEWES2022.0445

Assessment of Energy Efficiency and Flexibility Measures in Electrified Process Heat Generation Based on Simulations in the Animal Feed Industry

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Abstract

A large part of the energy demand in industry can be attributed to the provision of heat. To reduce greenhouse gas emissions, the energy demand must be reduced and renewable energies must be integrated. Since the capacity of renewable heat sources is often limited, the electrification of processes is a promising solution. Due to the increasing share of fluctuating renewable energies in the electricity mix, it is advantageous if consumption can be flexibly controlled. Thus, in-house energy management in industry faces many challenges. On the one hand, general consumption must be reduced through the efficient use of energy; on the other hand, load shifting and flexible use of energy may reduce both, emissions and costs. Often, however, both alternatives interfere with each other, and an either-or decision is the result. A practical efficiency and electrification measure is the use of heat pumps. This can reduce the final energy demand for heat generation, but the constant mode of operation due to the coupling of heat sources and heat sinks leaves little room for grid-serving operation. Other electrification options, such as an electric boiler, offer greater flexibility in combination with thermal storage, but have lower efficiency.

To quantify the energy requirements as a basis for comparison, the heat pump as an energy efficiency option and an electrode boiler in combination with a thermal storage tank as a flexibility option are simulated along a typical demand profile in the animal feed industry. To ensure maximum heat recovery, the heat pump is optimised using pinch analysis and designed for the respective process. For the flexibility option, an operational optimisation is carried out using Linear Programming. In addition, a hybrid variant is considered using Mixed Integer Linear Programming. While no electrification measure is currently more economical than the gas reference case, the electric boiler option is significantly more expensive than a Very-High-Temperature Heat Pump. The hybrid can reduce the size of the heat pump and get a further benefit from flexible prices, which gives it cost advantages.

SDEWES2022.0447

Heat Pumps in Industrial Processes – a Key Technology for Decarbonized Energy Systems

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Abstract

Motivation

Compression heat pumps will be an essential element as a key technology for decarbonization and will be used on a large scale in future. In a significant number of industrial processes, required utilization temperatures were not possible with heat pumps a few years ago. The development as well as demonstration of so-called high-temperature heat pumps have overcome this barrier.

High-temperature heat pumps in drying processes and steam generation

High-temperature heat pumps were successfully demonstrated in the process heat supply in the H2020-projects DryFiciency and BAMBOO. In DryFiciency, water-to-water heat pumps for utilization temperatures up to 160°C were developed and demonstrated. In BAMBOO, the next step was to further develop heat pump systems for steam generation, as steam is a very common energy carrier in industrial energy systems. Both developments were picked up by component and heat pump manufacturers and further developed until they were ready for the market.

Findings and market outlook

This paper provides insight into two areas of application for the cross-sectional technology of high-temperature heat pumps. It summarizes the developments and considers other heat pump technologies for steam generation. The essential design aspects are described, and measurement results are presented. Furthermore, an outlook on the market potential is addressed. Field testing is underway or in preparation for the near future to achieve a high number of operating hours and prepare the market for high penetration.

SDEWES2022.0493

Integrating Future Energy, Material, and Production Scenarios in Life Cycle Engineering of Automotive Lightweight Structures

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Abstract

To achieve the goals of the Paris Climate Agreement, a significant reduction in transport-related greenhouse gas (GHG) emissions is essential. Besides electrification of the powertrain, lightweight design is a common approach to reduce GHG emissions in the use phase of vehicles. In addition to further developments of conventional lightweight materials such as high strength steel, aluminium, and fibre-reinforced plastics, hybrid materials like fibre-metal laminates offer lightweight potential. However, the use of lightweight materials is usually associated with increased emissions in material production and manufacturing phase.

To avoid burden shifting from the use to the production phase a holistic consideration of environmental impacts with the help of Life Cycle Engineering (LCE) methods should be considered during product development. The products that are developed will however be produced 2-3 years after development and for a time of 5-7 years. For emerging technologies this time span is even larger. During this time, parameters that influence the Life Cycle Assessment (LCA) such as advances in the production technology and energy system can change significantly. Conventional LCAs have a retrospective character and do not account for these changes. Therefore, they can lead to wrong decisions. Prospective LCA provides methods to avoid this by analysing future scenarios with consideration of changes in the foreground and background system.

This paper uses prospective LCA in the context of LCE to investigate how future scenarios can influence the GHG emissions of different designs of an automotive component. For this purpose, methods from the field of prospective LCA are adapted and further developed for the practical application in the automotive industry. A case study is applied to monolithic and hybrid material designs of a crash management system (CMS). The case study shows how changes in the production, the energy system, and the material supply can lead to a shift in the ecological optimum of different designs.

In summary, the paper shows that in LCE of structure parts, future scenarios of material and energy supply as well as manufacturing routes and vehicle application must be considered comprehensively to reduce life cycle GHG emissions of future vehicle generations. It contributes to the methodological and practical integration of prospective LCA into the LCE process of automotive components and offers quantitative results for the case study of a CMS.

SDEWES2022.0569

Insetting in the Context of Industrial Climate Protection Strategies

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Abstract

The greenhouse gas emissions resulting from purchased products and services account for a large share of the corporate carbon footprint of industrial companies. Consequently, there is great potential for companies to implement and finance climate protection measures in their own value chain (insetting). However, the implementation of insetting measures by industrial companies is currently only rudimentarily established on the market. Moreover, there are no precise rules on how insetting should be accounted for.

The financing of energy efficiency measures at suppliers by a company is one possibility for insetting. The resulting reduced greenhouse gas emissions can affect the corporate carbon footprints of several companies. To avoid double accounting of the reduced greenhouse gas emissions, these can only be reported proportionately in the corporate carbon footprint of the financing company. Therefore, financing such measures is not very attractive for companies. This paper illustrates this issue using a case study with a simplified supply chain. A company finances an energy efficiency measure at a supplier and can only report 10% of the reduced GHG emissions in its Scope 3. Based on this, the accounting approach of the pillar model is presented. The novelty of this work is that the concept of the pillar model is further developed and applied to insetting. A methodical approach for clean accounting is developed. As a result, using this approach, companies that finance insetting will be able to report the associated greenhouse gas reductions transparently and at 100%.

SDEWES2022.0572

Development of an Advanced Digitalized Approach to Reduce Greenhouse Gas Emissions in the Industrial Sector – Using a Ceramic Study as Example

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Abstract

The challenges for companies in achieving climate neutrality are complex and driven by politics, stakeholders and rising energy costs at the same time. To face these challenges, a holistic approach is required that goes beyond the boundaries of individual industrial sites. The key and first step of reducing greenhouse gases is transparency about emissions in both the site-specific dimension and the entire value network. Starting from this, the identification and prioritisation of decarbonisation measures becomes feasible.

To enable companies acting more time and cost efficient an advanced digitalised approach to develop and monitor climate actions is discussed in this paper. The first objective of the to be developed system is a Product Carbon Footprint-Tracking system along the entire value chain accounting and allocating the CO₂e emissions automatically. Furthermore, the automated development of measures based on analysis of energy and material flow data by machine learning is addressed as second objective.

The method presented in this paper illustrate how different steps of a holistic decarbonisation strategy can look like. Beginning from the Carbon Footprint-Tracking, through the development of decarbonisation strategies to the implementation of measures the limits of conventional approaches are pointed out and the advantages of the digitalised solution are highlighted. As a result, it becomes apparent that the digital assistance system improves the holistic development and evaluation of strategic decarbonisation plans through the abstraction of data collection efforts, increased transparency through the aggregation of greenhouse gas emissions across the value chain and measure development based on a knowledge graph.

Special session: The Role of Combustion in a Sustainable World

Despite the fact that most of the energy today is still being extracted by combusting fossil fuels, releasing many environmentally dangerous greenhouse gases, all relevant analyses suggest that combustion will play an important role in future energy systems and will maintain a key role as a high-temperature technological process of choice for thermal treatment of residuals and for energy and secondary raw material recovery from waste streams. Regardless of the application, strict sustainability criteria will apply to all combustion processes, pushing the developments towards minimal harmful emissions and utilization of either bio-based, waste-based or synthetic fuels. Combined with novel combustion concepts, a myriad of opportunities for further advances in combustion science is therefore opening up, paving the way to sustainable combustion processes for future generations. The Special session thus welcomes experimental and numerical, fundamental and applied studies related to the combustion of conventional and alternative fuels in all relevant combustion systems, ranging from atmospheric combustion devices, engines, gas turbines and burners to special applications and new concepts. Topics include but are not limited to: renewable fuels, fundamental physical and chemical aspects of traditional and novel fuel sources; reaction kinetics, combustion emissions, pollutants, soot, and particulates; IC engine combustion; gas turbine combustion; furnace combustion; dual fuel, ammonia, coal, biomass, biofuel and waste combustion; multiphase flows and sprays, fuel introduction methods, fuel dispersion, droplet interactions; particle technology, gasification and pyrolysis; new combustion technologies.

Prof. Milan Vujanović, University of Zagreb, Zagreb, Croatia

Prof. Tine Seljak, University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana, Slovenia

Prof. Jakov Baleta, University of Zagreb, Sisak, Croatia

Milan Vujanović - Milan Vujanović is a researcher and team leader of CFD Combustion Research Group of the Power Engineering and Energy Management Chair at Department of Energy, Power Engineering and Environment, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb. Prof. Vujanović holds PhD in “numerical modelling of multiphase flow in the combustion of fuels”. His research is in the areas of modelling and simulation of turbulent combustion, pollution formation, multiphase flows and sprays, and also in the areas of sustainable energy, environmental protection and climate change. He holds lectures within courses “Combustion and Radiation Modelling”, “Numerical Methods in Continuum Mechanics” and “Energy Engines”. He has over 100 publications in Scientific Journals, Books and International Conferences Proceedings to his credit. Prof. Vujanović is a consultant to many industries and several public authorities. He is a member of the Combustion Institute, member of the European Research Community on Flow, Turbulence and Combustion, and member of the Centre for Sustainable Development of Energy, Water and Environment Systems.

Tine Seljak - Tine Seljak holds a PhD in process and energy sciences (2017). His professional and scientific activities are devoted to investigation and development of sustainable combustion concepts in internal combustion gas turbines, reciprocating engines and small-scale atmospheric combustion devices. Focusing on low-carbon, bio-based and waste-derived fuels, his research is oriented also towards combustion and incineration processes tailored to secondary raw material recovery. In Strategic Research and Innovation Partnership for Circular Economy he is co-leading

pillar Sustainable energy and is currently a coordinator of Sustainable Energy platform at University of Ljubljana, Faculty of Mechanical Engineering. He is the author of over 30 journal papers and is leading several national, international and industrial projects in the field of advanced combustion concepts and circular processes.

Jakov Baleta - Jakov Baleta received his PhD in 2016 from the Faculty of Mechanical Engineering and Naval Architecture. Since 2017, he has been working at the Faculty of Metallurgy, University of Zagreb, and his research work includes numerical modeling of multiphase flows, ammonia combustion, heat and mass transfer, and energy use analysis in thermotechnical and process plants. He is the leader of several domestic and international projects and the author or co-author of over 30 CC papers.

Invited submissions

SDEWES2022.0079

An Integrated Simulation Approach for More Efficient Estimation of Pollutant Formation Employing the Developed Radiation Models and Tabulation of Chemical Kinetics

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Abstract

The development and improvement of multiphase reactive systems are enormous challenges that have been attempted to solve for many years. Recent research has shown that it is necessary to reduce harmful emissions from combustion systems to achieve a sustainable ecosystem. Numerical modeling of the combustion process is a scientific field that covers complex phenomena such as interactions between fluid motion, heat transfer, turbulence, chemical reactions, and thermodynamics of combustion. Employing Computational Fluid Dynamics (CFD), complex phenomena such as interactions between fluid motion, heat transfer, turbulence, chemical reactions, and thermodynamics of combustion can be integrally observed. During the combustion process, high temperatures occur, and radiative heat transfer becomes increasingly pronounced. The gaseous phase participates in heat transfer and affects the temperature profiles and, consequently, the emission formation processes inside the combustion chamber. That is why it is not sufficient to exclude the influence of radiative heat transfer on the emission formation process to precisely calculate the emissions concentrations. Developed and implemented radiative heat transfer models are validated with the available experimental data, and the simulations will be made on both the simplified cases and the complex geometries for real industrial applications. Furthermore, an automated procedure is developed to efficiently calculate laminar flame velocity and the autoignition of an air-fuel mixture employing the tabulated chemical kinetics. The implemented radiative absorption coefficient model and the developed automated procedure will provide more accurate and industrially acceptable calculations of multiphase reactive processes. In the end, based on the obtained results, the most appropriate automated approach for calculation databases of autoignition and laminar flame velocity is proposed for the calculation of the combustion process, soot, and NO_x formation, together with the guidelines for further investigation.

SDEWES2022.0322

Technological Solutions for Utilization of Geothermal Energy in Urban Area by Exploiting Oilfield Aquifers

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Abstract

Geothermal energy will certainly be one of the most important renewable energy sources in the future. Unlike other forms of renewable sources (e.g., wind energy, solar energy, wave energy), geothermal energy is a stable energy source, which can cover base loads. This paper determines the possibilities of exploitation of geothermal water from geothermal exploitation field as well as oilfield bottom aquifers for the needs of heating public buildings. The case study was done for the area of the City of Ivanić Grad, Republic of Croatia, where part of the Ivanić oilfield is within the urban area and some oil wells are located in the city center itself. Furthermore, the aim of this paper was to optimize the exploitation of geothermal water and offer technological solutions that will enable the introduction of renewable energy sources in the energy system of the City of Ivanić Grad. Based on technological parameters, four technological variants for energy production were developed. The calculations showed that the variants where the brine is produced from both geothermal field and oilfield bottom aquifer meet the thermal loads of all considered facilities, over a significant period of time. In addition, the paper also analyzes the reduction of greenhouse gas emissions by switching from gas boilers to geothermal heating.

SDEWES2022.0463**Thermochemical Combustion Intelligence for Advanced Waste-to-Energy-And-Materials Processes in the Circular Economy**

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Abstract

Waste-to-Energy processes remain essential in the Circular Economy, to keep intended cycles of materials clean and to ensure a final and safe disposal for materials that are (or have become) unsuitable for reuse or recycling. For many years, waste combustion, in particular, with recovery of energy, has proven technically sound and reliable. However, challenges regarding tightening emission limits and global warming impact (e.g., by N_2O and CO_2 release into the atmosphere) urge for a more restrained application and a more performant process control of Waste-to-Energy processes.

First, it is illustrated that improvements in combustion control of Waste-to-Energy plants up to now almost exclusively relate to the control of heat production, and thus, the carbon-related chemistry of waste combustion. Conversely, the control of non-carbonaceous gaseous compounds (e.g., H_2S , SO_2 , SO_3 , HCl , HF , and NO_x) is still heavily based on removal by flue gas cleaning, and far less on prevention of formation during waste combustion. This causes operational problems, such as boiler corrosion and strong variations in compositions of combustion gasses, ashes and residues, which still affect the energetic and chemical efficiency of Waste-to-Energy plants in a negative way.

Next, an overview of strategies is presented to build thermochemical intelligence for advanced combustion control in Waste-to-Energy processes and the need for an industrially representative validation of such models and hence, experiments executed from a reactor engineering perspective, is explained.

Finally, mono-stream combustion is discussed as a full-fledged technique for closing cycles in the Circular Economy. With ever less but increasingly distinctive waste materials that remain after separation, reuse and recycling, this technique allows for thermal valorization of non-recyclable waste through the recovery of critical raw materials from combustion ash. In this regard, the recovery of phosphorous (P) from sewage sludge and the recovery of antimony (Sb) from plastics in electronic waste are shortly touched upon. These examples show how thermochemical combustion intelligence can contribute also to establishing the transition from Waste-to-Energy to Waste-to-Energy-and-Materials schemes.

SDEWES2022.0464**Ultra-Low Emission Power Generation with Chemically Stabilized Waste Plastics Pyrolysis Oil**

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Abstract

Emission standards in European Union, designed to reduce the environmental impact of power generation, present a significant challenge for fast-response distributed power generation systems based on internal combustion engines. Regulated emissions, such as NO_x and particulate matter present a major concern due to their adverse number of environmental and health effects. Simultaneously, European Union strives towards sustainable management of plastic waste and seeks the ways for its upcycling and production of new fuels and chemicals. As an answer to the presented challenges, the present experimental study addresses the potential for use of chemically stabilized Waste Plastics Oil (WPO), a product of pyrolysis process of waste plastics in a Reactivity Controlled Compression Ignition (RCCI) combustion concept. To establish a reactivity-controlled combustion, the study uses a combination of methane (a model fuel for biomethane) and WPO to a) simultaneously reduce NO_x and particulate matter emissions due to low local combustion temperatures and a high degree of charge homogenization and b) address waste and carbon footprint reduction challenges. Through experiments, influence of direct injection timing and energy shares of utilized fuels to in-cylinder thermodynamic parameters and engine emission response were evaluated in engine operating points at constant indicated mean effective pressure. Acquired results were deeply investigated and benchmarked against compression ignition and RCCI operation with conventional diesel fuel to determine potential for WPO utilization in an advanced low-temperature combustion concept. Results show that chemically stabilized WPO can be utilized in RCCI combustion concept without adaptation of injection parameters and that with suitable control parameters, ultra-low emissions of NO_x and PM can be achieved with utilized fuels. For diesel/methane mix, NO_x and PM emissions were compared to conventional compression ignition operation reduced for 82.0 % and 93.2 %, respectively, whereas for WPO/methane mix, NO_x and PM emissions were reduced for 88.7 % and 97.6 %, respectively, which can be ascribed to for utilized combustion concept favourable chemical characteristics of WPO.

Overview of Ammonia Combustion Chemical Kinetics Models

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Abstract

The scope of this article is to give an overview of available knowledge concerning ammonia combustion and also capture the current trends in research of this area. Ammonia came out as a prospect to play a key role in energy transition to carbon-neutral. Even though there are a few difficulties regarding ammonia combustion, the research conducted so far shows that most of these difficulties can be overcome with a degree of modification to the combustion systems and processes. This review is mainly targeted at topics of chemical kinetics in ammonia combustion, emission generation, validation and application. The first section gives an introduction and a brief overview of ammonia as a fuel, followed by a review of ammonia as a standalone fuel. The next two sections are targeted at ammonia mixture with other fuels, hydrogen and methane respectively. After that, a review of unconventional ammonia combustion will be given, more precisely, co-firing ammonia with other fuels and combustion in porous media burner. Lastly, a conclusion will be formulated with prospects to further research and utilization.

SDEWES2022.0471

Influence of LNG Supply on Gas Market Flexibility – Based on Case Study of Croatia

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Abstract

The analysis of natural gas consumption trends shows that natural gas consumption in the Republic of Croatia is extremely seasonal, with high fluctuations during peak consumption. To cope with this seasonally unbalanced consumption profile, the gas network must have considerable technical flexibility with stable and balanced profiles of natural gas production and supply at the interconnection points (imports), but also deliveries from the LNG terminal. The objective of the research was to show the importance of each part of the natural gas system in providing flexibility. By analysing the movement of natural gas flow through the individual parts of the natural gas system, data was obtained on the shares of the individual sources of flexibility in the Croatian gas system and the contribution of each for the realization of the overall flexibility of the gas system. The flexibility of the Croatian gas system in 2020 was satisfactory, as the system was undoubtedly functioning, with the largest contribution to flexibility coming from underground gas storage. The flexibility factor of natural gas imports at interconnection points, based on flexible supply contracts, was negative due to higher imports in the summer months. In addition, production has been steadily declining, so this source of flexibility has less and less opportunity to provide a significant amount of flexibility. On the other hand, the LNG terminal on Krk, which started operating at the beginning of 2021 as a new gas import point into the system, has not yet been considered as a possible source of flexibility. The LNG volumes from the new LNG terminal were analysed using an analogous methodology. The results of the research showed the analysis of the flexibility of each segment of the gas system and the movement of flexibility before and after the introduction of LNG into the market.

SDEWES2022.0486**Accelerating the Deployment of Carbon Capture, Utilization and Storage in the European Union Through Proposed Changes of the Existing Regulatory Framework Based on the USA Example**

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(*filip.vodopic@rgn.unizg.hr)**Abstract**

Greenhouse gas (GHG) emissions are a global issue that must be addressed and dealt with as a high priority at the global level due to the Paris Agreement. According to the European Green Deal, the European Union (EU) has set a target to reduce its emissions by 50% by 2030 compared to 1990 emissions, while achieving climate neutrality by 2050. To achieve the above goals, carbon capture, utilization and storage (CCUS) processes are being introduced as a transitional solution to decarbonization. The objective of this work is to explore the feasibility of the incentive system for certain quantity of emissions for 10 years if the newly established CCUS Fund would be charging until 2026 (5 years) or 2030 (9 years) by varying EUA prices, CCUS Fund size and incentives per ton of CO₂. Currently, the legal framework for CCUS in the EU (Chapter 2) is established by the CCS Directive. Another important EU instrument to mitigate climate change is the EU Emissions Trading System (ETS). EU ETS operates on the principle of 'cap and trade' and covers 40% of the EU's greenhouse gas emissions originating from energy-using installations and the aviation sector. Additionally, in Chapter 3, the 45Q Section of Internal Revenue Code from United States of America (USA) is presented. It is a tangible tax incentive for emitters to invest in CO₂ capture facilities. In Chapter 4, a methodology of the analytical model of incentive system is presented. The implementation of the new proposed system was carried out using Croatia as an example in Chapter 5, as this country has relatively low CO₂ emissions compared to other EU Member States (18 million tons in 2021) and would therefore be a promising candidate for a pilot phase. Several sectors were observed: paper and pulp manufacturing, glass manufacturing, cement manufacturing, fertilizers manufacturing, power sector, and refining of mineral oil. Based on scientific results the conclusions are very optimistic, since by 2026, there is reasonably high number of feasible scenarios for incentivizing the majority of sectors, while for 2030, nearly all scenarios are feasible for incentivizing most of the sectors. The contribution of this paper is to allow fast-paced deployment of CCUS technology on EU level by introducing the ton-based incentive system.

SDEWES2022.0582

Improved Numerical Absorption Model for Seawater Spray Scrubbing

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Abstract

Flue gas treatment in ships and coastal applications has received increased attention in recent years due to the reduction of allowed sulfur amounts in fuel. Scrubbers using seawater for sulfur dioxide absorption are an alternative technological solution offering some benefits compared to more common alkaline solutions. Still, accurate modelling of the absorption process remains an issue due to the overlapping and complexity of chemical and physical phenomena present in spray scrubbers: two-phase flow, intricate droplet behaviour, mass transfer into liquid droplets, and chemical reactions occurring in the liquid phase, to name some of them. This paper presents an improved numerical model based on the group's previous work, where a more detailed chemical seawater model was implemented, and mass transfer models used have been changed to fit the present spray conditions better. The obtained simulation results show an improved correlation to the experimental results, making the modeling tool more suitable for the investigation of spray desulfurization applications.

Special session: Transitioning towards Carbon Neutrality with Green Technologies, Systems and Strategies

Recent delegations at COP26 suggest that we still have a lot to do to reduce CO₂ emissions globally. More effective carbon reduction strategies must be put in place to cut CO₂ emissions and achieve carbon neutrality in the coming decades. However, the journey towards carbon neutrality entails many challenges ahead. Green technologies and systems will play a significant role in addressing these challenges. This special session aims to shed light on research advances on methods, technologies, components, processes, systems and policies that contribute towards carbon neutrality. The themes of this special session include, but are not limited to the following topics:

- Carbon capture and storage and negative emissions technologies
- Decarbonisation technologies, systems and supply chains
- Hydrogen related technologies and systems including generation, storage,
- transportation, and utilisation
- Renewable and hybrid energy technologies and systems
- Bioconversion and bio-based technologies and systems
- Energy storage technologies and systems
- Waste-energy recovery and energy efficient technologies and systems
- Green economy and circular economy
- Green and sustainable development roadmaps and policies

Dr. Viknesh Andiappan, Swinburne University of Technology Sarawak Campus, Kuching, Malaysia

Dr. Bing Shen How, Swinburne University of Technology, Kuching, Malaysia

Viknesh Andiappan - Dr Viknesh Andiappan currently serves as an Assistant Professor at Heriot-Watt University Malaysia and will be joining the Swinburne University of Technology Sarawak Campus as an Associate Professor. His area of specialization centres on the development of decision-making tools for energy systems and supply chains. His research interests also include process synthesis and analysis of energy systems, synthesis of integrated biorefineries, industrial symbiosis planning as well as energy planning for greenhouse gas emission reduction. Most recently, he has embarked on developing decision-making models for sustainable agriculture planning. Dr Andiappan is well-published and well-cited for a young researcher (over 70 publications with an h-index of 14) and presented several papers in various conferences. He was also shortlisted as a finalist for the IChemE Young Researcher Malaysia Award (2018 and 2019) and the Heriot-Watt University PRIME Award (2021). Dr Andiappan is an editorial board member for internationally peer-reviewed journals such as Process Integration and Optimization

for Sustainability (Springer), and Frontiers in Sustainability. He is also a member of the reviewer board for Processes (MDPI). In addition, he serves as a technical committee member for several conferences. In 2020, he led a COVID-19 research grant, which worked on developing an economic analysis model to formulate post-pandemic recovery strategies for the agro-industry in both Malaysia and the Philippines. In the same year, he was awarded the IBAE Young Researcher of the Year Award for his contributions in research. Aside from research, Dr Andiappan is a Professional Engineer with the Board of Engineers Malaysia and a Chartered Engineer with the Institution of Chemical Engineers (IChemE). He also serves as the Vice Chair for the IChemE Palm Oil Processing Special Interest Group (POPSIG) and was previously the University Roadshow Director. As the University Roadshow Director, he led efforts to promote the palm industry and the opportunities for chemical engineers, to young chemical engineering undergraduate students in universities around Malaysia.

Bing Shen How - As a senior lecturer in Swinburne University of Technology Sarawak (SUTS) Campus, Dr. How Bing Shen is diligent in higher education and committed to his profession. He joined SUTS in 2019 after completing his PhD degree at the University of Nottingham Malaysia. His current research interests include biomass supply chain, resource conservation network, process simulation, and optimization, etc. With his excellent track record in publication (h-index of 18 as of Jan 2022 by Scopus) and the significant contributions made towards the community, he has won the Young Researcher Award at both the 2021 IChemE Malaysia Awards and 2021 IChemE Global Awards. He has also bagged the Best Paper Award under Process Integration and Optimization for Sustainability for one of his papers published in 2019. He is also extensively engaged in conference planning. For example, he was the organizing committee of the 18th Conference on Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction (PRES'2015) back in 2015; while more recently, he was the lead of the secretary team for the 32nd Symposium of Malaysian Chemical Engineers 2021 (SOMChE2021). Besides, Dr. How also holds editorships in Frontiers in Sustainability (Associate Editor), MDPI Sustainability (Guest Editor), and Carbon Resources Conversion (Guest Editor). Aside from being a researcher, Dr. How is also dedicated to promoting youth awareness. Just to name a few, he has launched the first-ever Borneo Chemical Engineering Society (BoChES) Penultimate Year Prize event which is intended to acknowledge the active commitment to the chemical engineering community and the general public. Besides, he has partnered with Malaysian Palm Oil Council (MPOC) in organizing webinars and international competitions to raise the awareness of the younger generation on the palm oil sector. As the advisor of SUTS IChemE student chapter, he has consistently exposed the student chapter members to external sharing/seminars/webinars whichever can benefit in their teaching, research, and professional development.

Invited submissions

SDEWES2022.0200

Potential of Methane Pyrolysis for Production of Low-Carbon H₂ and Value-Added Products: a Mini Review on Current State-Of-The-Art

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Abstract

Hydrogen (H₂) is a crucial form of matter that sustains life on Earth. It is a promising renewable energy's storage medium, which finds wide applications as the world gears toward low-carbon economy. However, current H₂ production is heavily dependent on grey processes, such as steam methane reforming (SMR) of natural gas (NG) or gasification of coal, emitting substantial amount of CO₂. In view of this, alternative H₂ production technologies and renewable H₂ sources play pivotal role in decarbonizing H₂ production process and towards achieving net zero carbon emissions. Recently, methane (CH₄) pyrolysis has emerged as a potential technology to generate low-carbon H₂ and other value-added product such as carbon black, which has multiple and vast industrial applications. In this review, the current state-of-art and recent progress of H₂ production from CH₄ pyrolysis are reviewed in detail. Aspects such as fundamental mechanism and chemistry involved, effect of process parameters on the conversion and efficiency, reaction medium and catalyst selection are elucidated and critically discussed. Besides, the current techno-economic performance of the process will also be presented.

SDEWES2022.0325

Advancing Development of Catalytic Conversion of Polysaccharides and Purification of Bio-Based Ethylene Glycol: a Mini Review

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Abstract

Ethylene glycol (EG) is an intermediate monomer used in various industry applications, including energy, chemicals, automotive and textiles. It is also known for being the precursor for production of polyester and a major constituent of antifreeze. High global demand calls for production of 28 million metric tons of EG a year. Commercial EG synthesis route via hydration of ethylene oxide, coming from fossil fuel derived feedstock is highly dependent on depleting non-renewable resources. Catalytic conversion of polysaccharide to EG as alternative routes has drawn more attention in recent years due to its lower environmental impact. The abundance of sugar and lignocellulosic raw material makes it a desirable substitute to its petrochemical counterpart. This paper comprehensively reviews recent development of catalytic system for production of EG via hydrolysis and hydrogenolysis. Purification strategies for close boiling points polyol mixture product are also compared and presented.

SDEWES2022.0336

Enabling Circular Practices for Sustainable Production and Consumption (Spc) Through Deployment of Digitalization Technologies: Overview of Current Solutions and Future Trends

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Abstract

As an alternative to the linear economic model of “make-use-dispose”, the circular economy is a system that seeks to keep resources in use for as long as possible, extract the maximum value from them while in use, then recover and regenerate products and materials at the end of their useful life. The circular economy is an integral part of sustainability agenda and it contributes to global agenda such as the Paris Agreement and the Sustainable Development Goals (SDGs). The circular transition is not only vital to protecting social and environmental wellbeing and mitigating the climate change, it also offers economic opportunities by reducing waste, stimulating business growth, and creating jobs. Many developed economies have widely accepted and transitioned to a more resource efficient and circular economy by deploying technological innovations and digitalization technologies. Big data applications and digital platforms have also been increasingly employed to facilitate the development and identification of industrial symbiosis and help companies collect and analyze datasets related to industrial facilities, regional waste production and management, and supply chain networks. The integration of several information and communication technologies such as artificial intelligence (AI) and geospatial technology can also drive sustainable urban development and smart cities by providing data-driven solutions to efficiently operate urban and city infrastructure. This paper attempts to examine several digitalization technologies and solutions currently being deployed by industries to accelerate the transition to a circular economy. The paper also highlights future trends in digitalization technologies that may provide valuable policy and practical for both policy makers and industries.

SDEWES2022.0373**Microwave-Assisted Synthesis of Triacetin via Glycerol Acetylation over Commercial Pd/ac**Y.H. Chai^{*1}, N. Azmi¹, M. Ameen¹, Y. Krishan², S. Yusup³¹Universiti Teknologi PETRONAS, Malaysia; ²AIMST University, Malaysia; ³Tenaga Nasional Berhad Research, Tenaga Nasional Malaysia, Malaysia
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Non-renewable fossil fuels are getting depleted due to its wide range of applications. Thus, carbon-neutral resources have become increasingly significant in the production of sustainable fuels such as biofuel and biodiesel. Biodiesel exhibits better fuel properties compared to petrodiesel as it has excellent lubricity, non-toxic, and free from sulphur. The excess production of glycerol is one of the challenges in the growth of biodiesel usage. However, there are many ways to valorise this versatile by-product onto value-added products. One of them is through the acetylation process which occurs as three consecutive equilibrium reactions in the presence of acetic acid with the efficient catalyst. In this study, the catalyst support is activated carbon. The study aims to optimize the operating parameters for the acetylation of glycerol using acetic acid under microwave-assisted technique over palladium supported on activated carbon (Pd/AC) for selective triacetin production. Physicochemical properties of commercial Pd/AC were studied by FESEM-EDX, TGA, XRD, NH₃-TPD, and FTIR characterization techniques. The effect of reaction parameters such as temperature (80-110°C), the molar ratio of acetic acid to glycerol (5:1 – 10:1), and Pd/AC loadings (0.5-2.5 wt.%) were investigated by the response surface methodology (RSM) tool to optimize the reaction conditions for higher selectivity of triacetin. Significant catalytic activity was observed over the Pd/AC catalyst which resulted in a high glycerol conversion of 96.65%. The optimized parameters obtained are 110 °C, 1:10 glycerol - acetic acid mole ratio, and 0.602 wt.% Pd/AC loadings respectively for 96.64% glycerol conversion and 0.233% of triacetin selectivity. Based on the ANOVA analysis, the reaction temperature has a significant effect on the glycerol conversion while the glycerol - acetic acid mole ratio influenced the selectivity of triacetin. In summary, triacetin can potentially be used as a fuel additive for biodiesel blends to lower carbon monoxide (CO) and nitrogen oxides (NOx) emissions, particularly in transportation fuel.

SDEWES2022.0435

Optimisation as a Tool to Achieving Zero CO₂ Emission from Coal-Fired Power Plants by Post-Combustion Membrane-Based CO₂ Capture

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Abstract

Carbon dioxide (CO₂) capture, storage and utilisation technology is essential in achieving net zero-emission while sustaining economic growth. Membrane technology, as applied to post-combustion CO₂ capture, continues to attract interest amongst researchers due to several advantages such as continuous mode and ease of operation. Many techno-economic studies reported on CO₂ capture from coal-fired power plants set the separation targets at 95 % purity and 90 % recovery. A few optimisation studies have investigated higher separation targets; however, the cost, penalty and flowsheet of zero CO₂ emission from coal-fired power plants have not been presented. Therefore, this work presents a model for optimising a multistage membrane system for post-combustion CO₂ capture from a coal-fired power plant. The optimisation model, whose objective is to minimise the total annualised cost, is formulated based on a superstructure with numerous feasible process flows to achieve high recovery up to zero CO₂ emissions. A high purity target similar to that achieved by chemical absorption of 99 % and recovery ranging from 90 % to 100 % is imposed. Increasing the capture targets from CO₂ recovery of 90 % and purity of 95 % to a recovery of 100 % and 99 % purity results in a 36 % increase in the levelized cost of CO₂ capture. The study explores the cost and boundaries of the purity and recovery that superstructure optimisation can achieve.

SDEWES2022.0467**Sustainable Bio-Oil-Solvent Blend Design via Computer Aided Molecular Design**

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Abstract

The search for alternative renewable fuels has been intensified over the past decades in response to fast depleting resources, as well as to counter volatilities in crude petroleum oil prices. Biomass has been identified as one of the potential renewable energy sources by converting into liquid fuels via various conversion techniques. Among the available conversion techniques, fast pyrolysis received great attention for being a relatively simple and inexpensive technology. However, poor fuel properties of fast pyrolysis bio-oil such as corrosiveness, high viscosity and low heating value often limit its application as biofuel. These issues can be addressed by blending with suitable solvents that allow further processing and storage. However, most of the solvents are manufactured as specialty chemicals, and thus, leading to a high production cost of solvents. In order to be sustainable in its application, the final solvent-oil blend should be economically competitive along with demonstrating fuel functionality and low environmental impact. Hence, a multi-stage framework has been developed in this study to generate feasible solvent candidates by combining computer-aided molecular design (CAMD) techniques with economic analysis. At the initial stage, a CAMD model has been developed using molecular signature descriptors to generate potential solvents candidates that satisfied a set of desirable targeted properties. At this stage, higher heating value for the designed solvent was selected as the objective function in order to optimise the combustion quality of the solvent-oil blend. In the next stage, a multi-objective optimisation model was developed via fuzzy optimisation approach to analyse the trade-off between the profitability and heating value of the solvent-oil blend. A pricing model was employed to estimate the profitability of solvent-oil blend. In addition, a pyrolysis bio-oil production plant was used to support the applicability of the pricing model. Lastly, to ensure the stability and miscibility of the final solvent-oil blend, phase stability analysis was conducted by computing the Gibbs tangent plane distance. With the developed approach, a promising and cost-effective solvent-oil blend can be generated while displaying optimal biofuel properties with low environmental impact.

Alternative fuels

SDEWES2022.0072

Techno-Economic Analysis and Uncertainty Assessment of Green Hydrogen Production in Future Exporting Countries

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Abstract

The uncoordinated development of a green hydrogen economy may have far-reaching geopolitical implications. The differential access to resources and technologies worldwide will affect the import-export relations between countries. While some studies have focused on estimating the profitability conditions of green hydrogen production on small-scale concepts, there is a research gap related to the comparison of large-scale hydrogen production in countries that could become global market leaders. In this context, the objectives of this study are twofold: (a) to conduct a techno-economic analysis of large-scale green hydrogen production systems in countries that may emerge as major clean hydrogen producers and exporters (i.e., Australia, Chile, Morocco, and Colombia); and (b) to investigate the impact of different uncertainties on their levelized costs of electrolytic hydrogen. To address the research objectives, a comparative analysis of local wind and solar resources was conducted. The analysis also focused on the goals set by the local hydrogen strategies and roadmaps. Moreover, a Monte Carlo simulation method was employed for the techno-economic assessment of large-scale hydrogen production systems. The paper contributes to the existing literature as follows. First, it provides an analysis and comparison of national strategies of potential hydrogen-exporting countries. Second, it examines the economic competitiveness of green hydrogen production considering their difference in local meteorological conditions. Third, it discusses the potential impact of geopolitical factors on the development of domestic and international hydrogen markets. The results indicate that Chile has the potential to produce green hydrogen at the lowest cost (\$2.8–4.5/kg in 2030). The LCOH in Morocco may range from \$3.2 to \$3.6/kg, Australia from \$3.2 to \$3.6/kg, and Colombia from \$4.1 to \$4.9/kg by 2030.

SDEWES2022.0087**Techno-Economic Assessment of a Synthetic Methane Production Process by Hydrogenation of Carbon Dioxide from Direct Air Capture**

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Abstract

Direct removal of carbon dioxide (CO₂) from air, so called direct air capture (DAC), is widely investigated to capture CO₂ emissions from decentralised sources. As an alternative to geological storage, CO₂ from DAC can be reacted with a pure hydrogen (H₂) stream from water electrolysis driven by renewable energy to produce synthetic methane (CH₄), increasing the penetration of renewable energies and leading to a circular carbon economy. This study deals with the techno-economic assessment of an integrated system for DAC based on calcium looping and subsequent methanation of CO₂, modelled in a previous research paper. Key performance indicators such as total capital costs, levelized cost of CO₂ removal (LCCR) and levelized cost of methane (LCOM) were estimated. For the DAC plant, heat exchangers were identified as the most expensive component, followed by blowers/compressor, packed bed reactors and gas heater. The LCCR for DAC ranges within 722–1641 € tCO₂⁻¹ according to the parameters considered. If the methanation plant is built in Abu Dhabi, the PV field required for the H₂ production represents the most expensive component, followed by the electrolyzer, the hydrogen storage tank, and the array of reactors. Altogether, the LCOM ranges within 4.6–7.6 € kgCH₄⁻¹ for the DAC plant investigated. If the methanation plant is integrated with point source carbon capture instead of DAC, the LCOM reduces to about 2.7–3.3 € kgCH₄⁻¹.

SDEWES2022.0097

Technical-Economic Analysis in Dynamic Conditions of Cogeneration for the Rational Use of Power to Hydrogen

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Abstract

Hydrogen technology, with its many advances, is recognized to be the most promising choice to support energy transition and decarbonization of energy systems. Furthermore, it can play an essential role as energy storage to make up for intermittency of renewable energy sources. The present paper concerns the comparison, by numerical study and optimization, of a solution aimed at realizing a rational and sustainable use of hydrogen according to the Power to Gas and Carbon capture and utilization approaches.

A technical-economic analysis of a possible plant configuration to use the carbon dioxide captured from a cogeneration engine by coupling a photovoltaic field to produce green hydrogen, is carried out. The case study explores the production of synthetic methane by adding green hydrogen produced with the energy surplus, so to highlight the effect of main governing parameters. The main results of this study highlight how the technological solution is not viable, both for the required large size of the photovoltaic field and for negative economic indexes.

SDEWES2022.0187

Impact of Variation in Meteorological Conditions on the Operation of an Electrolysis System Integrated with a PV Panel

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Abstract

Although hydrogen is zero-carbon-emission energy at the final utilization point, environmental considerations must also take into account the cleanliness of the production pathway and the energy used to produce it. Hydrogen produced by proton exchange membrane (PEM) water electrolysis can play a significant role as a potential future energy carrier and alternative to conventional fuels. Integration of the PEM electrolyzer with renewable energy sources guarantees a zero-carbon pathway for hydrogen production, with no carbon emissions and no need for fossil fuels. This study evaluates the hydrogen production potential of a proton exchange membrane (PEM) electrolyzer system powered by a wind turbine and a photovoltaic panel for 3 device configuration options. The performance of each alternative system: (1) photovoltaic panel + PEM electrolyzer, (2) wind turbine + PEM electrolyzer, and (3) PV panel + wind turbine + PEM electrolyzer, is tested for energy efficiency. The amount of hydrogen produced from surplus electricity is also determined. The hydrogen production efficiency for the analysed system has been estimated on the basis of real measurement data carried out on the experimental bench integrating renewable sources with the PEM hydrogen generator in Gliwice, Poland. The main objective of the undertaken research is to develop a universal mathematical model of the hydrogen production system including PV module, wind turbine, and PEM electrolyzer in order to analyse the system performance. The secondary objective is to determine the performance relationship of the system in terms of hydrogen production for different values of meteorological parameters for the selected location.

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SDEWES2022.0222

Thermo and Thermo-Catalytic Co-Pyrolysis of Waste Plastic and Hydrocarbon by-Products Using ZSM-5 and B-Zeolite

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Abstract

Fighting for mitigation of the harmful effects of the increasing fossil energy consumption and plastic waste generation is more challenging than ever. To reduce the consumption of fossil energy and to produce valuable petrochemical feedstocks, the production of hydrocarbons from non-conventional sources or thermal and thermo-catalytic pyrolysis of wastes and high molecular weight by-products (e.g. Fischer-Tropsch wax) looks an attractive way.

Based on the aforementioned, thermal and thermo-catalytic pyrolysis of different high-molecular weight hydrocarbon mixtures (e.g. Fischer-Tropsch wax, pyrowax from polyethylene pyrolysis) and waste polyethylene was investigated at 450°C in a semi-batch reactor. Two different types of zeolites, ZSM-5 and Beta zeolite were used as catalysts for the thermo-catalytic experiments. During the pyrolysis effects of catalysts and feedstock composition were studied on the product yields and the compositions.

Based on the results, it was found that application of ZSM-5 and Beta zeolite is particularly advantageous for production of high value C₂₁- hydrocarbons. Among the tested catalysts, ZSM-5 zeolite – having 10-membered ring narrow channels – enhanced the formation of gaseous hydrocarbons. In contrast, the pore structure of Beta zeolite allowed the formation of liquid products in higher concentration (59.4-79.4%). The aromatic hydrocarbon content of the liquid products were low (0.2-3.5%) in case of each thermo-catalytic pyrolysis, but the application of Beta zeolite led more aromatic hydrocarbons in total. Regarding the fuel production, the pyrolysis of high Fischer-Tropsch wax containing feedstocks on Beta zeolite is recommended.

SDEWES2022.0247

Prospects for Hydrogen in the Transport Sector: Economics and Environmental Performance in Different Road Transport Modes

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Abstract

The transport sector is one of the largest contributors to the increasing greenhouse gas emissions. It is almost completely based on fossil fuels. Due to the pressing environmental problems, alternative fuels and alternative automotive technologies have been widely supported and promoted over the last years. However, all alternatives that we currently have, have some challenges which have to be solved in the future.

Hydrogen, especially green hydrogen produced from renewable energy sources, has been recognized as an energy carrier which can significantly contribute to the decarbonisation of the transport system. Hydrogen in combination with fuel cell technology could be a good alternative for fossil fuels in different transport modes. However, due to the high costs of hydrogen and fuel cell vehicles, as well as due to the need for development of extensive infrastructure, hydrogen is often seen as an energy carrier of the future. Indeed, hydrogen has been seen as an alternative to fossil fuels already decades ago but so far it had not yet delivered. However, although, over the last years a strong research focus was put on battery electric vehicles, they may not be suitable for all transport modes. Hydrogen and fuel cell vehicles have strong advantage by long-distance and heavy-duty vehicles, intercity buses and trucks, but also by shipping and aviation.

The major goal of this paper is to analyse recent developments and key barriers to the increasing use of hydrogen and fuel cell vehicles in different road transport modes with a special focus on their economics and environmental impact. Our method of approach is based on economic and environmental assessment of fuel cell vehicles in comparison to the corresponding conventional fossil-fuelled vehicles.

The first results of our analysis show that the costs of fuel cells have already been decreasing and interest in green hydrogen is increasing. With the ban of conventional vehicles, which will start already in 2025 in Norway, and with the current limitations related to the battery electric vehicles, such as short driving ranges and long charging times, fuel cell vehicles could become a viable alternative in some transport modes already in the mid-term. Yet, the future priority is the cost reduction of the fuel cells.

The major conclusion is that fuel cell vehicles and hydrogen may provide contributions to the transformation of the transport system. However, in general, the prospects for hydrogen are better for larger vehicles, e.g. buses or trucks. In addition, it is very important to ensure that hydrogen is produced from renewable energy sources and that the energy efficiency of the technologies, especially of the fuel cells and the electrolyzers is improved and supported by appropriate policy measures to ensure the transition towards sustainability.

SDEWES2022.0311

A Green Ammonia Production Model Based on Pem Technology and Solar PV

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Abstract

In a world with limited resources and the exponential increase of population spotted in the last century, the Haber Bosch process for ammonia production has been crucial to the exponential rise of agriculture production capacity. It is a high energy demand process, a demand that is currently covered by fossil fuels. Alternatives for the future decarbonisation of agricultural production are required to reduce the effects of global warming and resource scarcity.

In this work, a digital twin model of a green ammonia production plant has been developed in order to identify the best integration of the systems and their operation. It consists of an Air Separation Unit (ASU) that uses distillation and electrolyzers powered by renewables for hydrogen production. The model estimates the ammonia flow rate produced based on the electrolyser power. It is an energy-focused model for optimising the operation of the plant, integrating renewable energy sources, and diminishing the associated carbon footprint of fertiliser production. It is based on a general approach that allows extrapolating the results to different plant sizes and locations. Moreover, the model simulates the control system integrated into the ammonia production plant and its effects on the process. As an application case, it has been applied for a specific case located in the municipality of Baena, in the South of Spain. The hydrogen generation is based on the renewables profiles in the region, solar and wind, powering the electrolyzers. In the reference case, with an installed electrolyser power of 10 MW, production of over 2.7 tonnes of ammonia per hour is estimated. Furthermore, the operating profiles consider different scenarios in electricity market prices and the influence of external agents to estimate the viability of a project with these characteristics and location.

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Numerical Investigation in a Novel Packed Bed with Expending Tube for Methane Steam Reforming

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Abstract

Methane steam reforming has been extensively utilized for hydrogen supply. The packed bed is one of primary reforming reactors in industry hydrogen production. Optimizing the structure of packed bed reactor is a promoting method to improve the efficiency of hydrogen production. The diverging tube structure is commonly used in the engineering to improve the flow performance. There are few studies about packed bed reactor with diverging tube structure in methane steam reforming. In this work, the equivalent medium method was adopted to investigate the role of diverging tube structure in packed bed with methane steam reforming. It was found that the addition of diverging tube contributes to less pressure drop per unit length and higher outlet mass flow. The addition of diverging tube also results in higher heat transfer coefficient. Both flow performance and heat transfer affect the efficiency of hydrogen production. The addition of diverging tube leads to higher outlet mass flow as well as unreduced reactions rates. More hydrogen produced by the packed bed reactor with diverging tube structures. The diverging tube structure with inclination angle of 3 degree has the highest efficiency. It increases hydrogen mass flow per catalyst mass by 15 % compared with the normal structure.

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Optimized Operational Strategy of a Solar Reactor for Thermochemical Hydrogen Generation

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Abstract

Solar fuels are seen as an important component of a future sustainable energy and fuel supply. An interesting candidate is the production of green hydrogen by using solar driven two-step redox cycles with high theoretical solar-to-fuel efficiencies.

Here we present new results and insights in the most efficient operational strategy of a pilot plant for regenerative hydrogen production based on a two-step thermochemical redox cycle. The plant consists of a solar driven large-scale 250 kW thermochemical fixed bed inert gas reactor using ceria as reactive material for water splitting and an efficient fluid heat-recovery system.

The focus of this work is on optimal operational parameters for highest plant efficiency. The tuning parameters are the most important process conditions, which are here the operating temperatures within the two steps, corresponding fluid mass flow rates and switching times for both steps in the cycle.

A complex and detailed multi-physical simulation model is employed within two optimization routines for revealing dependencies between the varying parameters, gaining insight in areas of robust and efficient operational parameter settings, and finally for finding the most efficient operational strategy.

Material and technical limits of the used components are considered within the optimization; thus, the obtained results can be validated in praxis. Considering a reduction temperature of 1500 °C, the maximum efficiency is determined with 2 %, using optimal operational parameters within a large temperature swing strategy.

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Physical System Behaviour and Energy Flow Analysis of a Solar Driven Hydrogen Production Plant Based on Two-Step Thermochemical Redox Cycles

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Abstract

Two-step thermochemical water splitting using concentrated solar power offers promising potential for green hydrogen production as a part of a future sustainable energy economy.

Theoretical efficiencies are determined in a range of 30 to 40 %. Up to now, lower practical efficiencies of 5 % have been demonstrated successfully at high temperatures up to 1500 °C.

In this sense the improvement of existing prototypes is very important, which is the topic on this work. To gain more insight, the physical system behaviour and energy flow of a large-scale pilot plant including a heliostat field, a thermochemical fixed bed reactor, a fluid heat recovery system, several valves, and an electrical steam generator is investigated in detail.

For this study an accurate and complex 3D multi-physics simulation model considering detailed technical, material, and geometrical specifications of the entire plant has been developed and validated by real measurement data recorded in an experimental test campaign.

Potential efficiency improvements are revealed and useful possibilities for plant design, material modifications and control parameters are discussed. Considering the current plant layout, different kind of heat losses of involved components, as well as the influence of crucial reactor design parameters are analysed with respect to plant efficiency and hydrogen production. Regarding the operational strategy, the influence of applied cycle durations, temperatures, and mass flow rates are varied in a broad range. By comparing commonly used operational strategies, the temperature swing operation turns out to be by far more efficient than any isothermal or near-isothermal operation for the given plant concept. Going in more detail, the sensitive relation of control parameters and transient system behaviour indicates a complex optimization problem.

Outgoing from a base case scenario, the plant efficiency can be improved by a factor 4 within the investigated ranges. The results can be interpreted as basic comparable values for similar plant and reactor designs and further be used for subsequent analyses.

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Biomass to H₂, a Carbon Negativity Upgrading of Waste

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Abstract

Global warming, rapid population growth, and the gradual lack of raw materials are topics afflicting the whole world. They required rapid, urgent, and decisive reactions to allow a future sustainable life on Earth for humanity. In the EU this transition is synthesized in its vision at 2050: “A Clean Planet for all...” whose fundamental steps are reported in “fit for 55”. In particular, the major goal of the plan is to reduce GHG emissions by 55% compared to their level in 1990.

In this context waste biomasses and hydrogen play a crucial role in the containment of Greenhouse Gas (GHG) emissions. Indeed, on the one side, biomasses can be used for carbon-negative applications, by integrating Carbon Capture and Storage (CCS) technologies, essential to achieving net zero-emission in a short time. On the other side, the use of hydrogen for energy production in advanced conversion systems has no pollutant and GHG emissions being a suitable solution in the short-/mid-term for the decarbonization of hard to abate sector (such as heavy and fertilizer industry, truck and fossil-fueled train, etc.). Not least their potential use in Power-/biomass-to-H₂ application to store the seasonal RES surplus also enabling inter-sectoral synergies, due to the wide flexibility of hydrogen (automotive, injection in methane grid, production of fuel, electrical storage, etc.).

The aim of the study is to analyze the conversion of waste biomasses into hydrogen through an integrated process of Anaerobic Digestion (AD), fast pyrolysis, and steam reforming of intermediate energy carriers (biogas, syngas, and bio-oil) followed by CO₂ separation by a membrane reactor.

Results have highlighted the importance of the Thermal Energy Storage (TES) integration into the system to increase the energy efficiency when the conversion plant is fully powered by PV (22.16% from 9.76%). Indeed, TES integration brought the overall energy conversion efficiency close to the value of the system continuously powered by the Grid (24.9%).

SDEWES2022.0081

Investigation of Waste Biomass and 3 Ply Covid-19 Masks Co-Pyrolysis Products

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Abstract

The COVID-19 pandemic has caused a heavy expansion of the pollution by plastic wastes worldwide. Co-pyrolysis technique with a renewable biomass can be a one solution for tackling with these hazardous wastes. Thus, a thermogravimetric analysis coupled with Fourier-transform infrared spectroscopy and gas chromatography/ mass spectrometry experiments were carried out on pyrolysis volatile products of sunflower seed shells biomass and 3 ply face masks mixed in four different ratios (1:0, 2:1, 1:1, 1:2). It was established that valuable gas butane synthesis from the biomass was significantly increased by elevation of face masks proportion in a sample. Therefore, the potential co-pyrolysis technique with waste biomass may be a possible solution for the reduction of pandemic related plastic waste and valuable energetic products generation concurrently.

SDEWES2022.0086

The Environmental Impact of the Lignin-First Biorefinery: a Consequential Life Cycle Assessment Approach

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Abstract

The innovative reductive catalytic fractionation (RCF) and its lignin-first valorization strategy aim to entirely valorize wood into high-value end products. Although the RCF process has already proved its novel high-value applications among many innovative approaches, the extent of environmental impacts and consequences of the RCF process implementation and its lignin-first valorization strategy is not fully known.

Therefore, a demand-driven consequential life cycle assessment is conducted to study the expected environmental changes as a consequence of a change in demand for the RCF products – pulp, monomer, and oligomer – using Belgian long-term electricity and heat mixes. The RCF products are compared to their alternative counterparts (unbleached sulfate pulp, fossil oil-based phenol, and bisphenol A).

Under the current assumptions, RCF products have higher carbon emissions (kg CO₂-eq./kg) than their alternative counterparts. The contribution analysis shows that the high-polluting H₂ gas bypass waste stream causes underperformance. Other highly contributing activities are RCF's by-products that replace high-polluting alternative counterparts on the market and give (positive or negative) credit to the RCF process. Next, an additional RCF configuration (with higher processed end products) is assessed, showing that the higher-processed RCF products have lower carbon emissions than the lower processed RCF products in this study, but are still slightly higher than the alternative counterparts. It shows that carbon emissions are highly dependent on the RCF process configurations and the targeted alternative products that are potentially replaced by the RCF products on the market. Hence, a reorientation of the product development and the targeted markets is discussed. Next, the impact of the transportation distance and different transportation options are analyzed showing that with increasing distance sea shipping should be considered. Besides, the lack of in(-direct) land-use change, and the exclusion of the usage and disposal stage are discussed implying a potential increase in carbon emissions of the RCF process. A more global environmental view shows that RCF products can outperform their alternative counterparts in several other characterization indicators (e.g. land occupation). Overall, the study shows that the RCF process can be environmentally desirable if the appropriate RCF configuration and products are chosen.

SDEWES2022.0098**Valorisation of Glycerol to Propane-1,2-Diol with Heterogeneous Oxide Catalysts Based on Copper**

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Abstract

The production of alternative fuels from renewable sources is today supported by decreasing amount of fossil fuels and necessity to be respectful of nature. Some of the supported alternative fuels are for example bioethanol and FAME. FAME is produced by transesterification of vegetable oils with the glycerol as a by-product. With increasing production of FAME the amount of waste glycerol increases losing its price and usage. For this reason, new ways for valorisation of glycerol are looking for. One of the good and perspective example of glycerol valorisation can be selective dehydroxylation (hydrogenolysis) of glycerol to propane-1,2-diol (propylene glycol). Propane-1,2-diol have many practical applications in medicine, food and cosmetics industry. As a raw material for production of propane-1,2-diol is usually used propylene, which is produced from crude oil. The substitution of propylene in production of propane-1,2-diol is a promising way of utilization renewables in petrochemical industry.

Catalysts containing Cu as the main active metal are, in addition to noble metals, the attractive catalysts for hydrogenolysis of glycerol. Their advantage over noble metals is their low cost with comparable values of kinetic parameters, activity and selectivity. Heterogeneous catalysts containing a copper and other transition metal (Zn, Fe) as promotor deserve more attention.

The paper is focused on the use of heterogeneous oxide catalysts based on copper with promoter (Zn, Fe) in the transformation of glycerol to propane-1,2-diol. The reaction was carried out in autoclave reactor at temperature of 230 °C and under the pressure of 70 MPa of hydrogen. The synthesized catalysts were characterised by a number of analytic methods (XRD, TGA, TPR, TPD, etc.) for the determination of influence of promoter on the catalytic activity. It was found that the best catalysts containing copper with promoter achieve the conversion up to 95% after 6 hours. The catalysts achieved the maximal selectivity 95% to propane-1,2-diol at 65% conversion of glycerol.

This work was supported by the University of Pardubice, Czech Republic, project SGS_2022_007

SDEWES2022.0186**Waste to Biofuels Through Oxidative Liquefaction Process: an Experimental Analysis**

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Abstract

Plastic wastes are ubiquitous and acknowledged as an environmental stressor, adding micropollutants to the world's vulnerable ecosystems, which toxic impacts and pieces of evidence are being seen in all living organisms, including human beings. Synthetic polymers are highly useful and convenient materials with a range of positive properties, however, burdened with heavy environmental impact. Plastics are inexpensive, lightweight, and durable materials that are easily molded into a variety of useful products and have become indispensable to modern life and the global economy. A rapid growth in plastic consumption has been seen worldwide in recent years, and without any decisive action will continue to grow. Thus a critical point of waste management strategy is to reduce the amount of these wastes in a short term simultaneously developing a stable strategy to convert the plastic waste in a long term scenario. One of the prospective methods of developing methods are hydrothermal methods, including hydrothermal liquefaction. Hydrothermal oxidative liquefaction of waste is a reasonably new technique whose main objective is to reduce solid waste. During wet oxidation, the waste is degraded in water under subcritical conditions of temperature (150-320°C) and pressure (20-150 bar). The paper presents review of the hydrothermal technologies, including own concept of the wet oxidation of the wind turbine blade waste experimental research methodology. The process was carried out at high temperatures of 300°C and pressure of 30 bar in a Parr 4650 batch reactor with a capacity of 500 ml with the addition of an oxidizing agent H_2O_2 to obtain oxidative conditions. After conducting the experiment, one can see changes in the form of the waste subjected to the process. The sample was liquefied after the process. It is assumed that it is possible to produce a narrow group of chemical compounds.

ACKNOWLEDGMENTS

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SDEWES2022.0205

Emission Spectroscopy of Various Composition Biogases Treated in a Non-Thermal Plasma Reactor

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Abstract

Worldwide energy and environmental problems are a serious challenge for humanity and the different parts of industry. Energy consumption of the world is rising in a very intensive way and leading still to high usage of fossil fuels, which are the reason of global warming due to emission of the greengouse gases and pollution of the environment with substances such as nitrogen oxides, incomplete fuel combustion products, carbon residues, etc. One of the promising ways to deal with this problems is the usage of different types of renewable flammable gases like biogas and other Low Calorific Value (LCV) gases. Biogas and gases of it's conversion are a natural renewable fuel, that could be produced with usage of biomass, the source of energy that could not worn out. The disadvantage of Biogas is that it is heavily ballasted by the CO₂, which is uncombustible, that's why it requires conversion to the syngas with the help of non-thermal plasma reactors, which leads not only to sustainability but also for additional environmental benefits like utilization of wastes, shortage of methane emissions, etc. During this work was studied influence of millisecond type gliding arc non-thermal plasma on the biogas (mixture of the CH₄ and CO₂) with a low concentrations of methane (20-30%). The process of Plasma-Assisted Dry Conversion to the syngas (mixture of H₂ and CO) in the experiment was performed using tangential inlet type reactor which was hermetically sealed from the influence of outer gases using quartz glass column and end caps. To deepen knowledge on plasma-assisted combustion of biogas and LCV gases, the plasma conversion effect was investigated, what provides an information about mechanisms of conversion, also as the possibility to find out the most effective parameters of plasma to reach highest rates of conversion with lowest implied power. For understandance of the plasma influence on the threatened gases were used methods of emission spectrometry and flow gas analysis. The spectrometry of generated species and radicals were provided by the Flame series spectrometer manufactured by Ocean Insight for observing the distribution of the exited species and radicals (OH, CH, C₂ and N) and the gas analysis was done with the help of Visit-o₃ manufactured by Messtechnik EHEIM. The spectral analysis showed that the intensity of selected radicals (C₂*,OH,CH) has been changed, which leads us for understanding how different characteristics like voltage and frequency of the plasma discharge influence the final product. Tendency of changes in the gas characteristics were also determined in correlation with the containment of flammable parts in treated gas and overall gas flow.

SDEWES2022.0223**Hydrothermal Liquefaction of a Sewage Sludge for the Production of Biofuels: Optimization of the Experimental Apparatus and Effect of Operating Parameters on the Process Performance**

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Abstract

The release of CO₂ in the atmosphere from fossil fuels combustion is one of the biggest drivers of global warming. Phenomena such as climate change and fossil fuel shortages are encouraging the development of alternative routes for energy production, to diversify the current energy portfolio. The biomass represents, one of the promising alternative to fossil fuels for the production of bio-fuels as energy vector or chemicals, due to the large availability of these resources in form of agricultural residues, food and animals waste and sludges deriving from both industrial and civil wastewater treatment. Among the different biomass conversion technologies, particularly interesting are those that lead to the production of a liquid fuel, required for many applications such as in the transport sector. The however, the traditional thermochemical process of pyrolysis presents some weak points, in particular the necessity of managing dry feedstocks – biomass water content can reach up to 80% of the starting weight. In this context the hydrothermal liquefaction (HTL) is an emerging technique for the conversion of wet biomass into liquid fuels by processing it in a hot, pressurised water environment (250–350 °C and 15–220 bar), for sufficient time to break down the solid biopolymeric structure and produce a liquid bio-oil as energy vector. Besides the target bio-oil, an aqueous phase, a bio-char and a gas phase are also obtained. For HTL carried out in batch reactors, the minimization of thermal transients is crucial to obtain a high-yield bio-crude with more attractive energy properties. To this end, in this study a lab-scale plant consisting in a batch autoclave was optimized to limit thermal transients that could lead to the formation of undesired products. Moreover, sampling during heating ramps were carried out to assess the yield of products derived from HTL of sewage and verify the production of bio-oil during the transient heating. After the optimization of the experimental apparatus, the yield of the bio-oil produced at different temperatures and reaction times was evaluated. Preliminary HTL tests carried at 300 and 350 °C for 20 min revealed that best results in terms of bio-oil yield were retrieved at higher temperature, with a bio-oil yield of 38.3% a figure 37% greater than the one determined at 300 °C.

SDEWES2022.0280**Flame Chemiluminescence from Premixed Biogas/Air Flames Under Syngas and Ozone Enrichment**

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Abstract

The European Union based on Paris Agreement is foreseen to reduce greenhouse gas emissions by around 45% till 2030. To achieve this goal, more stringent requirements of environmental protection are brought, but also the share of renewable energy sources should be increased. In the last decade, biogas is gaining a lot of attention as a valuable renewable energy resource that could substitute fossil fuels for heat, electricity production and at the same time help in reducing bio-waste and greenhouse gas emissions. However, the biogas consists of CH_4 from 40 to 70%, while the rest part is CO_2 , which negatively affects the combustion process in terms of decreased flame stability, lifted flame and occurrence of incomplete combustion. To ensure clean and stable combustion, innovative methods should be applied in existing burners.

To expand knowledge of syngas and ozone enrichment upon biogas combustion, simulated biogases (70-30 %) were combusted in a flat flame burner coupled with a dielectric barrier discharge plasma reactor at lean-fuel conditions. In order to determine the effect of syngas and ozone enrichment on biogas flames, the flame emission spectroscopy was used to acquire changes in the flame structure and to evaluate the flame behaviour by mean of lift-off height. The flame images were captured using an Andor iStar DH734 Intensified Charge Coupled Device (ICCD) camera with an optical system for observing the spatial distribution of excited radicals OH^* , CH^* and C_2^* in the flame. In addition, the post combustion products were analysed by a gas analyser Testo 350XL

The spatial distribution of registered radicals (C_2^* , CH^* , OH^*) indicated that the flame structure changes from flat flame to cellular one with increasing CO_2 /decreasing CH_4 concentration in the mixture and with the increase of fuel to air ratio. According to OH^* emission intensities, the flame stability decreased with changes mentioned above and maximum emission intensities of OH^* corresponded to flame lift-off height rises. The addition of 20% syngas reduced the biogas flame lift-off height from 20 to 70% changing biogas composition (CH_4 from 70 to 30%). the enrichment of syngas with ozone, the flame lift-off height was reduced by additional 5% only at lean-combustion conditions. It was determined that the applied methods ensure reduction of NO_x emissions by 10-17 mg/m^3 . However, the enrichment by syngas with ozone led to increased NO_x emissions compared to the results with the addition with syngas, though the highest CO decrease was observed.

SDEWES2022.0544**Modelling Framework for Increasing Feedstock Flexibility in Biorefineries: Producing a Targeted Set of Oleochemicals from Alternative Feedstocks**

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Abstract

Renewable feedstocks are increasingly used to produce chemicals and energy. However, variable availability and quality of renewable feedstocks remains a major challenge. In this study, a modelling framework is developed, based on process simulation and life cycle sustainability assessment (LCSA), which can be used for increasing flexibility of feedstock use in biorefineries. The presented framework should aid decision making on valuing, procuring and processing feedstocks, by calculating the techno-economic feasibility and environmental, economic and social sustainability for different feedstock scenarios. The modelling framework is developed and applied to an oleochemical plant producing a tallow-like fatty acids mixture, glycerol and propylene glycol. Currently, animal-based fat (tallow), with a C18 content of 60-70% m/m, is used as feedstock. However, tallow supply has become scarce due to high demand by the biofuel and hydrotreated vegetable oil (HVO) sectors. In this study, the technical feasibility and environmental sustainability of switching feedstocks from tallow to palm oil is investigated. Palm oil has a higher C16 content, 45-50% m/m. The results show that it is technically feasible to switch the current operation and use palm oil instead of tallow to produce tallow-like fatty acids. However, a fractionation process with withdrawal of an extra stream rich in C16 fatty acids, is required. It was shown that for an LCA adopting economic allocation along the entire value chain, tallow-like fatty acids from palm oil have a higher impact for global warming, freshwater eutrophication and land use. The greatest difference is observed for the global warming impact, being ± 5 times higher for the palm-based alternative. For other selected indicators, the palm-based fatty acids score better than tallow, e.g., for fossil resource scarcity, which was ± 2 times higher for the tallow alternative. In future work, the economic and social sustainability of both alternatives will be integrated in the assessment. This work illustrates that the developed framework can become a crucial decision support tool for selecting and using feedstocks in biorefineries, allowing a plant to switch to other and lower quality feedstocks and increase its adaptability toward changes in demand and supply.

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SDEWES2022.0329

Hydrolysis of Cellulose to Glucose Using Green Acid Catalysts Based on Supercritical CO₂

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Abstract

The efficient depolymerization of lignocellulosic biomass into its monomer unit such as glucose is the critical step for the cost-effective production of biofuels and biochemicals. However, the current biomass deconstruction technologies such as enzymatic and acid hydrolysis involves extremely long reaction time (a week or so) and harsh reaction conditions (>50 wt% H₂SO₄ solution). Herein, we investigated the feasibility of the supercritical carbon dioxide-induced carbonic acid as an in-situ acid catalyst for the enhanced hydrolysis of cellulose to glucose for the first time. Our thermodynamic calculation showed that the calculated pH of the produced carbonic acid under reaction conditions (150 °C and 300 bar) was approximately ~3, which is sufficient for generating the acidic environment for cellulose conversion. By combining the carbon acid with the sulfonated carbon catalysts, we attempt to maximize the glucose yield. The acid functional groups and pore structure of the carbon catalysts were systematically adjusted, and their combination effects with the carbon acid were investigated under various reaction conditions to demonstrate the synergic role of CO₂ and carbon catalysts on the enhanced hydrolysis of cellulose.

SDEWES2022.0364

Spray Combustion of Fast-Pyrolysis Bio-Oils

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Abstract

In the EU funded SmartCHP project, biomass derived fast-pyrolysis bio-oil (FPBO) is used to fuel modified stationary diesel engines for combined heat and power applications. In this study, the spray combustion characteristics of FPBO and FPBO/ethanol blends are experimentally investigated in a combustion research unit. The pressure-based heat release analysis is used to evaluate fuel ignition and combustion characteristics, while a high-speed imaging technique is adopted to visualize natural flame luminosity. Results show that FPBO has much lower sooting tendency while it significantly alleviates the fuel dribble phenomenon when compared to diesel. At low injection pressure, the poor atomization of FPBO leads to rather grainy-looking spray flame images, and nozzle orifices becoming blocked within several injections. The increase of FPBO injection pressure results in an obvious improvement of the atomization quality and nozzle durability. Adding 30 wt.% ethanol into FPBO could further reduce the natural luminosity.

SDEWES2022.0408

Production of Upgraded Fuel from Solid Wastes via Catalytic Thermoconversion Process

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Abstract

In this study, catalytic pyrolysis of cow manure (CM), a representative solid wastes, over HZSM-5, HBeta, and HY zeolites was conducted for the first time to produce upgraded biofuels containing valuable components such as benzene, toluene, ethylbenzene, xylene, naphthalene (BTEXN). Among HY, HBeta, and HZSM-5, HZSM-5 revealed the highest BTEXN production efficiency, followed by HBeta and HY due to different acidity and pore structure of the catalysts. Largely increased production amount of BTEXN (Peak area; 203.7×10^7 counts) was achieved by applying HZSM-5 on the catalytic pyrolysis of CM alongside with the decrease of oxygen containing compounds (O-CCs) due to the effective deoxygenation and aromatization. Increase of the HZSM-5 acidity by decreasing the $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio (SAR) from 280 to 30 also increased the BTEXN production efficiency with the proportional decrease of O-CCs, suggesting the importance of catalyst acidity. Increase of reaction temperature, from 550 °C to 600 °C, and catalyst to feedstock ratio (C/F), from 1/1 to 5/1, also increased the production amount of BTEXN with the further decrease of O-CCs. Between in-situ and ex-situ catalytic pyrolysis, in-situ reaction was more effective for aromatics formation.

SDEWES2022.0499**High Temperature Lignin Separation for Improved Yields in Ethanol Organosolv Pre-Treatment**J. Adamczyk^{*1}, S. Beisl¹, A. Friedl²¹TU Wien, Austria; ²Technische Universitaet Wien TUW, Austria
(*johannes.adamczyk@tuwien.ac.at)**Abstract**

Full utilization of biomass is vital for a transition from a fossil- to a renewables-based economy. Residual lignocellulosic biomass from agriculture, like wheat straw, is abundantly available, but currently underutilized for material applications. Organosolv pre-treatment can be used to fractionate lignocellulose into its main constituents, namely cellulose, hemicellulose, and lignin. Ethanol has shown promising results when used as a solvent in organosolv pre-treatment and can be produced from renewable resources at competitive costs, enabling a completely renewable-based process. However, the organosolv process has additional demands compared to conventional pre-treatment technologies due to the necessary solvent recovery. Compared to other processes, organosolv extraction produces high-quality lignin viable for value-added applications, which can simultaneously offset the higher cost and improve sustainable material use.

Previous works have indicated that more lignin is solubilized at elevated temperatures during the extraction and re-precipitates onto the biomass during cooling. Thus, separating solids and liquids at elevated temperatures could be a relevant route to process optimization, improving both delignification and lignin yield. However, systematic research exploring this process-oriented approach is still scarce. In this work, samples were taken at various temperatures during cooling after ethanol organosolv pre-treatment of wheat straw. The resulting extracts were analyzed on their composition and lignin properties. The results show how lignin concentration in the extract decreases during the cooling, and thus gives some insight into temperature dependency of lignin solubility. This opens up possibilities for process optimization and more efficient biomass utilization by potentially increasing delignification and lignin yield.

SDEWES2022.0500

Production and Characterization of Pickering Emulsions Stabilized by Colloidal Lignin Particles Produced from Various Bulk Lignin

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Abstract

The modification of processes and products to fulfil green chemistry or green engineering principles can only be achieved by utilizing materials based on renewable resources. Lignin, which can be found in wood or woody plants, is the second most abundant bio-macromolecule. This aromatic biopolymer is mainly obtained from waste streams in pulp & paper but is nowadays also produced as the main product from new lignocellulosic biorefinery plants.

However, lignin is a highly irregular branched polyphenolic polyether. Its high structural complexity and inhomogeneity is a challenge for lignin valorisation. A possible way to cope with this heterogeneity in the processing stage is the transformation of lignin into colloidal lignin particles (CLPs) with well-defined surface chemistry and morphology, which have a great potential in many applications such as substitutes for synthetic emulsifiers.

These CLPs can be used as an emulsifier in so-called Pickering Emulsions, where solid particles stabilize the emulsion instead of surfactants. Commercial surfactants often show adverse effects on human beings and the environment, while CLPs are renewable based and biodegradable. CLPs with a particle size around 100 nm stabilize small droplets of the disperse phase surrounded by the continuous phase, leading to high coalescence resistance.

This work investigates the influence of different properties of the various CLP suspensions on the applicability as emulsifiers. Therefore, commercial bulk lignins were solubilized in aqueous ethanol and afterwards precipitated to form CLPs. The aqueous CLP suspensions were characterized by different methods like scanning electron microscopy, dynamic light scattering, size exclusion chromatography, and density measurements. Emulsions of different fats and oils with water were produced and stabilized with CLPs. The characterization of these emulsions comprised viscosity measurement, different stability tests, and droplet size measurements by fluorescence microscopy.

SDEWES2022.0531**Bio-Oil Recovery from Industrial Hemp Waste by Hydrothermal Upgrading: Liquids Yields Dependency on Fiber Presence and Hemp Specie**

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Abstract

Nowadays, fuel producers are increasing their interest in alternative raw materials due to rising fossil fuel prices, limited crude oil reserves, and especially CO₂ emissions, which must meet strict European standards. While industrial hemp is grown to extract fibers for textiles, its waste biomass can be used as an alternative material [1] for the production of liquid biofuels through the hydrothermal refining process (HTU), which does not require high energy costs such as pyrolysis, because it takes place at 300-350 °C. Moreover, the HTU process uses a green catalyst and water as the second reactant, which makes the process more environmentally friendly [2]. This research aimed to compare the bio-crude yield results and its quality when processing stalks of raw industrial hemp before and after fiber extraction. In addition, the goal was to investigate the effect of two industrial hemp species and three different weights of catalysts on the HTU process efficiency. In total, twelve HTU autoclave reactions were performed, using two species of industrial hemp (Futura 75, Fedora 17) in the form of stalks with and without the fiber sheath. Three tests for each 10 g hemp waste material were performed using 2, 3, and 4 g of potassium carbonate per reaction as a catalyst. The reaction conditions for all the tests were as follows: the reaction temperature of 315 °C, the reaction time of 15 min (after achieving reaction temperature), the heating rate of 8,3 °C/min and using 100 ml of demi water as a solvent. After each test, the gas sample was taken, as well as, a bio-oil fraction was recovered. Obtained bio-oils were analyzed using elemental analysis (C, H, N, S, O), attenuated total reflection (ATR) spectroscopy, and simulated distillation (SIMDIS). Moreover, the expected higher heating value (HHV) was calculated according to the elemental composition of the sample. Gaseous products were analyzed using the refinery gas analysis (RGA) method by Agilent. It was found that the oxygen content in all collected bio-oil products (26-36 %) was lower compared to the feedstock material (47 %), giving the product more fuel-like properties. At the same time, the calculated HHV of the products, which varied around 30 MJ/kg, represented an increment of about 62 % over the value of raw hemp biomass - 18.5 MJ/kg [3]. In the case of the bio-oil fractionation, the major product part consists of a diesel cut, with a boiling range of 180-360 °C. Our work emphasizes the usefulness of using a new bio-sourced raw material, which can be transformed into possible biofuel streams in a relatively undemanding process, especially in the current unstable time of energy transformation in the EU.

SDEWES2022.0561**Novel Catalytic Tar Cracking Reactor Downstream Indirect Gasification**

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Abstract

The challenge of climate change calls for a drastic reduction in CO₂ emissions associated with electricity production, transport and industrial activity. The CONVERGE project will contribute to the emission reduction in the transport sector by demonstrating an innovative process for biodiesel production starting from secondary biomass. Gasification of secondary biomass streams, followed by novel technologies for gas cleaning and catalytic synthesis (shown in Figure 1), offers a potential to improve the overall energy efficiency of biodiesel production by 12%.

This work focuses on the catalytic cracking of tar compounds, formed during indirect gasification, to below green C8 components. Recovery of the C6-C8 fractions by the BTX scrubber will create an extra revenue stream that will maximize the value of the feedstock. However, one of the main challenges tar cracking catalysts are related to is the deactivation by carbon deposition and sulphur compounds.

In this work, numerous different natural (olivine, ilmenite, halloysite, sewage sludge ash) and commercial (metal-zeolites, noble metal-based) catalysts are tested either as received or modified. Preliminary tests of all the optimized materials are performed at NIC, in a fixed bed reactor shown in Figure 2, using 5 wt% naphthalene in 95 wt% 1-methylnaphthalene as model tar compounds. The experimental conditions used are: GHSV = 9000 h⁻¹, TOS = 24 h, P = 1 bar, T = 370°C, S/C ratio = 0 - 2 mol/mol. The results show >90 mol% conversion of the model tar compounds.

The five catalytic materials that exhibited optimum performance, are tested under real gasification conditions at TNO in the experimental setup shown in Figure 3. Raw product gas from indirect gasification at 850°C is used, from beech wood and solid recovered fuel (SRF) (see Figure 4), with a tar content of 40 and 90 g/Nm³ (dry basis), respectively. The effect of the operating conditions of the cracking reactors is studied: T = 400 - 900°C, 1 NL/min outlet gas flow, S/C ratio = 1 - 3 mol/mol, and GHSV = 2000 - 5000 h⁻¹. The performance of the catalysts is assessed in terms of product gas composition, as well as tar content and composition, applying online micro-GC and SPA analysis. The tar cracking tests will be complemented by an extensive characterization of fresh and spent materials to investigate the processes taking place during operation. The catalytic tar cracking tests are currently ongoing and the results will be presented in this work.

Acknowledgement: The CONVERGE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 818135

SDEWES2022.0587**Membrane Methanol Reactor to Decrease Costs of 2nd Generation Biofuel Production**

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Abstract

Liquid biofuels have a significant role to play in meeting the climate change targets. Presently approximately 0.1 percent of all biomass is used to produce biodiesel, owing to an inefficient and complex production process. The EU CONVERGE project demonstrates a new innovative process, that will make biodiesel competitive with fossil fuels in terms of both effectiveness and price.

One of the technologies developed in this project, is an enhanced methanol membrane reactor. In-situ methanol and/or water separation greatly enhances per pass production of methanol, thereby reducing equipment size significantly. Additionally, selective removal of reaction products will decrease the energy demand in downstream processing. This project aims to increase the CO₂ and H₂ conversion per pass to 33% and to reduce CAPEX by 10%.

To demonstrate membrane reactor performance the multi-tubular membrane reactor system was constructed and tested. This multi tubular system that consists of: packed bed reactor and, cooler and multi-tubular membrane reactor in series. The membrane reactor has 7 membrane tubes ceramic supported polyimide membranes with total effective area of 0.25 m². An isothermal conditions are maintained by circulating of the thermal oil. Membrane reactor showed stable performance over 2664 h of testing. In all experiments, achieved CO₂ conversion and methanol yield in the multi-tubular membrane reactor were beyond equilibrium measured in the packed bed. For the stoichiometric H₂/CO₂ ratio, the highest CO₂ conversion and MeOH yield were achieved at GHSV = 449 h⁻¹ at temperature of 230 °C: CO₂ conversion =30% and MeOH yield = 17%. Feed pressure was 35 bara, and permeate pressure 1.5 bara. This represents 36% and 21% increase of the CO₂ conversion and MeOH yield, respectively, compared to the equilibrium conditions.

Buildings 1

SDEWES2022.0002

Dynamic Building Energy Modelling of Healthcare Facilities: an Italian Case Study

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Abstract

The aim of continuously increasing building energy efficiency implies the need to experiment with different solutions as changes in energy systems layout or building energy management strategies. To this end, dynamic energy simulation techniques are becoming increasingly important in the context of industrial and commercial buildings, allowing to identify the operations that result technically and economically feasible. Furthermore, since healthcare facilities have very specific service continuity constraints, carrying out experiments to improve energy efficiency can be difficult. The present study aims at realizing a Building Energy Model able to qualitatively reproduce the energy requirements of the systems of a healthcare facility located near Florence, Italy. The results were compared to available data on the facility's energy and water consumption for the year 2019. Then, the realized model was exploited to evaluate two different changes in the building energy systems. The first involves replacing the current evaporative towers with more efficient evaporative cooling towers and dry cooling towers. The second case concerns the installation of an electric power generation system composed of photovoltaic panels on the building roof. Both cases were evaluated from a techno-economic perspective to assess their potential of improving building energy efficiency and their feasibility in the healthcare context.

SDEWES2022.0064

Evaluation of a Real-Time Optimization and Decision Making Framework in Virtual Reality for Life Cycle Analysis of Flexible Industrial Building Structures Incorporating Production Processes

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Abstract

Integrated Industrial Building Design is based on collaborative decision making and coupling of discipline-specific tools. This process is subject to following problems: 1. Conflicting stakeholder goals and absence of effective communication workflows during early design stage, 2. Industrial building structures often lack flexibility for future production changes; once a building has been designed for a certain production type it cannot be used for other production types 3. No performance feedback in terms of life cycle cost (LCC), life cycle assessment (LCA), recycling potential and flexibility in early structural design. Interdisciplinary optimization and decision making tools in virtual reality providing collaborative visualization and enable variant studies within design meetings are lacking. We propose a Virtual Reality-based optimization and decision-making framework. Multidisciplinary stakeholders can collaboratively change parameters related to structural and production planning and observe changes in the performance of the building design in real-time. This way, the limitations posed by different planning components and potential compromises can be easily explored by all stakeholders. The VR framework is coupled to an automated background structural optimization process that considers production layout planning and gives feedback to LCC, LCA, recycling potential and flexibility assessment. This paper presents the VR framework for integrated industrial building meetings for early design stage. The framework builds on our previous studies conducted in the funded research project BIMFlexi. The parametric design approach, integrating production planning and structural design with automated calculation of the load-bearing structure and simultaneous assessment of LCC, LCA, recycling potential and flexibility, has already been presented. The VR framework, based on Grasshopper for Rhino3D (parametric) and Unity3D (VR), is tested within a pilot evaluation with multidisciplinary teams to extend the workflow towards improved collaboration and visualization. Forty industry professionals (architects, civil engineers, and production planners) tested the framework and were then interviewed about the usability, VR navigation, collaboration, and decision-making experience using the VR-tool. The results of the expert interviews are finally supplemented with findings from literature to develop the holistic VR workflow for early stage industrial building design meetings.

SDEWES2022.0129

The Building Condition Assessment: a National Benchmarking Exercise to Guarantee Building Performance for New Construction – a Maltese Case Study

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Abstract

As standards and green practices become more widespread and important, one aspect which must be considered are existing building standards, and how these standards are enforced, and are effectively used in construction methodologies. Having the tools readily available must work in tandem with the aim of implementing and enforcing these standards. The research being presented in the paper, seeks to determine whether buildings are compliant to such demanding criteria when systematically analysed using local Maltese parameters and European Regulations. The authors of this research paper attempt to respond to this by conducting a critical analysis of local building codes and their enforcement, relating the results to the efficacy, variance, and certainty of the codes once they have been implemented. Based on this premise, a Building Condition Assessment is proposed through which one can observe the presence or absence of such attributes. From the initial studies, conducted on a number of buildings, it is clear that the versatility of the Building Condition Assessment could allow users to focus on specific elements, as well as identify patterns that can predict potential defects. This process could in turn be used to create benchmarks, allow stricter enforcement in certain building practices while simultaneously building upon existing regulations, and finally be able to provide users with guarantees of the building's performance.

SDEWES2022.0177

On the Lighting and Energy Saving Contribution of Photoluminescence for Innovative Window Applications Considering Occupants' Behavior and Visual Comfort

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Abstract

The impact of windows' properties on buildings' visual environment and energy performance has been under investigation for a long time. In this context, peculiar materials with photoluminescent properties may be considered for energy-saving purposes. In this work, materials that persistently emit light after being activated by solar and/or artificial radiation are introduced as windows coatings. Their two-fold behavior as diurnal translucent materials and nocturnal light emitters is analyzed by means of a multiscale approach. After the optic and photometric in-lab characterization, the best photoluminescent options are applied to a real environment and monitored according to different boundary conditions, focusing on the photoluminescent gain for indoor lighting.

Results prove that a translucent-photoluminescent solution is preferable if compared to an opaque one, despite its lower afterglow intensity. Indeed, a homogeneous daylight diffusion is better perceived for visual comfort, while a general sense of orientation is provided by photoluminescence during the evening hours.

SDEWES2022.0226

Evaluation of the Effect of Changing Climate Conditions on Data-Driven HVAC Fault Detection and Diagnosis Performances for Energy-Efficient Building Operations

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Abstract

The heating, ventilation and air-conditioning (HVAC) fault impacts vary with changing climatic conditions, but the acquisition of fault data from real buildings covering annual seasonally climatic conditions is often difficult. This study evaluates the performance differences of the proposed combined CNN-RNN framework under the limited seasonal fault data scenarios and the ideally fault data scenario covering climatic conditions from four seasons. The fault and normal data were collected from fault simulations using EnergyPlus based on a verified prototype medium office building model. Four data experiments were designed based on the data scenarios considering the practical issue related to the season coverage. The results show that the FDD architectures trained on sufficient fault data under a certain season show poor generalization ability on identifying the faults under the other seasons. In addition, the influence of the amount of fault data under a season on the FDD performance under this season is confirmed. Moreover, the coverage of fault data under different seasons is more crucial in enhancing the FDD performances than the amount of fault data under each season. The findings of this study are helpful for FDD researchers to take into account this practical issue when developing new data-driven FDD methods or evaluating existing methods.

SDEWES2022.0229

Analysis of the Impact of Evaporative Cooling Strategies on the Aero-Thermal Comfort Performance of Courtyard Buildings in Hot and Dry Climates

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Abstract

A courtyard is a central open-air area that can ventilate room spaces surrounding it via wind-driven and buoyancy (stack effect) forces. Evaporative cooling strategies such as well or water features are integrated with courtyard spaces to provide additional cooling. The role of different water bodies in providing evaporative cooling and increasing humidity in the courtyard has been the focus of several studies. However, the impact on the aero-thermal comfort conditions of the surrounding building or rooms adjoint to the courtyard is still not tackled. The present study investigates the effect of an evaporative cooling system on the wind and thermal conditions inside a courtyard and the indoor spaces ventilated using single-sided and cross-flow ventilation. A computational fluid dynamics (CFD) model has been developed and validated for assessing the aero-thermal comfort conditions of various evaporative cooling water spray configurations. The courtyard and hollow-cone nozzles were validated based on previous data from wind tunnel experiments. Indoor thermal comfort conditions under four scenarios were assessed. The results showed that the evaporative cooling water spray had positively impacted the indoor aero-thermal comfort conditions, with a maximum cooling effect of 1.62°C for the single-sided ventilation courtyard, while an increase in indoor wind speed of 14% was observed for the cross-ventilation courtyard. The cooling for the indoor space is limited especially in cross ventilation courtyard and not economical, however, it could still provide cooling for the courtyard area, with more than 3°C cooling effects for the cross-ventilation courtyard and 1°C to 2°C temperature reduction for single-sided ventilation courtyard area, which can be used to prevent overheating during extreme conditions.

SDEWES2022.0252

Design and Control Strategies for Optimal Operation of an Air-Based BIPV/T System in an Institutional Net-Zero Energy Building

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Abstract

This paper investigates design and control strategies to improve the operation of an open loop air-based Building Integrated Photovoltaic/Thermal (BIPV/T) system located at the first net-zero energy building in Canada, the Varennes library. Optimal control of the BIPV/T flow rate can greatly improve BIPV/T – HVAC integrated performance, however, is often overlooked resulting in systems that operate inefficiently.

The strategies consider variations of the existing system, to achieve higher thermal utilization efficiency. The commissioned system covers 16% of the south-facing roof and operates under a simple rule-based control strategy. A control-oriented BIPV/T model is calibrated and validated using monitored data from the existing system.

This study investigates the potential of covering more roof area with BIPV/T and exporting excess heat to adjacent buildings. Model Predictive Control (MPC) is applied on the BIPV/T flow rate for simultaneous heat supply to an Energy Recovery Ventilator (ERV) and air-to-water Heat Pump (HP), reducing the energy consumption by 40%.

SDEWES2022.0260

Experimental Characterization of Variable-Speed Packaged Rooftop Units in Presence of Evaporator Fouling

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Abstract

Variable-speed packaged rooftop units have been increasingly adopted in the tertiary sector. If not properly maintained, the fouling of heat exchangers and the improper refrigerant charge could increase energy consumption. In this work, the response of variable-speed rooftop units to evaporator fouling is investigated based on experiments on a variable-speed 17.5 kW rooftop unit.

A novel testing procedure is proposed, aimed at covering a broad range of operating conditions by a reduced number of tests. Two opposite cases were investigated: (i) even in presence of fouling, the controller can restore the required cooling capacity, and (ii) the intensity of the fouling does not allow the controller to restore the cooling capacity. While in the former case an increase in the

indoor fan rotating speed is observed, with no variations in the evaporating pressure and the inlet temperature of cooled air, in the latter one the mismatch between the cooling load and the capacity induces a deviation of the indoor air condition from the setpoint. A regression model is proposed to quantify these deviations. Experimental results showed that in a faulty scenario, the maximum cooling capacity deliverable could decrease up to 15-20 %, and the indoor fan consumption increased up to 40%. In case of heavy faults involving cooling capacity shortage, a 2.3 °C deviation from the indoor setpoint temperature was estimated by the proposed regression model. Although the testing procedure was here used to investigate only the effects of evaporator fouling, it can be similarly applied to other faults such as condenser fouling or improper refrigerant charge.

SDEWES2022.0269

The Double C Block Project. Thermal Performance of a Novel Concrete Masonry Unit with Embedded Insulation: Preliminary Test Results

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Abstract

Concrete Masonry Units (CMU) are a popular construction technology manufactured in a variety of thicknesses for the building of load and non-load bearing walls. The Double C Block is a novel composite CMU developed to offer enhanced thermal performance over the standard blocks. It features an original design registration where a polyurethane foam is inserted in between two concrete c-shape layers, thus acting as the insulating layer and the binding agent of the two concrete elements. The scope of the research is to describe the preliminary test results obtained when assessing the thermal performance of the block against three different methodologies: theoretical steady-state U-value calculations; a two-dimensional conduction steady-state heat-transfer simulation based on the finite-element method; and in situ monitoring of the U-value by means of the Heat Flow method. The results obtained thus far, show that the first two methodologies are corroborating each other, the U-Value of the Double C Block is $0.71 \text{ W/m}^2\text{K}$ including mortar. Whereas in-situ measurements are ongoing, results have so far given a range $1\text{--}1.5 \text{ W/m}^2\text{K}$

Buildings 2

SDEWES2022.0300

Thermal Comfort Prediction and Evaluation Method for People Without Autonomous Consciousness : a Review

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Abstract

Appropriate indoor thermal comfort is of great significance for reducing building energy consumption, decreasing overheating risk of buildings in summer and improving the physical and mental health of occupants. The traditional thermal comfort survey method requires subjects to give subjective thermal comfort feedback, which is often difficult to investigate the thermal comfort of special groups such as people with physical and mental issues and the elderly. This paper systematically reviews the thermal comfort survey methods for special populations who are unable to give subjective thermal comfort feedback autonomously, highlights the latest research methods, and provides an agenda for improving indoor thermal comfort of special populations, such as autistic patients and the elderly with dementia. The work will review works from the last 22 years focusing on. This study categorises such populations into three groups: sleeping people, people with mental diseases, and special age groups. The results showed that most of the reviewed studies focused on the thermal comfort of sleeping occupants while there are less studies focused on the thermal comfort of psychiatric patients, primarily for dementia and autism spectrum disorder, and on the collection of thermal comfort data for special age groups, including the elderly and children. The research methods of related studies are mainly divided into three categories. The first is the traditional subjective thermal comfort questionnaire, which is mainly used to study the thermal comfort of sleeping people. The second is subjective questionnaire and objective image recognition collection, which is common in patients with mild mental illness, the elderly and children with autonomous consciousness, and people in sleep state. The third is the combination of subjective thermal comfort collection of healthy adult caregivers and image recognition of the respondents, which are mostly used for patients with severe mental diseases and special age groups without autonomous consciousness. Machine learning and artificial intelligence are introduced in some studies, which have a positive impact on improving prediction accuracy. It is suggested that future research should increase data gathering efficiency and introduce technologies such as the Internet of Things to compare the methods' accuracy differences between different individuals.

SDEWES2022.0342

Influence of Wall Insulation Structure on Summer Overheating Risk of Residential Buildings in the Severe Cold Region of China: a Case Study in Harbin

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Abstract

Overheating risk of residential buildings in the severe cold region of China in summer increases with global warming. The thermal performance of the exterior wall has a significant impact on the indoor thermal environment. The existing regulation for the severe cold region of China stresses winter insulation in the construction of residential buildings without considering summer overheating. The influence of wall insulation performance on summer overheating in the local climate, on the other hand, is still unknown.

This study aims to investigate the impact of various wall insulation features under the present code on indoor overheating in the summer. Taking Harbin as a representative city in the severe cold region of China, insulation method, insulation material, and insulation layer thickness were chosen as independent variables. Two typical apartment models were developed and simulated in the building energy simulation (BES) tool Design Builder. The indoor overheating time with three different elements was predicted to evaluate the indoor overheating risk of residential buildings in summer.

The results show that the wall with an external insulation structure has the lowest risk of overheating in summer, followed by the internal insulation structure. Regarding thermal insulation material selection, apartments with EPS thermal insulation board, rock wool, and STP ultra-thin thermal insulation board have a lower risk of overheating in summer. XPS insulation board and PUR insulation board may increase indoor overheating time in summer comparatively. Furthermore, within the thickness range indicated by present requirements, overheating risk in summer increases with increasing insulation thickness, but the overall trend is slowing down.

Future research should address the overall performance of wall insulation in winter and summer under local climate conditions. In addition, it is recommended that the current codes and relevant atlas be updated to address summer overheating risk in severe cold region of China.

SDEWES2022.0343**Model Predictive Control for Energy Flexibility of a Building Coupled with Advanced Solar and Energy Storage Technologies**A. Maturo*¹, C. Vallianos¹, A. Buonomano², A. Athienitis¹¹Concordia University, Canada; ²University of Naples Federico II, Italy
(*a_matur@encs.concordia.ca)**Abstract**

The penetration of renewable energy sources in the built environment has led to challenges in planning and controlling the energy production, transmission, and distribution communities. Research is needed to optimize the interaction of building-integrated renewable energy technologies with the grid. In this context, the energy flexibility of buildings with and without renewable energy systems is attracting much interest. Energy flexibility is, in fact, recognized as a part of the solution to deal with some of the upcoming challenges in the future demand-respond energy systems (electrical, district heating and gas grids). Buildings can supply flexibility services in different ways, e.g., by utilizing thermal mass, adjusting HVAC system use, charging electric vehicles, shifting plug-loads, and solving or mitigating the grid congestion and steep ramps problems. In this regard, the present study proposes a model predictive control strategy under different demand response events, for load shifting and peak shaving purposes. The overall energy system combines building integrated photovoltaic/thermal (BIPV/T) with energy storage systems (ESS). The proposed predictive control strategy focuses on the optimization of the link between these components, optimizing the self-consumption and energy flexibility of the proposed system. Several scenarios concerning different storage technologies, like phase change material heat exchanger (PCM-HX) and radiant slabs, are proposed to enhance flexibility and highlight the main energy and economic results. The research is conducted by creating a physics-based simulation model of the proposed integrated technologies, by using the resistance-capacitance (RC) thermal network approach. Preliminary numerical results highlight the potential of both the integrated technologies and the implemented control strategy towards flexibility; encouraging results, in terms of key performance indices (KPI) are obtained.

SDEWES2022.0350

Summary of Current Knowledge on Building Window's Influence on Indoor Human Health and Well-Being

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Abstract

Indoor comfort and well-being are considered the major design goals of sustainable architecture. Previous research has established a linkage between daylighting and indoor human health and well-being. As a transparent intermediary between the interior and external environments, building windows may influence incoming daylight properties, affecting the inhabitants' psychological and physiological demands. In particular, with increasing needs for indoor environmental quality and health occupants, a variety of new glazing or window-associated technologies have been developed, such as smart windows, dynamic blinds, luminous glazing, etc. The objective of this study is to present a short literature review of recent studies that have specifically focused on the influence of windows on the health of occupants to expand information about the impact of various glazing systems on the overall health of occupants. Using Google Scholar, Science Direct, and Taylor and Francis Online as research engines, this review identified twelve studies that explored window and/or glazing features such as size, window to wall ratio, location of the window, and window/glazing optical characteristics to see how these factors affected the physiological and/or psychological aspects of indoor occupants. Indeed, the limited number of publications identified on this topic demonstrates a lack of concentration in this discipline and research needs in this area. This review basically confirms the potential influences of the window and/or glazing properties on indoor well-being, especially circadian-related health issues, which provides a basis for future potential comprehensive human-centered experiments and investigations.

SDEWES2022.0357

Implementation of Different Renewable Technologies in a Canadian Virtual Community

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Abstract

The introduction of load management and Demand Response programs is motivating utilities to propose demand-side management to incentivize customers to modify their energy demand during critical periods, providing energy flexibility to the grid. Therefore, buildings are undergoing a transformation from passive elements of the energy supply chain to local energy management nodes. Energy aggregators have grown significantly through the creation of virtual communities. This paper presents an investigation to define the energy flexibility potential of a virtual community. Four case study scenarios are described to analyze renewable technologies and their contribution to the overall flexibility. A Canadian virtual community is used as a case study to assess the reference profile and estimate the potential benefit of such an implementation. A representative DR event is described to simulate the combination of an air heat pump for space heating, with photovoltaics and building integrated photovoltaic/thermal systems. Different configurations are presented to reduce the energy consumption during Demand Response (DR) events. A sensitivity analysis is performed to evaluate the optimal sizing of such systems. Preliminary results show the potentials of the proposed methodology to aid the design and operation of virtual clusters integrating renewable technologies towards energy efficiency, showing a reduction of 30% of total energy consumption and a peak reduction of around 15%.

SDEWES2022.0360

Large-Scale Deployment of Model Predictive Control in the Residential Sector: Proposed Methodology and Assessment of Aggregated Impact

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Abstract

Electrification of heating has a significant potential to reduce greenhouse gas emissions, especially when combined with advanced control strategies that utilize building energy flexibility. This study analyses data from approximately 7,500 houses in Ontario and Québec, Canada to investigate the aggregated effect and potential of Model Predictive Control strategies on the grid based on current Time of Use rates and Dynamic Pricing. A first-order model for each house is calibrated using 10 days of data from the winter of 2019-2020. After selecting the 1,682 most accurate calibrated models, the study compares a simple deadband controller with on/off cycling to a Model Predictive Controller that minimizes the cost of electricity for a cold day in January. The results show that the optimal control can decrease the power peak demand during the high-peak periods by 70% in Ontario and 60% in Québec, as well as reduce the daily cost of electricity for the homeowners by an average of 19 ¢/kW_{inst} and 66 ¢/kW_{inst} respectively while improving thermal comfort. If just 1,000 houses adopt optimal strategies, the grid could see an average reduction in energy consumption of up to 27 MWh and 17 MWh during high-price periods in Ontario and Québec respectively.

SDEWES2022.0384

Comparison of Business Models for Building Energy Flexibility

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Abstract

Energy flexibility of buildings is getting a promising solution as further service to the Power Grid in contexts where stability, congestion and weak connection are crucial. This is the case of Geographical Islands where the strong changes in energy loads between winter and summer season highlight the drawbacks of existing connection to the mainland. Improving knowledge and characterizing the flexibility of those buildings can help the energy planning strategy as well as understand the dynamics of energy exchanges. This study analyses a building, in the Island of Procida, Italy. The results are a useful insight to plan the installation of further local renewables as well as the energy retrofiting interventions to empower such flexibility potential. The loads in the buildings are mapped and a detailed characterization is provided. Moreover, the real data of electricity exchanges between the building and the Power Grid at 15-minutes resolution are processed to identify what the potential temporal allocation of such energy flexibility is.

SDEWES2022.0399**Is the Bimtobem a Valuable Tool for Designing Energy-Efficient Ships?**

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Abstract

Nowadays, the energy efficiency of large ships attracted increasing interest because of their very high energy demands and pollutants emissions. Several studies addressed both power plant optimizations and adoptions of different emerging technologies to reduce environmental impact of ships. To achieve these goals, it is essential that advanced skills on systems energy efficiency are involved in the initial design of new ships to ensure high standards at all stages of construction. To this aim, ships designers and manufacturers need modern modelling tools to both manage the project complexity and analyse the related energy performance. Although Building Information Modelling (BIM) is a standard methodology for building design and construction, the naval industry only recently begun to adopt this tool within the design workflow. Energy design via a Building Energy Modelling (BEM) approach for the whole ship system (envelope and energy plants) is even less used, except in research projects. These shortcomings are still observed today, although both BIM and BEM could significantly improve the sustainability of ships by also simplifying the manufacturing process from design to delivery.

In this article, the new BIMtoBEM approach to ship design is presented and applied to ships for addressing the challenges of reducing the energy consumption and the related environmental impact. In order to investigate the capability of this novel ship design methodology a novel case study is also presented. It regards the modelling of a large and modern cruise ship through a suitable BIM tool (Autodesk Revit). The obtained 3D complex model (including envelope, operating schedules, and system details) was inputted into a BEM environment (OpenStudio). Here, by means of a semi-automated and swift process the energy performance of the whole system was dynamically and accurately simulated by potentially enhancing the design procedure normally based on stationary approaches. Although further research is still required to improve the interoperability among the considered software, useful results are achieved in terms of temperature, flow rate, and energy loads/demand profiles. Finally, useful optimization procedures and economic results are achieved in terms of design parameters and paybacks, respectively, of the considered innovative technologies adopted for energy efficiency purposes.

Buildings 3

SDEWES2022.0067

Parameter-Based Rule Sets for an Algorithm-Aided Bim Tool for Sustainable Building Design

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Abstract

We face the challenge of digital transformation of the construction industry and industrial housing construction and lack of integration of digital technologies in planning and construction processes for sustainable and affordable buildings. This paper addresses research conducted to provide sustainable and affordable housing within a digitized Architecture Engineering and Construction (AEC) environment. The aim is to exploit the digital potential in planning and construction to accelerate processes, optimize costs and minimize resource consumption, especially through the use of digital tools. In order to exploit the potential for improvement in these areas, research is being conducted into Building Information Model (BIM) based planning. This approach is extended by the development of an Algorithm Aided BIM tool (AABIM tool) for semi-automated building design and evaluation. With regard to the development of an algorithm based on Algorithm Aided Design (AD) and BIM in modular residential construction, this paper deals with the design-relevant basic knowledge that such tool must be able to access. For this objective, rules of residential design and construction are elaborated and transferred to an appropriate structure in natural language. With the complexity of residential buildings, however, a large number of parameters and constraints inevitably arise. This study incorporates both the explicit specification requirements at legal level and building codes and the implicit expert knowledge-based requirements for quality and use. The obtained results i) housing specific parameters, ii) constraints and iii) rule sets are based on a systematic literature and building code review and implicit expert knowledge and are processed in natural language to be subsequently implemented into the algorithm. The results of this study serve as a guideline and knowledge base for the development of the Algorithm Aided BIM tool for sustainable and affordable building information models in an early design stage. The definition of the constraints and the development of the rule sets in natural language format are the main results of this paper.

SDEWES2022.0460

Environmental Measures of Prefabricated Buildings: Insights from Two Decades of Literature

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Abstract

Implementing sustainable principles in the construction industry plays a significant role in the sustainability transformation of our communities. Advocacy of environmental protection and recognising the building industry's contribution has recently been actively promoted. Environmental measures are one of the most significant contributors to sustainability assessment. A plethora of research works has been published over the past two decades to address the environmental measures of prefabricated construction. However, a systematic review and critical analysis of the research development on the environmental benefits of prefabricated is deemed required. Therefore, this study focuses on the environmental performance assessment of prefabricated buildings during their life cycle. This research employed a comprehensive literature review of 74 related studies in the past two decades. The descriptive and thematic analyses revealed four different environmental measures: waste, GHG, energy, and use of resources materials. The mainstream literature mainly provided a qualitative study of the prefabricated concept and its environmental gains within domestic construction. At the same time, limited research focused using of resources and materials within the prefabricated buildings. Waste as an environmental parameter is significant in developing countries, while waste, GHG and energy parameters are equally important in developed countries. The findings of this study contribute to increasing prefabrication practice.

SDEWES2022.0505

Energy Conservation Measures in a Prototypical School Building Using Designbuilder

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Abstract

In this study, various Energy Conservation Measures (ECMs) for a prototypical school building are investigated using DesignBuilder (DB) building energy simulation. The school is a 2-story building and has 7286 m² total floor area with total occupancy of 478. The base case energy model of the school building was created based on the collected data from the Ministry of Education (MOE). Its Energy Utilization Index (EUI) was verified using field-measured data of the annual energy consumption from Azda and Sauda schools which had similar design and construction. The simulation results show that the implemented ECMs reduced annual energy consumption by between 0.3 to 13.5%. The maximum savings of 13.5% achieved by using efficient lighting system meanwhile minimum savings achieved of 0.3% by roof insulation. The predicted EUI was in range of 83.7% to 96.7 kWh/m²/year whilst peak Power Density (PD) is in range of 43.8 to 61.1 W/m². Furthermore, the predicted EUI and PD from the combined ECMs were 69.1 kW/m²/year and 40.1 W/m² respectively.

SDEWES2022.0551

Evaluating the Feasibility of Building Material Flows in a Circular Economy

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Abstract

The scarceness of resources, dependence on imports, and a high volume of waste are current social problems. Measures to solve these problems are represented by the waste hierarchy and, in an extended form, by the 10 Rs principle of the circular economy. One principle of the circular economy is to extend the life of products, to keep them in the material cycle as long as possible, and dispose of them only if no other way is possible. Therefore, waste management regulations require material recycling if this is technically possible, ecologically sensible, and associated with disproportionately high costs. To be able to assess this, however, requires an evaluation methodology that links these areas together.

Based on actual data of a deconstruction object, a conceptual framework for assessing sustainable circular economy potentials is applied and tested. For this purpose, a waste balance, material data, a material systematization is required.

As a preparatory measure, data collection was carried out, including the collection of the material fractions, different surveys based on as-built plans combined with material exploration, BIM model based on laser scanning combined with pollutant and contaminant exploration, and actual waste records during the demolition process. Furthermore, a survey was required to implement the assessment framework, ranging from LCA data and recycling rates to data on material reserves and financial information. Moreover, the assessment was applied based on the data collection, and the results were analyzed.

A large part of the existing assessment frameworks used for the process can be seen in EPDs. However, it is to be criticized that connecting them to digital tools is very difficult. Furthermore, not all possible material paths are usually accounted for, which makes a holistic view of the possibilities difficult. Furthermore, this refers to materials, but in demolition projects, waste is often not sorted by type. Data for extended application to be able to operate resource management, unfortunately, the data basis is missing at present (at least in a central information source).

For a serious application, it is necessary to obtain the necessary data from as few data sources as possible, all of which have been collected uniformly and transparently. This suggests that its state administration, or purely NGO, would be a suitable institution to manage and maintain. Furthermore, it is necessary to extend the here carried out ranges to be able to illustrate as far as possible all materials (and further utilization ways), to be able to represent such a decision-making aid for the entire building industry, as well as to receive with material producers a feeling for the monetarily necessary employment.

SDEWES2022.0577

Streams of Reuse of Building Elements: Case Study Analysis

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Abstract

Grounded in an ongoing research project, this paper aims at showing different flows of reuse of building elements and its requirements. For that purpose, a case study is analyzed, starting from the process of building assessment in the end-of-life stage, followed by the different possible streams of element reuse. The main objective was to determine currently existing processes and regulative frameworks for the reuse of building elements in Austria. Furthermore, in collaboration with an industry partner, to explore and determine the relevant parameters for that task, such as material quality, costs, logistics, etc.

The in-depth case study displays workflows regarding a building for deconstruction and the preparation for reuse of three selected building elements. These elements find their way into new building projects, as well as onto a company platform aimed at selling refurbished elements to customers. In that context, the relevant stakeholders and the corresponding business models are identified.

From the case study and the validation through interviews with industry stakeholders, it can be concluded that the process of reuse is bound to e.g. unclear or non-existent regulative frameworks or tender procedures, extensive knowledge of material composition and building element quality, still very few new building projects designed with reused elements. In summary, the three analyzed elements are good examples that there is no shortage of elements and materials for reuse. It requires however regulations and obligations from the legislature both on the potential building owner's side and on the client's side for the achievement of a much higher reuse rate. The potential for this is particularly evident in larger buildings due to high quantities involved and will certainly gain importance in the context of the growing need for circular building design.

SDEWES2022.0583

Efficiency Improvement of a HVAC Axial Flow Fan Through Design Optimization Study

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Abstract

Axial flow fans are widely used in many HVAC systems and required to be operated at high efficiency and wide flow capacity range. For this reason, recent R&D efforts have been devoted to the design of axial flow fan with high efficiency and performance. The present study is focused to optimize the 3D design of axial flow fan rotor blade. The present design model of axial flow fan rotor blade is to construct and stack the section profiles using single circular arc and airfoil thickness distribution with the camber and stagger angles as design variables along the blade span height from hub to tip, and the chord length distribution is designed in a parabolic fashion from hub to tip. The performance and efficiency of the fan rotor are predicted by applying through-flow analysis method. The combined model of the fan design and through-flow analysis is used as the simulation engine for optimization problem which is mathematically formulated with several fan design variables and design constraints, and the optimization technique of Hybrid Metaheuristic Algorithm is used. Through the design optimization process of the present study, optimal fan blade geometry is obtained and computational fluid dynamics analysis is conducted to verify the result of the present optimal design. From the computational fluid dynamics calculation results, the performance and efficiency of the present optimal fan are well agree with the CFD results and the present optimal fan design gives the efficiency improvement of about 2% compared to the initial design.

SDEWES2022.0596

Proposed Rc Model Structure for Estimation of Building Performance Using Limited Data

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Abstract

The greatest obstacle to large-scale utilization of predictive control in buildings is acquiring a suitable building model. Due to its interpretability and smaller training periods, the resistance-capacitance (RC) model is one of the most widely used models for buildings. However, in most cases, a modeler needs to develop a model structure specific to the respective building and approximate its parameters based on the building's physics, which is error-prone and time-consuming. This paper proposes an RC model structure to predict temperatures for various buildings based solely on four easily measured inputs. The goal of the paper is to show that this simple structure trained on a limited dataset can effectively predict internal temperatures for various inputs. Model parameters were estimated using training data for different parts of the year, namely, heating, transitional and cooling periods, to generate three models. The least squares regression and global start method were used to reduce non-convexity issues. The developed models were validated in heating, transitional and cooling validation periods, each lasting 48 hours. The root-mean-square errors (RMSE) ranged from 0.2°C to 0.8°C, indicating low-error models. The conclusion is that the proposed model structure can be used for temperature prediction without considering the specific characteristics of the building in question, as long as the limited data set is available. To some extent, the model parameters capture the building's physics. The models trained over a heating period can be used for predictions over the cooling period and vice versa, which is demonstrated by comparing prediction errors for three different validation periods.

SDEWES2022.0611

Specification Vdma 24247-7 for Monitoring the Energy Efficiency of Refrigerating Systems - a Review

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Abstract

German specification VDMA 24247 deals with energy efficiency of refrigerating systems and currently consists of nine parts. In 2011, the first version of part 7 of this specification was published. In contrast to other key performance indicators that are only applicable under certain test stand conditions, VDMA 24247-7:2011 presented an efficiency metrics aimed specifically at the evaluation of energy efficiency of refrigerating systems under real operating conditions. However, a literature review shows that little has been published on the applicability of this approach to real-world refrigerating systems until today. This lack of published data might be due to the fact that the examples and illustrations in the first version of the specification focused heavily on chiller systems (for air-conditioning applications with chilled water and thermal energy storage). However, systems used in supermarket refrigeration are often different (circulating refrigerant, without a water loop). As latter systems were not directly addressed, it is very likely that operators of such systems did not identify themselves as a possible target audience.

A second, revised version of part 7 of VDMA 24247 was published in September 2021. After a discussion of the fundamental concept based on the first edition, the new key features of the revised version will be elaborated in detail in this paper. Among these new features is the equal treatment of both indirect and direct refrigerating systems (for air-conditioning and commercial refrigeration respectively). Moreover, the authors will show how the monitoring concepts recommended in the revised VDMA 24247-7 can be applied to two real-world direct refrigerating systems of a cafeteria. These systems serve as field sites for a case study of the assessment of their energy efficiency using monitoring data.

Decarbonisation, Energy and water efficiency 1

SDEWES2022.0001

Deployment of Power-to-X and CO₂ Utilization Technologies: Synthetic Natural Gas and Methanol Production Processes

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Abstract

The need to reduce anthropogenic CO₂ emissions is of great importance in an attempt to combat global warming and climate change. In this respect, the development of a low carbon economy is of paramount importance. To reduce the global CO₂ emissions, several options can be implemented e.g., increasing the utilization of renewable energy sources, improving the overall efficiency of energy conversion and utilization routes, large-scale deployment of Carbon Capture, Utilization and Storage (CCUS) technologies. The Power-to-X technologies utilize renewable energy sources (e.g., solar and wind) to produce electricity which then is used to generate hydrogen (via water electrolysis) as a key chemical to transform captured CO₂ into valuable chemicals e.g., Synthetic Natural Gas (SNG), methanol. These technologies are seen as very promising to increase the share of renewable energy, enforce the energy storage capabilities as well as tackle the time variability of renewable energy sources.

This work is assessing the production of SNG and methanol from renewable hydrogen and captured carbon dioxide from a techno-economic perspective. The sizes of investigated systems are 500 MW_{th} for the SNG concept and 100000 t/y for the methanol concept. These Power-to-X and CO₂ utilization concepts were modelled and simulated using process flow modelling software ChemCAD being subsequently thermally integrated for optimization of overall energy efficiency. The mass & energy balances were used to quantify the key performance indicators (e.g., overall energy efficiency, ancillary energy consumption, H₂ and CO₂ utilization yields, capital and operational costs, SNG and methanol production costs, sensitivity analysis etc.). As the results show, the SNG and methanol production systems from renewable hydrogen and captured CO₂ are very energy efficient (e.g., about 50 - 55%), CO₂ conversion rates are high (about 96 - 99%) but not yet economic comparable to the existing fossil-based solutions (e.g., the production costs are about 25 - 30 €/GJ for SNG and about 700 - 750 €/t for methanol) but with the expected reduction of renewable energy prices, predicted high prices of fossil energy (natural gas), as well as the increase of carbon emission taxes, these Power-to-X and CO₂ utilization systems, can become economically promising and contribute to the development of low carbon economy.

SDEWES2022.0059**Environmental Impact Assessment of Green Ammonia Coupled with Urea Production**

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Abstract

Ammonia is one of the largest synthesized industrial chemicals being predominantly used for fertilizer production (about 85%), as a refrigerant, while also presenting optimistic perspectives as an energy carrier. The goal of the current research is to investigate from an environmental standpoint using process modelling and simulation tools, as well Life Cycle Assessment (LCA) methodology, green ammonia coupled with urea production process. Ammonia is produced following the Haber-Bosch process. The amount of N_2 is obtained from an Air Separation Unit (ASU), whereas to achieve green ammonia production, water electrolysis is employed for H_2 generation considering three different renewable energy sources (i.e., wind power, hydro power, photovoltaic), and nuclear power as a carbon free source. As a benchmark, a conventional ammonia production process coupled with urea production was considered. For the benchmark scenario, steam methane reforming (SMR) process is considered for the H_2 supply. A CO_2 rich flow obtained from carbon intensive processes (i.e., cement production, iron and steel etc.) is used for the urea production. An annual productivity of 450,000 tonnes of urea was set for all investigated cases. The results of the process modelling and simulation led to purities higher than 99% for both ammonia and urea.

The mass and energy balance data derived from the modelling and simulation section using ChemCAD software are used as valuable inputs for the environmental assessment. A cradle-to-gate evaluation is carried out by means of GaBi software. System boundaries include the following processes: i) upstream processes: N_2 generation from ASU, H_2 production through water electrolysis, H_2 generation through SMR process, electricity supply chain ii) main processes: ammonia and urea production processes, iii) downstream processes: disposal of wastes, waste water treatment etc. Details about the most important sub-processes that significantly influence the main environmental impact categories obtained using ReCiPe method, are extensively discussed.

SDEWES2022.0069

Enhancing the Post-Combustion CO₂ Carbon Capture Plant by Tuning and Setpoints Optimization of the Decentralized Multi-Loop Control System

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Abstract

Carbon capture using absorption/stripping systems is one of the most recommended technologies for CO₂ removal from post-combustion processes, due to the high capture efficiency. However, the energy penalty and reduction of solvent regeneration cost remain important challenges. Thus, control strategies are essential in achieving both operability and cost-efficiency of CO₂ removal processes, being effective in disturbance effects rejection and preserving high plant performance. Assessing the control system's performance and its consequent operation flexibility are consistently based on the dynamic simulations of the controlled carbon capture plant. Relying on a comprehensive mathematical model for a post combustion carbon capture plant and the simulation results from previous work, this paper presents and analyses a complex decentralized control system that consists of multiple control loops, along with a cascade control loop. The present work investigated the appropriate choosing of the setpoints for the decentralized control loops, using the PI tuned controllers, and targets the operation optimization by considering as performance indicators the carbon capture rate, cost and energy efficiency. Results show the incentives of implementing the proposed setpoint values for enhancing the carbon capture plant performance.

SDEWES2022.0140**Assessment of Renewable Energy Use in a Gas Fractionation Plant**

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Abstract

This paper presents the analysis and the electrification scenario of the existing gas fractioning unit. The application of renewable energy within the industrial process is one of the challenges of modern society. The transition of industrial processes from conventional boilers and heaters to electric ones makes the electricity main utility, and it can be covered by clean and renewable energy. The data extraction and acquisition are based on process simulation with UniSim Design. The method discussed in this paper utilises the process integration tools to reduce primary energy targets and assessment for transition to the power utility. Heat recovery of the process stream is maximised, and heat pump options are assessed for process stream level and distillation columns. The remaining hot utility requirements are covered by steam boilers and heaters. The cooling side is estimated for Organic Rankine Cycle application and distribution of cold utility. The case study analyses the gas fractioning unit of the petrochemical plant and electrification potential was assessed. Three scenarios are investigated, the integrated electrified scenario consumes 61 MW of power compared to the basic scenario that needs 241 MW of power. The integrated electrified scenario has the reduction of energy costs by 21 M\$/y when using power obtained from renewables. Energy targets of the investigated gas fractioning plant can be 100% covered by electricity and initial power targets reduce by 4 times with the application of process integration appliances. Energy costs are reduced by 75 % compared to fossil fuel use.

SDEWES2022.0256

Integration of Renewable Energy Systems at City Gate Stations to Reduce Pre-Heating Gas Consumption

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Abstract

The Italian Natural Gas (NG) distribution network includes thousands of NG metering and pressure reduction stations, also called City Gate Stations (CGS), for injecting gas into low-pressure networks. These plants are mainly based on the isenthalpic throttling of the gas flow to reduce its pressure, which leads to a significant reduction of its temperature by the Joule-Thompson effect. Gas preheating systems that avoid excessive cooling are installed upstream of pressure reduction valves and usually exploit conventional gas boilers. The energy consumption and carbon footprint could be significantly reduced by integrating heat pumps coupled with renewable energy sources for NG preheating to support gas boilers. For this work, an ad-hoc thermodynamic model for estimating the thermal energy demand for pre-heating is developed, exploiting experimental data from a real CGS, and simplified models of heat pumps and renewable systems. The work aims to assess the actual technical and economic feasibility of energy savings through these technologies. Results show the validated model to be sufficiently accurate to estimate the need for gas preheating for these applications. For the considered case study, up to 38%, 32% or 26% of the total thermal energy can be recovered with a PBT of less than 20 years, 15 and about 13 years, respectively.

SDEWES2022.0301

The Role of Ets in the Existing District Heating Systems Decarbonisation

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Abstract

The FitFor55 sets ambitious targets for reducing net European carbon emissions by at least 55% by 2030 compared to 1990 and for being the first climate neutral continent by 2050. EU Emission Trading Scheme has been reviewed, however participation in the EU ETS is still mandatory for energy operators with an installed capacity higher than 20 MW, but units with a rated thermal input under 3 MW shan't be considered for the purposes of calculation.

The paper highlights the ETS impact on the choice of investments by operators in the energy sector considering the current regulation and supposing ETS extension. The analysis concerns the simulation of four revamping scenarios (two fuelled by natural gas and two partially renewable) on an existing district heating system located in Italy. The economic analysis points out that the ETS extension alone is not effective enough to hinder scenarios based on natural gas production. Contextually a reform of power exchange market is necessary to drive decarbonization and favour investment in renewable generation plant.

SDEWES2022.0320

CO₂ Compression and Dehydration for Transport and Geological Storage

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Abstract

Carbon geological storage (CGS) as an element of the CCUS/CCS process is considered to be the most viable option for the storage of the large CO₂ quantities needed to reduce global warming and related climate change effectively. Storage of natural gas and partially decarbonized gas (with addition H₂) will play a vital role in the stability of energy supply in the EU. The innovative concept of the AGaStor project is based on synergy between natural gas storage and CO₂ storage process in a location near captured CO₂ emission sources (e.g. in NW Poland). The main objective of the project is to facilitate the implementation of advanced Underground Gas Storage (UGS) using dynamic support of Carbon Dioxide Cushion (CDC) in saline aquifers. The purpose of research was to investigate the main technologies of CO₂ capture, separation and dehydration as well as methods of its transport and methodology of selecting a suitable geological storage site. An installation of dehydration and compression of carbon dioxide captured after the post – combustion was designed at a temperature of 35°C, a pressure of 1.51 bar and a mass flow rate of 2.449 million tons / year assuming that the geological storage site is located 30 km from the capture place. For the dehydration process, a multistage compression and cooling system was applied, combined with a triethylene glycol dehydration unit. The diameter of the transport pipeline and the pressure drop were simulated. The amount of energy needed to power the designed installation for 25%, 60% and 100% of its load was tested. The pressure and temperature distributions values for different variants of the number of compression stages used in the compression and colling system were analyzed.

Acknowledgments:

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SDEWES2022.0528**Analysis of the Valorization of Steel Mill Off-Gases into Added-Value Products. A Life Cycle Perspective: Current Status and Gaps**

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Abstract

The steel industry is responsible for about 20% to 25% of all industrial CO₂ emissions in the European Union (EU)¹. In this context, the Clean Steel Partnership (CSP) aims to reduce CO₂ emissions from EU steel production by 80-95% compared to 1990 levels by 2050². To achieve this goal in the steel industry, two main decarbonization pathways can be followed: Carbon Direct Avoidance (CDA) and Smart Carbon Usage (SCU). The latter consists of ways to use carbon from steel production for other applications via carbon capture, utilization, and storage (CCUS) and process integration (PI)¹. Following the SCU pathway, this work provides a systematic literature review of Life Cycle Assessment (LCA) studies on the valorization of steel mill off-gases into added-value products. Keywords such as “steel mill”, “CCU”, and “LCA” were applied in the main search-engine databases. A total of 6 peer-reviewed papers, from 2013 to 2020, were found in the literature. The defined goal of the studies relied on assessing the potential impacts of the CO₂-based fuels/chemicals and comparing them with the corresponding benchmark. Two main off-gases valorization routes were found: methanol and ethanol production. The Basic Oxygen Furnace Gas was the most common feedstock utilized for fermentation processes, while the Cokes Oven Gas and Blast Furnace Gas were used for the metal catalyst conversion processes. Regarding the LCI modeling principle, the attributional approach was applied in all studies. Cradle-to-gate system boundaries were selected for most of the assessments, and system expansion by the “basket of products” and substitution approaches were applied to handle the multi-functionality of the systems. The studies were only focused on fuel production; however, other applications such as microbial protein³ for food and feed can be found in the literature. Another current gap is the limited number of peer-reviewed papers in the literature and the lack of analyses comparing different CCU alternatives through a life cycle perspective. In this sense, the present work highlights the need for assessing and comparing the potential environmental impacts of the different pathways of valorizing the steel mill off-gases (e.g., fuel, chemicals, feed, and food). Future research should also address the implications of the added-value products’ final application in order to provide decision support for potential alternatives.

SDEWES2022.0546**Valorisation of Steel Mill Off-Gases into a Novel Plasticiser Through Chain Elongation: Prospective Life Cycle Assessment**

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Abstract

Nowadays, one of the greatest challenges for the steel industry is the decarbonisation to decrease its pressure on the environment. For this purpose, carbon capture and utilisation (CCU) technologies are being developed, which valorise steel mill off-gases (SMOG) and produce high value products. With these new CCU technologies however, certain impacts are associated that need to be identified properly. In this study, a prospective gate-to-gate hotspot analysis was performed of a new CCU value chain valorising SMOG into a novel plasticiser through syngas fermentation and chain elongation (scenario 'PLAST'). As the technologies of this value chain are still under development, scale-effects were included. The results were compared with two other valorisation pathways: incineration of the SMOG with electricity production (scenario 'ELEC') and syngas fermentation for the production of ethanol for use as a fuel (scenario 'ETOH'). The results of the analysis show that the climate change impact of the ELEC scenario is the lowest, followed by the ETOH scenario. The new PLAST scenario has the highest climate change impact (1946, 2191 and 2289 kg CO₂-eq. per ton of steel mill off-gases for ELEC, ETOH and PLAST, respectively). The biggest contributors to the higher impact of the new value chain are its electricity consumption and chemicals consumption, especially K-acetate and the used polyol. A sensitivity analysis, however, shows that the assumed electricity mix has a major influence on the results. Overall, the new value chain shows great potential because of its ability to replace a traditional fossil-based plasticiser. Therefore, several improvement opportunities were identified for the new system, such as changes in process configurations and increases in caproic acid productivity. These could lower the environmental impacts and allow to fully exploit the potential of the new value chain, and should therefore be the focus of future research.

SDEWES2022.0607**Benefits of Material and Heat Integration of CO₂ Mineralization in Industrial Clusters: Modelling, Simulation and Optimization Approach**

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Abstract

Long-term CO₂ sequestration technologies need deployment, helping industrial sectors to reach ambitious emission standards. Mineral carbonation, a process in which CO₂ reacts with metal-oxides forming stable and insoluble carbonates, is a promising pathway to deliver net-negative emissions. The formed carbonates, having a potential market value, can be used to encourage mineralization adoption. In this work, we quantify the economic and environmental benefits of integrating direct and indirect mineralization in different industrial clusters, by exploring mass and heat integration. The work was developed in three stages: (i) a dynamic simulation model, using thermodynamic and kinetic equations for CO₂ mineralization, providing the time of reaction, heat loads and mass flows to the next stages; (ii) superstructure models development, using a black-box approach to simulate the different process units (i.e. CO₂ capture, feedstock preparation, mineralization reaction, industrial process and utility system); (iii) an optimization tool (based in a mixed-integer linear programming formulation) to identify sectors and mineral feedstocks that minimize cost and emissions.

Two industrial sectors, waste incineration and cement production were used to showcase the applicability of the model. Different types of mineral ores (i.e. feedstocks) were considered: serpentine, olivine and wollastonite. Results show how mineralization can be successfully integrated into reducing and achieving net-negative emissions, by leveraging industrial waste heat and profiting from a readily accessible (and free) solid residue. Nevertheless, the required investment is non-negligible: a CO₂ tax can be used to favour mineralization and was computed for both sectors; values range from 60 to 90 \$/ton CO₂ for cement and between 120 to 200 \$/ton CO₂ for waste incineration. Break-even values for carbonated products are estimated at 100 \$/ton.

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SDEWES2022.0338

The Pulp and Paper Industry as an Active Contributor of the Future Energy System

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Abstract

Pulp and paper mills are known to convert large amounts of biomass, usually being net exporter of energy in form of electricity. As wood is a limited resource, its efficient conversion is crucial to a sustainable future. In the future energy system, a shift from fossil energy carriers to renewables is likely to generate uncertainties in electricity supply, causing miss-match of demand and supply. Simultaneously, the transportation sector; especially the hard-to-electrify freight transport; is seeking options to become carbon-neutral.

This paper aims to analyze the potential of pulp and paper mills to assist closing demand and supply gaps in the energy system, while co-producing pulp and liquid fuels from biomass, intensifying the exploitation of the biomass.

For this purpose, a conventional Kraft pulp mill is integrated with thermo-chemical conversion processes in which residuals of the pulping process are converted to fuel. Furthermore, the integration of power-to-fuel and fuel-to-power units is enabled to contribute to the flexibility of the energy system and enhance additional fuel production in times of an oversupply of electricity.

For improving the carbon balance of the mill further and enabling net-negative emissions, carbon capture, utilization and storage systems are included in the analysis. The system is modeled as a mixed integer linear programming problem, including mass and energy integration between units.

The mathematical model is formulated in the AMPL language and the CPLEX solver is used for optimization. The problem is analyzed in a multi-time scope, considering annual variations in electricity prices and environmental impact.

Multi-objective optimization is coupled with systematic solution generation and exploration approaches in order to identify promising configurations that are economically competitive, robust regarding market variations, and able to provide flexibility to the energy system by acting not only as a consumer of energy, but also a supplier of fuel and energy when needed.

Preliminary results show that the simultaneous generation of pulp and fuel coupled with mineralization of captured biogenic carbon dioxide holds potential of being profitable for the mill operator under a variety of market conditions, while unburdening the energy system by providing required resources and storage capacities when necessary.

SDEWES2022.0340**Identifying the Foremost F-Gas Refrigerants for Vapor-Compression Technologies**

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Abstract

Fluorinated gases (f-gases) used for refrigeration have a global warming potential as high as 12,000 kgCO₂-eq (for e.g., HFC-23). These are key to climate mitigation discussion as f-gases are critical to delivering the surging demand for air conditioners which is expected to triple by 2050 and are targeted by international policy agreements such as the Montreal Protocol and Kigali Amendment. Given their increased use as cooling demand soars, can we identify the climate-optimum f-gas for use in cooling technologies? This paper examines the metrics used to account for the carbon footprint of f-gases which are used as refrigerants for cooling. F-gases exacerbate atmospheric warming when leaked from cooling equipment, or during other phases of their life-cycle. Thus far, the way these gases impact global warming is mostly reported based on their CO₂-equivalent emissions with a time horizon of 100 years. However, the problem is that f-gases have significantly different lifespans and the Global Warming Potential (GWP) of 100 years metric does not account for these variations. We address this with a critical review of the available metrics for carbon foot-printing of f-gases, and present a gap analysis between the existing carbon foot printing metrics and the need to better understand warming from f-gases. Next, we exemplify the application of the incumbent metric (GWP₁₀₀) in the estimation of emission by using an atmospheric model, whose preliminary results show the challenges that current metrics pose. The model shows profiles of atmospheric concentration, radiative forcing, and temperature, after three set scenarios in the release of a illustrative f-gas (HFC-134a). Scenarios A models the response to a positive step change in emissions, while Scenario B is the inverse. Scenario C models a reduction of 85% by 2036 of emissions according targets for high-emitting countries set in the Kigali Amendment. The results compare the atmospheric contributions of set emissions of HFC-134a to its CO₂ equivalent-emissions (using GWP₁₀₀). The paper offers insights into which metric can identify the best f-gas in terms of reducing global warming in a rapid timeframe, and its policy implications.

SDEWES2022.0427

Improve Energy Efficiency in Shipping via Optimum Design of Propeller Boss Cap Fins

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Abstract

This project is to cost-effectively improve the energy efficiency of large vessels in shipping by optimum design of propeller boss cap fins (PBCFs). First, a modern four-blade controllable pitch propeller in a Ro-Ro ship, with no boss cap fins in its original design, is experimentally and numerically investigated based on a down-scaled model. The computational fluid dynamics (CFD) model reproduces all the experiments very well. Then, the CFD model is used to conduct a comprehensive optimum design of PBCFs for the down-scaled propeller. Besides the widely used rectangular PBCFs, nine airfoils, which see successful applications in maritime industry such as constructing propellers and rudders but are rarely used as PBCFs, are investigated, due to their favorable lift/drag ratio and great potential of being effective PBCFs. Among the ten shapes, the best performing profile is chosen as the PBCFs for further optimization. Finally, the optimum design of the PBCFs for the propeller/rudder system is achieved, in terms of the profile, sizing and installation. The optimum design of the PBCFs is found to yield remarkable efficiency gains for the modern propeller/rudder system under both design and off-design operation conditions, mainly due to the suppressed hub vortex and partly due to the extra thrust. The yield strength analysis of the optimum design confirms that it is feasible in practice and can be used in industrial vessels. The generalized criteria for the optimum design of PBCFs can benefit other propeller/rudder systems for cost-effective energy saving.

SDEWES2022.0483

Policy Instruments for CO₂ Valorisation Support

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Abstract

Mitigation of CO₂ emissions has become a top question in international and national arenas, likewise on the city level. Existing CO₂ mitigation measures are primarily oriented towards wider deployment of low-carbon technologies of renewable energy sources and energy efficiency measures, focusing on energy production, distribution, and energy use sectors, transport. In the recently announced European Green Deal strategy, response action on climate and environmental protection challenges for Europe 2050 is set. The strategy targets "to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use." To reach this ambitious target, rapid and intelligent solutions are needed, which beyond others requires converting to profoundly transformative policies. An evident-based multi-sectoral forecasting model must be timely and effectively deployed to initiate and maintain such transformative policies. The purpose of this work is to analyse existing laws, regulations, and directives, both local and European, to identify limiting factors and factors that contribute to a more active introduction of systems for capturing, using, and/or reducing the amount of carbon dioxide created in production processes. The work results give an idea of how developed countries' laws are regarding carbon dioxide emissions - its capture, storage, and/or utilisation. At the time of writing, the most extensive legislative framework is represented in Belgium, Croatia, Lithuania, and Sweden, the least – Ireland, Cyprus, and Greece. Analysing the legislation of the countries of the European Union, it was concluded that Sweden's most extensive issue of CO₂ emissions, storage, and utilisation had been worked out.

SDEWES2022.0487

An Approach to Integrated Resource Efficiency Management in Medium Sized Chemical Companies

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Abstract

The transformation of complex production systems and processes towards sustainability poses a challenge, especially in medium-sized companies. Nevertheless, many medium-sized enterprises are already implementing environmentally relevant measures (use of energy and environmental management systems, installation of photovoltaic systems, construction and operation of heating networks, implementation of energy efficiency measures). More complex approaches, however, remain unused, so that existing potential for reducing greenhouse gas emissions, energy and material demand as well as costs is not exploited. A concept for an overarching approach to facilitate the implementation of more comprehensive efforts is missing. The objective of our research is thus to develop a concept for integrated resource efficiency management to make a substantial contribution to circular economy, climate protection and the energy transition.

Taking medium-sized companies from the chemical sector as an example our approach systematically addresses the potentials for circular economy and the associated potentials for energy and resource efficiency by

- analyzing and assessing the companies and their internal processes and products with regard to the challenges posed by the circular economy, energy transition, and environmental and climate protection, and
- deriving and evaluating internal and external action options and improvement measures for circularity.

The development, application and validation of our approach for integrated resource efficiency management is subject of an ongoing research project funded by the German Federal Ministry for Economic Affairs and Climate Change. We build on case studies at two medium-sized company of the chemical industry (Buzil-Werk Wagner GmbH & Co. KG and Münzing Chemie GmbH) with the objective to prepare and to communicate the obtained results in a transfer oriented matter. First analyses targeting the reduction of greenhouse gases (GHG) show, that the production processes at the companies themselves show potential esp. with regard to implement increased energy efficiency, but regarding resource efficiency and the accompanying GHG the supporting functions require attention: e.g. liquids purchased in one way canisters constitute a valid starting point for circular strategies over several companies as they contribute substantially to the greenhouse gas balance.

SDEWES2022.0560

Internal Carbon Pricing Mechanism of Wood Procurement in Forest Industry

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Abstract

The internal carbon pricing is used to manage the risks in wood procurement of integrated material and energy production after wood import ended from Russia. Further, the European Union announced plans to sell more carbon emission permits to fund European Union's exit from Russian energy. Therefore, new internal carbon pricing mechanism is developed for wood procurement optimization. Particularly, the effects on the changes are considered in relation to available forest carbon sink. The results of the new scenario were compared to the basic scenario of renewable carbon sink of carbon-neutral forestry. The internal carbon pricing mechanism provides the optimum wood-procurement operations maintaining a carbon neutrality in the industry. The experiments' results revealed that the mechanism could consistently and significantly outperform the solution adopted by the company prepared in terms of economic costs. As a conclusion significant increase in profitability are possible if size of wood procurement area is allowed to vary in respect to transport distance to take optimal advantage of the renewable forest carbon sink.

SDEWES2022.0602

Development of Digital Twins to Optimise the Industrial Process Parameters in the Rubber Industry Considering the Energy Vector as a Key Input Data

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Abstract

This work focuses on the manufacturing of sealing systems for the automotive industry, particularly on the co-extrusion process of the EPDM rubber. The objective of this work is to make the extrusion lines more flexible to adjust the production schedule by including energy parameters such as energy price and associated CO₂ emissions, as well as local availability of PV self-generation. A real-time Digital Twin (DT) is developed, which allows virtually reproducing the industrial processes, applying explainable artificial intelligence (XAI) techniques. Multi-physics models of the processes are built by combining Computational Fluid Dynamics (CFD) and/or Finite Element Methods (FEM), which are then transformed into real-time models using Reduced Order Modelling (ROM) techniques. This methodology provides both physical sense and accuracy resulting in robust models. The developed DT allows not only for analysing the industrial process response on product quality when changing parameters but also to predict and help minimise energy usage.

SDEWES2022.0610**Decarbonisation of Glass Melting with Hybridisation**

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Abstract

In an effort to combat climate change, the European Union (EU) set to become climate neutral by 2050. This implies that energy intensive sectors, such as the glass industry need to start innovating now, as 2050 is only 3 furnaces away. The premium glass producer, Steklarna Hrastnik (SH), as one of the frontrunners in decarbonisation of glass manufacturing, plans to demonstrate a first-of-a-kind hybrid end-fired regenerative furnace with a more than 40% electrical melting share and throughput capacity of 170 tons of glass per day. The furnace will replace the existing end-fired regenerative furnace for extra-white flint glass production. Due to the high-quality requirements and small series needed for luxury goods (spirits, perfumery), which require a high pull flexibility, the hybrid regenerative furnace concept was chosen over conventional low carbon technologies. Namely, the hybrid furnace makes it possible to use a high share of carbon neutral energy sources, while maintaining the operational flexibility of conventional regenerative fossil-fuel furnaces, both in terms of output flexibility as well as cullet rate.

In this paper, the end-fired hybrid regenerative furnace concept is presented and compared against the current state-of-the-art glass melting technologies. Different hybrid operation strategies are evaluated in terms of energy consumption and efficiency as well as greenhouse gas (GHG) emissions, considering various scenarios for electricity generation. Depending on the carbon intensity of utilized energy sources, the hybrid regenerative furnace presents a viable option to decarbonise the container glass sector. The increased electrification enables to align the glass melting process with the availability of renewable energy sources (RES) and opening-up glass manufacturing to provide ancillary services. Furthermore, the possible shifting in energy source share represents an unprecedented degree of adaptability to changing energy markets and geopolitical conditions, without endangering the manufacturing process and, thus, jobs.

SDEWES2022.0621

Development of a Virtual Battery Concept Demonstrator: a Case Study from the Pulp and Paper Industry

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Abstract

Energy intensive industries face the challenge of reducing carbon emissions while remaining competitive in the market. An energy transition from a fossil driven energy system toward renewable energies and a reduced energy consumption are key parameters to meet carbon neutrality by 2050. However, the integration of fluctuating renewables such as solar energy is challenging, since industries must adapt their current consumption and production patterns.

This study introduces the virtual battery concept (VBC), demonstrated in the pulp and paper industry. The VBC utilizes flexibility options of electricity and heat aligned to the regional electricity generation/demand. The analyzed pulp and paper plant acts as a virtual battery. On the one hand, it integrates and utilizes excess electricity from renewable sources (mostly PV) and from the public grid in times of high generation (e.g. in summer). Consequently, fossil-based generation from the on-site combined heat and power (CHP) plant is substituted. On the other hand, electricity with the on-site CHP plant is provided in periods of lower energy generation (e.g. winter). As an additional system benefit, bottlenecks in the transmission grid are avoided and grid stability is increased.

The analysis of the configuration of the pulp and paper plant as virtual battery is followed by the evaluation of possible new commercial assets and technologies to be implemented for the overall functioning of the system to enhance flexibility of the production site. The analysis is based on (i) existing power flexibilities, (ii) existing power and heat facilities, and (iii) existing power and heat facilities and new assets. Consequently, the flexibility potentials both at process level as well as in the energy supply chain are evaluated and the most promising technologies are selected. Life cycle assessment is used to evaluate the ecological impact of the measures.

Acknowledgement

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District heating and/or cooling/Thermal power plants

SDEWES2022.0093

Modelling of a Prosumer's Substation in a District Heating Network: Validation and Dynamic Analysis

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Abstract

Thermal grids will play a key role in the development of local energy communities and the achievement of 100% renewable societies. However, challenges are related to the capability of dealing with the increasing number of producers which could supply heat to thermal grids. Indeed, as in the case of the electricity grid, heat could be available for some hours in a day from RES plants installed at user level and distributed in the network (also referred to as “prosumers”). To achieve more reliable results when performing energy analyses of these innovative applications, there is a need to rely on accurate models of each component. For instance, substations are of paramount importance in the interaction of prosumers with thermal grids. These systems must properly exchange heat with the network according to the prosumer demand and production while complying with grid constraints. In this respect, there is a need to develop models of prosumers' substation, which accounts for technical details (e.g., connections, heat exchangers, valves, etc.) and controls. Starting from the layout of a bidirectional substation for a thermal energy network proposed in the literature, this paper proposes a dynamic model that replicates the experimental setup in the TRNSYS environment. Simulations are performed to validate the model. The results show a good matching between experimental and simulated results in terms of dynamic behavior and energy balance. To show the capabilities of the proposed model, a prosumer with heat available from solar thermal collectors installed onsite is considered as a case study. Results show that almost 13.8% of the heat produced by the prosumers is exchanged with the grid. It is worth noting that the validated TRNSYS model will support studies on the feasibility of Thermal Energy Communities in existing systems, to develop strategies for energy-efficient and cost-effective operation and monitoring the performance.

SDEWES2022.0233**Computing the Potential of Green Heating in District Heating Networks**M. Schindler^{*1}, L. Gnam², M. Puchegger³, P. Jasek¹¹Forschung Burgenland GmbH, Austria; ²FH Burgenland, Austria; ³Research Burgenland GmbH, Austria (*markus.schindler@forschung-burgenland.at)**Abstract**

In order to achieve the climate targets of the European Union e.g.: reducing greenhouse gas emissions to at least 55% below 1990 levels by 2030, it is necessary to massively expand renewable energy sources (RES). However, the major problem with some types RESs is their highly fluctuating production output, where production peaks potentially lead to grid and market instabilities. In Austria, electricity generated by RESs is currently subsidized by the OeMAG, the Austrian settlement agency for green electricity, with a fixed feed-in tariff. However, this tariff is limited in time with 13 years, resulting in numerous challenges for these production units after this subsidy period. However, recently the Renewable Expansion Act was put into force, enabling different market premium and tendering models in Austria. These incentives shall now boost the development of novel business models for the marketing of energy stemming from RESs. To adapt not only the electricity sector in order to achieve the ambitious target of creating an emission-neutral energy system, but to include other sectors (e.g. heating) as well. The heat sector is a common option for a so-called sector coupling, where power-to-heat technologies connect the electricity sector with the heat sector. Hence, the created hybrid energy network can provide storage effects to the highly volatile production characteristics of RESs. Based on a real existing heating network in the federal state of Burgenland, Austria, which is currently operated by a biomass plant and a wind farm, a mixed-integer linear program is modelled. In addition, sector coupling by means of a heat pump is incorporated into the model. To achieve the optimum energy yield, there are two different operating modes: In summer, the heat pump obtains the energy from its surroundings; in winter, the energy is additionally obtained from the biomass power plant by means of flue gas condensation. In order to evaluate different hybrid energy network configurations, simulation studies based on mixed-integer linear optimization models, formulated with Pyomo and solved with Gurobi, were conducted. The input data for the optimization runs are on the one hand the heat demand data from cities located in the state of Burgenland, Austria, and on the other hand the production characteristics of wind turbines in their vicinity. All conducted optimization runs aim at minimizing the total net cost of the evaluated network configuration. The provision of green heat, i.e., heat energy produced by heat pumps powered by wind energy, yields to opportunity costs, based on the day ahead prices.

SDEWES2022.0257

Experimental Investigation of Water Washing Effect on High-Chlorine Coal Properties

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Abstract

ShaErHu (SEH) coal in Xinjiang province of China, with a reserve of 90 billion tons, is one of the most representative high-chlorine-alkaline coal. The chlorine content in raw coal can exceed 1%, which leads to severer corrosion during its combustion in the furnaces. Although water washing pretreatment technology can effectively remove chlorine, but it influences the coal quality. This paper focuses on the characteristics of inorganic elements and organic matter in filtrate from water-washed coal. Furthermore, the combustion and ash migration characteristics of the SEH coal were studied at three different temperatures (550°C, 700°C, and 815°C), before and after washing. Result show that water washing can remove approximately 80% of the Na and Cl elements and some of the organic matter. The extracted organic matter is primarily aromatic compounds, accounting for more than 75% of the total organic matter. In raw coal, Cl is mostly existed in the inorganic components, accounting for 82.82% of the total, whereas in wash coal, it is mostly present in the organic components, accounting for 70.98% of the total. The alkane structure and -OH group are more prominent in water-washed coal than in raw coal. The combustion properties of SEH raw coal can be improved by pretreatment with water. When the temperature of the muffle furnace rises above 700°C, the Na and Cl of SEH raw coal release 99.6% and 92.8 %, respectively, whereas washed coal cannot release nearly all the inorganic elements.

SDEWES2022.0258

Integrated Thermodynamic and Electrical Modeling of a Reversible Variable-Speed Air-to-Water Heat Pump

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Abstract

Variable-speed reversible heat pumps are increasingly adopted for space heating and cooling in residential and tertiary sectors. It is recognized that these systems will play a key role in medium- and small-scale 4th generation district heating and cooling networks. Indeed, with the high penetration of intermittent renewable energy sources, such technology could help reduce issues related to the surplus of electricity from renewable energy sources by converting it into heat or cold. To reliably assess the benefits achievable in these emerging applications, it is necessary to develop models which can simulate not only the steady-state operation but also the dynamic response of the system with various boundary conditions (e.g., users' demand, environmental conditions, etc.). However, heat pump operation is usually assessed by highly simplified models, which consider a Coefficient of Performance value available from the producer at fixed rating condition (eventually corrected to account for off-design operation), being the electrical modelling and embedded controls usually omitted. This paper aims at filling this knowledge gap. Starting with a reversible heat pump operating in cooling mode, this paper developed an integrated thermodynamic and electrical modeling, while considering details on refrigerant circuits, electrical motor, and embedded control. Results showed that the model can simulate the transient and steady-state operation of variable-speed chillers coupled to an induction motor, and the chilled water temperature set-point was duly maintained. Results give a full insight into the electrical and thermodynamic aspects while accounting for the effects of the inertia of the hydronic circuit on the COP of an air-cooled. Results present a faster 2% settling time for low values of inertia that serves the hydraulic system with a high overshoot for water temperature.

SDEWES2022.0282

Thermal Oxidation of Degradation Products from Thermoplastic Polyvinyl Alcohol: Determination on Oxidation Temperature and Residence Time

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Abstract

The degradable protective articles made of thermoplastic polyvinyl alcohol (TPVA) are widely used in nuclear power plants, and they are thermally decomposed after use to reduce solid waste. However, in the real decomposition of TPVA, the temperature in the oxidation reactor is not self-sustaining; as a result, the degradation products contain a lot of CO, resulting in more pollution and energy waste. In this paper, jet stirred reactor (JSR) and CHEMKIN software were used to study the reaction kinetics characteristics of the oxidation process of degradation products from TPVA in the range of 550 to 700 °C. Both experiments and kinetic simulation show that a higher average temperature of the oxidation reactor is needed to achieve lower CO emission. When using 5% or 10% TPVA degradation solution, the average temperature in the oxidation reactor should not befall below 625 °C or 675 °C. The combination of research findings and engineering practice provides great help to the optimization of the actual work process.

SDEWES2022.0302

Thermodynamic-Based Cost Allocation Criterion in District Heating and Cooling Network in Presence of Distributed Energy Producers

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Abstract

Thermal grids are well-established technologies that can cover the thermal demands of buildings in a more sustainable way. The lower operating temperature will allow not only for the integration of heat produced by thermal renewable energy sources but also for the storage of surplus electricity from the grid using power to heat technologies. To ensure a wider diffusion of this technology, it is important to propose a method for the cost allocation among producers connected to the grid. In this regard, this paper proposes Exergoeconomics as a possible solution. To show the capabilities of the method, some operating scenarios are compared for a cluster of five buildings in the tertiary sector interconnected by a thermal grid, where heat is produced by a cogeneration unit, heat pumps, and an industrial process. Thanks to the exergy and exergoeconomic unit costs, insights into the cost formation process of the heat consumed by users are provided. Results indicated that the substitution of the cogeneration plant with a centralized heat pump and waste heat could reduce the unit exergy cost of the heat supplied to the users. In addition, the analysis revealed a great sensitivity of the heat unit cost to the price of the waste heat recovered from the industrial process

SDEWES2022.0385**Energy, Economic and Environmental Analysis of a Geothermal-Based Energy Community Equipped with Heating and Cooling Network Coupled to an Organic Rankine Cycle Plant: the Geogrid System**

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Abstract

The Renewable Energy Directive of 2018 pushes for the diffusion of renewable energy communities, introducing the possibility of thermal and electric energy sharing. Despite that the large number of developed energy communities and countries transposition are focus only on electricity. One of the most energy-demanding sector in Italy is the civil sector which includes the residential and tertiary sectors (for commercial or office use). In this sector the energy communities can be defined by using the district heating and cooling (DHC) technology for thermal energy sharing, that is one of the pioneers towards carbon neutrality as it allows to increase energy efficiency and decrease primary energy supply. Innovative technological concepts such as renewable integration in heating and cooling supply grids, sector coupling and waste heat utilization allow reaching new goals towards the complete phase out of fossil fuels.

Recent studies showed that geothermal energy is a renewable energy source that must be used and preferred to other forms of renewable energies due to its low environmental impacts.

Campania Region has a high geothermal energy potential. As part of the GEOGRID research project, funded by the European Community through the Campania Region, the site in the Agnano district was chosen for the design of a four-pipe district heating and cooling network coupled with an Organic Rankine Cycle (ORC) plant: The GeoGRID system. The system supplies the electric, cooling and thermal energy demands of a small community consisting of eight multi-user buildings, using the geothermal energy source in the Solfatara area. The geothermal fluid is firstly used to supply the ORC evaporator and then thermal network. The configuration of the system allows direct space heating and Domestic Hot Water (DHW) production during the winter. During the summer the system guarantees the air conditioning of buildings by using an absorption chiller feed by the DHC network. The system is modelled through different energy tools that allow the dynamic simulation of the chosen configuration. Buildings and plants are modelled and simulated by means of TRNSYS 17 simulation software; while ASPEN model was used to estimate the parameters of the ORC plant.

A techno-economic analysis has allowed to evaluate the energy potential extractable from the geothermal fluid, the ORC electric energy production, the pressure and dissipated heat losses of the network layout. The analysis has concerned calculation of community efficiency indexes achieved in renewable energy community configuration and from individual buildings in terms of quantity of electricity imported, exported from/to power grid and consumed on-site. Also, the advantages of thermal sharing have been defined.

SDEWES2022.0593**Modeling Milling and Drying Process of Raw Coal in Fan Mill – Part 1:
Characterization of Coal Particles Movement in Fan Mill Impeller**

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Coal preparation system in case of firing lignite at thermal power plant is mainly consisted of high speed impact mills (hammer or fan mills) designed to perform efficient milling and drying of raw coal in order to significantly reduce moisture content and median diameter of particles leaving milling facility. Modeling of such complex rotating two phase flow includes processes of mass, impulse and heat exchange between phases as well as interaction of coal particles with flow domain boundaries. In general, on the basis of performed researches it can be stated that dissolution of single particle caused by impact on solid surface depends on intensity of cohesion forces inside particle structure and relative velocity of particle in respect to surface during contact. The aim of this part of research is to identify conditions under which contacts between solid phase and rotating impact plates mostly occur. In order to observe coal particles movement CFD calculations of two-phase flow for the geometry model of operated fan mill within TPP “Nikola Tesla”, Unit B, have been performed. Two-phase flow has been treated by use of CFD-DPM approach. Inlet boundary conditions has been set according to the measurements performed on concerned fan mill. Breakage phenomena has not been considered while contacts between solid phase and flow domain boundaries have been modeled by use of hard sphere model. Restitution coefficients has been adjusted so the movement of solid phase corresponds to the wearing pattern of impact plates. After performed calculations pattern of solid phase movement has been examined. Zones with lower and higher solid phase concentration in flow domain has been detected. Relative impact angles and relative impact velocities of coal particles in respect to the rotating impact plates during contact of these two entities has been identified. Additionally, kinetics of drying process used in calculations has been evaluated by use of measured moisture content in coal dust at milling plant outlet. Based on results of this study in next phase of research identification of coal particles breakage function in mill impeller will be performed. Given conclusions in this paper may be of importance for considering mill geometry modification for the purpose of increasing overall milling operating efficiency.

Energy policy 1

SDEWES2022.0145

Strengthening Energy Resilience with Smart Solution Approach of Rural Renewable Energy Communities

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Abstract

The ongoing massive energy transition to reach carbon neutrality by 2050 means a significant shift towards decentralization, energy efficiency, and active involvement of citizens and communities in the energy system as consumers and energy producers (known as prosumers). Achieving the objectives of the European Green Deal and Fit for 55 package requires a holistic approach, not only partial changes in traditional economic sectors. Each solution has to serve the meeting of several targets; it must be multi-purpose. Thus, biomass may not only play the role of a renewable energy source but also serves carbon sequestration, biodiversity promotion, soil protection, the resilience of local communities, and energy self-sufficiency.

The global COVID-19 pandemic has shown the need for overall society resilience, enabled much better than before by innovative and eco-friendly technologies, digitization as the primary tool for change in all areas of public life, including traditional industry sectors, energy production, and distribution. The SMART Czechia concept is based on a holistic approach to the territory of the Czech Republic with a huge number of municipalities and relatively low population density. The whole territory can be viewed as an organism – a city using smart technologies, distributed solutions, and decentralized energy sources, attaining an overall increase in resilience and quality of life. Citizens are allowed to participate in discovering opportunities for community development.

This study represents a contribution to the synergy of the Citizen Energy community using the SMART Czechia concept. The increase in overall resilience is verified on the model of local and self-sufficient provision of thermal energy supply in a smaller rural area. These areas are most at risk of energy shortages and the potential for future energy poverty of their inhabitants due to the planned widespread decommissioning of coal as an energy fuel. The local energy community independently produces alternative pellet biofuel, from the initial cultivation of young woody plants to the final production of ecological wood-based fuel with a calorific value of 16 MJ / kg. The proposed innovative method of heat production leads to environmental benefits, energy savings, reduced payments for energy supply, and overall modernization of the technologies used. Short-rotating plants contribute to carbon sequestration during growth and are selected to promote biodiversity in the area.

SDEWES2022.0275

Systematic Proposal of Measures Against Energy Poverty at a District Level in a Mediterranean City. Actions on the Energy Quality of Dwellings

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Abstract

This research aims to contribute to an inclusive Carbon Neutral Districts or Positive Energy Districts planning. The proposed method for reducing residential GHG emissions combines the estimation of fuel poverty and its most influential variables. Furthermore, the energy quality of the buildings is being studied and parametrised. Crossing both models the preferred intervention actions to mitigate energy poverty are identified.

The method is applied at the district level in Valencia. The findings include the estimation of fuel poverty in the district and the analysis of the relative importance of the fuel poverty variables. In parallel, the authors have classified the energy quality of the dwellings and have elaborated a list of interventions to decarbonise a city's district and fight energy poverty. Finally, cross-checking the models, the proposals that will contribute the most to mitigating energy poverty in the district are determined, among those devoted to the decarbonisation of the city.

SDEWES2022.0277

A Methodology to Characterize Energy Consumption in Smes at National Level in European Countries

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Abstract

The 25 million of European small and medium enterprises (SMEs) represent 99% of businesses and account for the two thirds of the jobs and a half of Gross Domestic Product. Thus, SMEs are considered as the backbone of European' economy. The crucial importance of energy efficiency and its potential in SMEs is worldwide recognized.

Public reports and database regarding SMEs are very detailed in terms of economic features. However, information regarding the energy use and consumption of SMEs is very limited and the disaggregated data between SMEs and large enterprises (LEs) are not available at national or European level.

The aim of this work is to present a methodology for the energy consumption characterization of European SMEs at national level, developed in the framework of LEAP4SME H2020 project.

In order to achieve this goal two main data sources have been analyzed. On the one hand, Member States provide to Eurostat detailed energy statistics which are complemented with environmental-economic accounts. Specifically, the global characterization of all the economic activities have been carried out from National Energy Balance (NEB) and Physical energy flow accounts (PEFA). On the other hand, the consumption of large companies can be evaluated from the national Energy Efficiency Directive (EED) databases. Specifically, art.8 of EED establishes the obligation for all LEs to carry out energy audits (EA) every four years.

The methodology has been developed and applied to Italy and Austria, where the National Energy Agencies (ENEA and AEA respectively) manage the national mandatory energy audit mechanism. Preliminary results show significant differences in the relative weight of SMEs' energy consumption between the two countries mainly due to their specific productive structures. A detailed analysis of uncertainties of the method has been carried out. The main uncertainties are related to energy statistics 1) the correction methods between NEB and PEFA in order to allocate the transportation consumptions, 2) the refinement of analysis of system losses in NEB, and above all, 3) the transposition, enforcement and monitoring of art.8, key to determine the available information to be used in this methodology, and to obtain a reliable estimation of SMEs energy consumption. For this reason, the application of this methodology to the available data on other 13 European countries could provide useful insights on the impact of different national approaches to comply with art.8. This methodology shows that harmonizing the different strategies to monitor EAs obligation would significantly help to characterize the energy consumption of SMEs in Europe. At the same time, the knowledge of the distribution of energy consumption between LEs and SMEs would help in assessing the impact of mandatory and voluntary energy audits on potential savings in industrial and tertiary sectors.

SDEWES2022.0424

Exploring the Energy-Saving Potential and Cost-Effectiveness of Energy Efficiency Measures in the Residential Sector in Europe

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Abstract

Buildings in Europe are responsible for approximately 40% of energy consumption and 36% of CO₂eq. emissions. Furthermore, about 35% of the residential building stock is over 50 years old and more than 75% is considered energy inefficient. In this context, renovation of existing residential buildings can lead to significant energy savings and play a key role in the clean energy transition. However, the energy performance of the building stock is improving very slow, with only 1% of the building stock being annually retrofitted.

The energy consumption of the residential built environment varies substantially across the European Union (EU) depending on the age of buildings and different climatic conditions, which have a major influence on heating and cooling demand patterns. As a result, the energy-saving potential of energy efficiency measures differs among member states and tailored renovation strategies that take into account aspects such as climatic conditions, energy uses, and, ultimately, the age of the building stock itself across Europe are required.

Additionally, energy retrofit measures in buildings often require high initial investment costs and their benefits accrue only slowly over time. It is, therefore, crucial to identify retrofit measures that are not only beneficial for the environment but will also incentivise building owners and will ensure effective private and public budget spending.

In this context, our study aims to investigate the energy-saving potential of energy efficiency measures and their cost-effectiveness in residential houses in 8 European countries with different climatic conditions and consumption patterns. To do so, we make use of the Dynamic high-Resolution dEmand-side Management (DREEM) model, developed in-house on open-source Modelica libraries and Python programming, along with the Tabula Webtool to account for the characteristics and the properties of the different building typologies in Europe. For the technoeconomic analysis we use the Levelised Cost per unit of Saved Energy (LCSE) indicator, which allows assessing the cost-effectiveness of retrofit packages according to different strategies. Our results show that the replacement of an old heating system with an energy-efficient heat pump and the installation of a smart thermostat are among the most cost-effective measures for all countries due to the high potential of energy savings of these measures. Overall, our work intends to assist policymakers for the redesign of effective renovation strategies towards the decarbonisation of the building sector in Europe.

SDEWES2022.0425

Pioneering a Performance-Based Future for Energy Efficiency in the European Union: the Case of Pay-For-Performance Schemes

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Abstract

Energy efficiency continues to rank at the lower end of the spectrum of realised sustainable energy investments, with current building renovation rates in the European Union (EU) ranging between 0.4 and 1.2% per year. Energy efficiency interventions cannot be financed from the public sector alone and will require substantial private sector involvement toward the achievement of the 2030 and 2050 decarbonisation targets. However, barriers such as high upfront costs, high financial risks, limited payback expectations, and uncertainties regarding savings achieved, hinder the wide uptake of energy efficiency measures.

An innovative financial mechanism to support the implementation of energy efficiency interventions in buildings is Pay-for-Performance (P4P) programmes. These programmes aim to remove the barrier of uncertainties regarding energy savings and the high financial risks of energy efficiency interventions using data-driven Measurement and Verification (M&V) approaches. P4P schemes have been widely deployed so far to engage both energy and third-party service providers in energy efficiency projects in North America, but there are only a few applications in Europe. Furthermore, there is still limited analysis of P4P schemes in the scientific literature.

In this context, our study aims to present the main characteristics of P4P programmes, identify the barriers to, and drivers for, their implementation in the EU, and investigate how they can be developed using the innovative business model of the energy efficiency aggregator. To do so, we use a three-pillar model as a conceptual framework to examine how P4P schemes can be developed. In particular, we consider aspects related to (i). design, (ii). policy, and (iii). business.

We examine each pillar using a multi-method approach including desk research, semi-structured interviews with relevant stakeholders, and EU-wide surveys. As a result, experience and lessons learnt from real-world cases are provided, and a set of key implications and recommendations for policymakers and other practitioners on designing P4P pilot projects in the EU are presented. Finally, the added value of P4P schemes for different stakeholders and different business cases that could make use of P4P schemes are highlighted.

SDEWES2022.0468

Optimize the Mobilization and Valorization of Biomass and Waste Deposits in Côte D'Ivoire to Meet Long-Term Energy Challenges

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Abstract

The observed consequences of climate change are leading to a modification of energy strategies. Thus, for Côte d'Ivoire, this work aims to quantify the biomass and waste deposits to meet the long-term energy challenges. The literature was consulted and the deposits were estimated. It was found that the cumulative biomass used as primary energy was 21847.12 million tonnes from 2010 to 2019, i.e. 6423.054 ktoe of energy constituting 75% of the primary energy mix, mainly wood and charcoal. Other agricultural residues were estimated to be 29.53 million tonnes in 2020. The overall amount of municipal solid waste collected in Abidjan from 2018 to 2021 was 5.862 million tonnes. In contrast, our estimate for the whole of Côte d'Ivoire is over 79.16 million tonnes of cumulative household waste from 2020 to 2029 and 726.37 million tonnes from 2070 to 2080. This work shows the exploitable energy potential to achieve a renewable energy mix. However, prospective modelling should define desirable, possible and acceptable energy transition scenarios according to the principles of sustainable development.

SDEWES2022.0564

Predicer – Abstract Stochastic Optimisation Model Framework for Multi-Market Operation

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Abstract

An open-source modelling framework Predicer, standing for Predictive Decider, for multi-market day-ahead market operation purposes is described in this paper. The Predicer model uses scenario-based stochastic optimisation to obtain decision variables and bid matrixes for energy and reserve markets by maximising the risk-adjusted expected value of the profit during the model time frame. The modelled energy system structure is abstract, that is, based on basic elements such as nodes representing different energy types and processes representing flows between nodes. The abstract model structure enables user to construct arbitrary energy systems and define links between assets, commodities, energy markets and reserve markets. Predicer model can include properties such as unit ramp rates, online units, dynamic energy storages, market realisation and market bidding requirements. The aggregation of unit-based energy and reserve opportunities into a virtual power plant allows the asset owner to make optimized portfolio-level bids for different market products. The model scenarios consist of user defined forecasts for market prices, renewable energy supply, energy demand and other system related time series. Predicer is implemented in Julia programming language and uses the JuMP optimisation package.

Energy policy 2

SDEWES2022.0287

Assessing Socio-Economic Impacts of Local Renewable Hydrogen Supply Chain: an Input-Output Approach

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Abstract

In recent year, hydrogen fuel has been widely recognized as an alternative to fossil fuel. With the construction of a local hydrogen supply chain, new industries and new business areas are expected to be created at each stage of the supply chain, leading to the revitalization of local economies. Quantifying socio-economic impacts associated with a local hydrogen supply chain and accurately grasping the current situation of local economies are essential for taking measures to increase these benefits.

Input-output (IO) model is useful to assess direct and indirect socio-economic impacts on whole economy. However, there is no input-output table for detailed assessment at city, town and village levels. The aim of the present study is to develop input-output model for municipalities and to apply for the demonstration projects of hydrogen production and use in a city of Japan.

The input-output model for municipalities is constructed based on the national input-output table for Japan. The output value, total value of intermediate input and final demand value of 390 sectors of the national input-output table are divided into 47 prefectures, and then the estimated value for each prefecture are divided into municipalities included in each prefecture.

Case study is performed for the demonstration project in Tomiya City, Miyagi Prefecture, which is conducted by the Ministry of the Environment (MOE). The hydrogen is produced by solar power generation system and stored in the cassettes containing hydrogen storage alloy. These cassettes are delivered to households and attached to a pure hydrogen fuel cell. We develop a hydrogen diffusion scenario from the start of the project to the year 2030 and evaluate the socio-economic impacts over the entire period.

The assessment reveals that direct and indirect effects related to the facility construction are significant. In particular, it is indicated that a percentage of fuel cell installations and solar power generation system installation are high. Although the equipment is manufactured outside the city, the construction work is performed by the city's construction companies. Furthermore, the economic benefits associated with construction are generated continuously each year.

However, for the most part of the benefits in the manufacturing sector are generated outside the city and overseas. This is because almost all parts and equipment needed for construction work are produced out of the city. In order to increase the socio-economic benefits on Tomiya city, the promotion policy to create the related manufacturing industries are needed.

In conclusion, the present study develops an input-output model for quantifying the socio-economic impacts of local renewable hydrogen supply chain. The model can provide valuable information for formulating the hydrogen policy towards local economic development.

SDEWES2022.0476

Investigation of the Solar Rooftop Penetration Across the Ganga Basin Region of India

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Abstract

Urgency to address the issue of climate change and high fossil fuel import dependency, and to meet carbon neutrality targets have forced the decision makers to push the deployment of greener alternatives such as solar rooftop. State governments in India have implemented solar rooftop policies for meeting the national targets. Ganga Basin region comprises 25% of India's geographical area and has significant solar potential. However, the penetration of solar rooftop in the region has been lacklustre compared to other states. Our study investigates holistically the barriers and enablers in achieving the full potential of solar rooftop installation in this economically and ecologically important region of Indian mainland. Qualitative methods are applied to integrate the varied perspectives of residential, industrial and commercial consumers, solar vendors, nodal agencies and government officials and suggest policy implications to address the challenges.

SDEWES2022.0612

Policy Making Method for City-Scale Decarbonization Based on a P2P Simulation Considering Each Incentive

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Abstract

Many cities have declared their intention to decarbonize, to reduce carbon emissions to virtually zero by 2050. As the costs of rooftop photovoltaics and batteries are decreasing, a combination of these technologies can help to advance decarbonization. However, it is not yet clear in what order these technologies should be implemented to achieve efficient decarbonization. In addition, each city has a different climate, population, industrial composition, and land use patterns. Therefore, policy formulation must be adjusted to the characteristics of each city.

The objective of this study is to propose measures on how energy storage resources can be allocated to achieve efficient decarbonization, taking into account the characteristics of cities and the electricity-related incentives of the various residents and industries of the city. Existing studies have shown a path toward urban decarbonization by assuming that all energy storage resources can be centrally controlled and that they can be operated optimally. However, centralized control is not realistic because each holder will use storage batteries for its own purposes. Therefore, it is necessary to consider the incentives of each storage resource holder.

This study proposes a new approach to solve these problems: a P2P simulation on a city scale to find the optimal placement of storage batteries, taking into account the incentives of each storage battery owner. We conducted an actual simulation of Odawara City, a suburban city in Japan.

First, we implemented the general households and various industries that make up the city as multiple types of agents. Then, the agents were combined to reproduce the city according to the characteristics. In the simulation, each agent uses storage batteries according to its own purpose and shares power with each other via a P2P market. In order to find the optimal placement of storage batteries, multiple scenarios were prepared for the installation of storage batteries, and the percentage of renewable energy in the city was evaluated under each condition. The best performing of these scenarios is presented as a measure.

Simulations based on real data from Odawara City, Japan, show that PV and batteries contribute differently to decarbonization depending on the industry and households where they are installed. The results suggest measures that Odawara City needs to take to promote efficient decarbonization.

SDEWES2022.0622

LEAP4Sme International Observatory on Energy Efficiency Policies for Enterprises and Smes: Key Messages

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Abstract

The role of energy efficiency (EE) in small and medium-sized enterprises (SMEs) is crucial for reaching climate objectives. The importance of SMEs in terms of economic and environmental impact has been extensively recognized on aggregate. However, due to their heterogeneity, the development of SME-tailored successful energy policies remains a very challenging task for national public bodies. In the context of LEAP4SME project, partner Countries are currently organising national observatories, involving policy makers and other relevant stakeholders, such as business associations and ESCOs, to collect their views on specific core-topics related to energy efficiency in SMEs. Moreover, the central meeting of the “International observatory on energy efficiency policies for enterprises and SMEs” was held in Rome (Italy) on 15 and 16 September 2022. During these 2-days meeting representatives and experts from 15 National Energy Agencies (Industry and SME areas), European Commission (DG-ENER, CINEA and JRC), UNIDO, MEDENER, Green Industry Platform, Polytechnic University of Milan, Chamber of Commerce of Malta, and European Energy Network, shared good practices and addressed the most relevant topics on EE in SMEs. The main objectives of this international observatory are 1) to discuss among National Energy Agencies, relevant international and local Organisations, the state of the art of the National and European policies for SMEs, their barriers and enabling factors to unlock the enterprises’ energy efficiency potential; 2) to look for links among SMEs and large enterprises policies; and 3) to discuss on the topics of Energy Management Systems and Energy Audit policies/techniques for SMEs in view of the new Energy Efficiency Directive (EED) requirements. This paper summarizes the most relevant key-messages from the Observatory with special emphasis on lessons learned from national policy schemes, industrial sharing information schemes, strategies to promote the implementation of EE measures, plans for saving energy and operational aspects to support the new EED. Additionally, some results from the 9 European countries (Austria, Croatia, Greece, Italy, Malta, Poland, Portugal, Slovakia, and United Kingdom) involved in LEAP4SME project were presented to data-driven support the discussions: energy data availability, surveys and good practices.

SDEWES2022.0624**Pathways for the Uae's Energy System and Energy Intensive Industries to Achieving the Paris Agreement Targets**A. Hummieda¹, A. Bouabid^{*2}¹Khalifa University, United Arab Emirates; ²Khalifa University of Science and Technology, United Arab Emirates (*ali.bouabid@ku.ac.ae)**Abstract**

The UAE's Energy sector is the largest contributor to the country GHG emissions. Electricity generation and energy intensive industries (EII) have the largest emissions reduction potentials. In recent years, the nation has outlined its Energy strategy 2050 to increase renewable power generation and reduce its emissions. It recently announced the Net-Zero by 2050 Initiative. In this light, an up-to-date GHG emissions inventory, and a study of the possible pathways to achieving 2050 targets is essential. This study entails building an emissions inventory and future projection for the energy production and energy-intensive industry sectors (Aluminum, Steel, and Cement manufacturing). This is done through a review of available literature, national and international reports. Further, the structure of these sectors is modeled, using a system dynamics (SD) model. The SD model is developed and validated to reflect the real-world state of the system using the emissions inventory and preliminary projections as reference modes. 19 mitigation policies are considered across the selected sectors, and four policy scenarios are simulated. The results show that by 2050 and with reference to the Business as Usual (BAU) scenario, implementing the Energy 2050 strategy in the power sector can result in a 63.5% emissions reduction in that sector, which translates to a 33.5% GHG emissions reduction overall. Further implementing all identified mitigation strategies to full utilization in energy-intensive industries yields a 95.9% reduction in that sector, which translates to a 78.8% GHG emissions reduction overall. Decarbonizing the Aluminum industry yields the highest emissions reductions, followed by power production, then Cement, and finally steel. In the best-case scenario, 21.2% of the BAU emissions are still released, and further decarbonization, mainly in the power sector, will be required. This is achievable given the trajectory of the UAE's successful nuclear energy program thus far, and the prospect of utilizing CCUS even further.

SDEWES2022.0626

Electrification in Sweden: a Q Study Exploring Socio-Technical Barriers

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Abstract

Electrification of industry and transport is a key measure in the transition to meet the Swedish climate targets. Although most of the technologies required for the transition are available, there exists different socio-technical barriers to implementation. To find ways to reduce and overcome these barriers, what lies behind the barriers needs to be clarified and understood. Considering the research gap, this paper aims at identifying the narratives surrounding the barriers in the Swedish context and how they possibly relate to each other from key stakeholders' perspectives.

The work applies a so-called Q methodology, combining qualitative and quantitative approaches, to assess and compare stakeholder viewpoints on a given topic. From a literature review of papers on socio-technical barriers to the energy transition in Northern Europe, we compiled 55 statements on how such barriers can influence electrification. The statements cover issues such as social acceptance, permit application process, justice, and economic impact.

For the survey, around 25 participants, who either work with or are affected by the possible changes brought by electrification, will be interviewed. The participants were selected to cover different roles in relation to the energy transition. The Q method makes each interviewee rank the importance of each statement, relative to others on a fixed normal distribution grid. The ranking is statistically analyzed to identify factors with significant variances. From the correlation matrix, the factors are extracted by centroid analysis, then paired with varimax rotation to give the factors identified a simple structure for interpretation.

The paper provides first experiences from application of the Q methodology to a selected number of stakeholder interviews. The results will reveal which narratives on barriers to electrification dominates in Sweden, and the extent the rankings of these are similar or dissimilar to each other among the various viewpoints that the interviewees represent. This is expected to be an important basis for mapping out what drives the barriers and how they are connected. The findings will be applied to future work to design scenarios in traditional techno-economic energy systems modelling to evaluate the implications on different barriers such as the value of reaching public acceptance for a certain technology or measure.

SDEWES2022.0636

Gis-Based Approach for Natural Gas Consumption Mapping- the Case Study of Croatia

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Abstract

The current geopolitical conditions accelerated the need to phase-out natural gas consumption. In order to model the phasing out of natural gas on a national level, it is crucial to know how the geographical distribution of natural gas consumption. This is a very challenging task in national energy systems with relatively scarce data on the subject, like Croatian.

This work presents a GIS-based approach for natural gas consumption mapping. The proposed method implements a top-down approach. It enables the allocation of natural gas consumption on a high spatial level, based on the population distribution, as well as the existing district heating networks. The proposed approach is tested in QGIS, on the case study of Croatia. The results present spatial distribution of natural gas consumption on hectare level (100x100 m), for two essential sectors-households and services. This research is expected to be beneficial for defining technologies and measures for accelerated phasing out of fossil gas consumption.

Energy system analysis 1

SDEWES2022.0005

Energy Transition Towards the Goal of “Fit for 55”: the Case Study of Univpm Campus as Multi Energy-System

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Abstract

The EU's climate plan, namely the “Fit For 55” package, has the target of saving 55% of the CO₂ emissions by 2030. Hence, the energy systems paradigm must be reconsidered and transformed by not only widening the deployment of Renewable Energy Systems (RESs) but also including Energy Storage Systems (ESSs) that will play a key role in addressing the intermittent nature of the RES. Furthermore, also sector coupling measures, namely end-user electrification, and cross-sector coupling would aid the emissions reduction. Even though these solutions could guarantee the achievement of the planned goals, they would require a considerable financial investment; hence, at current stage it is not still economically convenient to replace the whole energy systems infrastructure completely.

The goal of this work is to evaluate different pathways to reach the 2030 agenda by analyzing the historical data of the UNIVPM campus' energy consumption located in Ancona (Center of Italy). Indeed, the medium-term planning assessment is carried out focusing on the current energy infrastructure enhancement. The present case study has multiple energy carriers that satisfy the energy demands using both the national grids and the energy conversion technologies installed onsite. Twenty configurations of the technologies mix involved in the case study under investigation have been analyzed. Results underline the essential role of i) RESs in the decarbonization path requiring, at least, an additional 3 MW PV capacity, ii) an electric battery with a required capacity of 7 MWh, and iii) sector coupling technologies such as heat pumps supported by heat thermal storages.

SDEWES2022.0012

Validation of Methods to Select a Priori the Number of Typical Days for Energy System Optimisation Models

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Abstract

Studying a large number of scenarios is necessary to consider the uncertainty inherent to the energy transition. Typical Days (TDs) clustering is a commonly used technique to ensure the computational tractability of energy system optimisation models. Its capability to approximate accurately the full-year time series with a reduced number of days has been demonstrated. However, its impact on the results of the energy system model is rarely studied and has never been studied on a multi-regional whole-energy system. To address this issue, we analyse the sensitivity of the energy system strategy to reach 90% direct emission reduction for Atlantic European countries. For each number of TDs, the technologies sizes and primary energy uses with an error below 5% are considered as well approximated. At 36 TDs, they cover more than 79.5% of the system's total cost. This is the best trade-off found and it divides the computational cost by 6.3. Finally, we validate the classical method to select a priori the number of TDs by showing its strong correlation of -0.92 with the developed a posteriori metric.

SDEWES2022.0020

Comparative Evaluation of Hybrid Solutions Based on Membrane Separation and Chemical Absorption Technologies for Capturing CO₂ in Post-Combustion Processes

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Abstract

The central objective was to analyze different hybrid or simple configurations of chemical absorption technologies using monoethanolamines (MEA) and membranes based on hollow fibers developed within the CO₂-HyBrid project for which the CO₂/N₂ selectivity was 50, and the CO₂ permeability was 1000 GPU. Thus, in this research study, different configurations were analyzed:

Single configurations in which chemical absorption processes (CAP) or hollow-fiber membranes (M) were used separately.

Parallel configurations in which the 2 decarbonization technologies were analyzed in parallel, each technology treating 50% of the flue gas flow.

Series configuration in which the hollow-fiber membrane technology is placed before the chemical absorption technology in order to pre-concentrate in CO₂ the flue gas and reduce the thermal regeneration effort of the chemical solvent.

The aim of the paper was to evaluate technically and economically the influence of the integration of the proposed cases in a CFPP with an installed capacity of 330 MW. The CO₂ avoided cost was higher when the hybrid process was treated, 66.98 €/tCO₂ for hybrid series, 50.69 €/tCO₂ for hybrid parallel compared to membrane alone, 39.98 (€/tCO₂) or solvent process, 37.88 (€/tCO₂). SPECCA indicator showed that hybrid process is a big energy consumer, 6.6 MJ/kg for hybrid series, 5.46 MJ/kg for hybrid parallel comparing to membrane alone, 4.42 MJ/kg or solvent process, 3.55 MJ/kg. On the other hand, including the CO₂ capture process increased the capital costs per net electricity more in the case of membrane alone 4 927 €/kW than in the hybrid series case, 4 131 €/kW, but less than in the hybrid parallel case, 5 184 €/kW. However, the capital cost for the hybrid series case is even better than in the solvent process case, 4 664 €/kW. However, to increase the performance of membranes, the development of their physical characteristics in terms of selectivity, permeability, and operation at low pressures is essential for improving the technical and economic parameters.

SDEWES2022.0025

Comparative Assessment of Treated Wastewater Heat Recovery into District Heating System of the Three Baltic Capital Cities

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Abstract

While all cities have great potential for sewage wastewater (WW) and treated WW, they are still an underutilised heat resource in many European cities, including the three Baltic capitals of Tallinn, Riga, and Vilnius. The aim of this study was to evaluate the integration of waste heat (WH) into a district heating (DH) system via absorption heat pumps. The study presents a three-step methodology that develops an innovative multi-dimensional approach to energy poverty analysis and includes the three main drivers of energy poverty: fuel prices, household income, and energy efficiency. The study shows that the integration of WH is economically feasible from the consumer's point of view and reduces energy poverty. It was concluded that the three capitals have a similar WW heat potential about 30 MW. Results show that the recovery of WH from treated WW by the introduction of an absorption heat pump increases the share of renewable energy sources (RES) in the fuel mix by 7.5%, 2.7%, and 9.4% for Tallinn, Riga, and Vilnius respectively, especially if natural gas combustion technologies are replaced. Riga has the lowest performance among the studied countries due to the considerable distance of the WW treatment plant from the main heating network of the DH system.

SDEWES2022.0029

The Role of Power – to – Hydrogen in Carbon Neutral Energy and Industrial Systems: Case Finland

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Abstract

To achieve carbon neutrality, large-scale variable renewable energy must be deployed, and energy intensive sectors such as transportation and industry must switch to carbon neutral alternatives. The objective of this paper is to investigate the role of power – to – hydrogen in achieving carbon neutrality in an energy and industrial system containing large-scale variable renewable energy.

This contribution models the effects of substituting fossil hydrogen in industry with renewable hydrogen and introducing hydrogen to replace fossil fuel use in steel industry and transportation sectors in a highly renewable power and heat system. This was achieved by using the EnergyPLAN – software to provide a case study of a highly renewable Finnish energy system set in 2040. Introducing the hydrogen increased electricity consumption by 31.87 TWh/a, but significantly reduced the CO₂ emissions by 71.5 % and fossil energy usage by 72.6%. Changing the electrolyser generation profile to match wind power generation was investigated, but additional hydrogen market mechanisms are needed to make this feasible.

SDEWES2022.0053**CFD Simulation of Syngas Chemical Looping Combustion with Randomly Packed Ilmenite Oxygen Carrier Particles**V.C. Sandu¹, C.C. Cormos¹, A.M. Cormos^{*2}¹Babes-Bolyai University, Romania; ²Babes-Bolyai University, Faculty of Chemistry and Chemical Engineering, Romania (*ana.cormos@ubbcluj.ro)**Abstract**

Chemical looping combustion (CLC) is an innovative carbon capture technology where fuel decarbonization is achieved by circulating an oxygen carrier (OC) between separate reactors. The fluidized bed system enables OC transport between fuel and air reactors, where OC reduction and oxidation take place, respectively. By avoiding direct contact between fuel and air, minimal energy is required for CO₂ separation. The disadvantages resulting from the conventional circulating fluidized bed system are the additional energy necessary for OC transportation as well as separation of particles from the hot stream of air.

A novel approach to CLC (as presented in this work) considers a packed bed system with stationary OC particles undergoing periodic reduction and oxidation stages by shifting feed gas streams. While the packed bed CLC concept enables the inherent circumvention of gas-particle separation, the major benefit to the design lies in the prospect of process operation at high pressure, unlike the limitations seen when using CFB reactors. Finding optimal operating conditions is a mandatory step prior to implementing the process at industrial level. In this work, COMSOL Multiphysics was used for computational fluid dynamics (CFD) modelling in order to simulate the syngas-based CLC process with ilmenite OC in a packed bed reactor configuration. Mass, momentum and heat transfer were accounted for to describe the combustion, purge and regeneration stages within a bed of randomly packed spherical OC particles at both macro- and microscale dimensions.

The scope of the particle-resolved CFD multiscale model of a fixed bed reactor with realistic bed morphology was the investigation of local interactions of transport phenomena in combination with local reaction kinetics, in addition to the in-depth analysis of the intraparticle phenomena occurring during the reduction and oxidation reactions, with emphasis on heat transport. Model results indicated sharper and more efficient mass transfer rates at lower flow rate values and decreasing particle dimensions, due to suppression of diffusion-related limitations. Model results provide additional understanding regarding syngas-based CLC with ilmenite OC in a packed bed configuration and contribute towards the design of a flexible and energy efficient power plant concept.

SDEWES2022.0068**The Long-Term Planning for the Energy Transition of a Region with the Power System Based on Lignite**T. Čurčić¹, L. Herc², A. Pfeifer*³¹University of Zagreb Faculty of Mechanical Engineering and Naval Architecture, Croatia; ²Faculty of Mechanical Engineering and Naval Architecture, Croatia;³University of Zagreb - Faculty of Mechanical Engineering and Naval Architecture, Croatia (*antun.pfeifer@fsb.hr)**Abstract**

The energy transition of predominately coal-powered energy system is significant a challenge, which needs to be addressed using various energy system modelling efforts, to enable the substitution of coal, in this case lignite, with variable renewable energy sources. Coal is by far the most used fossil fuel in the energy systems of Western Balkans. There were 65 coal mines in the area in 2018, producing 93 Mt of hard coal and lignite – around 20% of the coal produced in the European Union, according to the recent report of the Joint Research Centre of the European Commission. The synergic effect between energy supply and different sectors of energy consumption is shown as the appropriate way to handle the challenge of this transition. But optimal energy system configuration through the decades of transition is sought after, to serve as a guideline to the policymakers. This research proposes a method for such long-term energy modelling and planning tasks, using the long-term energy planning tool and implementing it in the case of Bosnia and Herzegovina. The system analysis and simulations are carried out in H2RES model. H2RES model is a linear optimization program. It considers capacity expansion, decommission in the sectors of power generation, heating, industry, and transport sector. Using such a tool, the optimal configuration of the energy system, minimizing the investments in new generation capacities and CO₂ emissions is presented through 5-year steps, from 2020 till 2050 for the energy system of Bosnia and Herzegovina. Results show in which dynamics can the energy transition from a lignite-based energy system to a zero-emissions energy system be achieved, using the optimal combination of synergies with the electrified transport sector, efficient heating and cooling sector, and the industry sector based on electrification and synthetic fuels, such as hydrogen produced from the excess of electricity generated by variable renewable sources.

SDEWES2022.0100**Natural Gas as a Transition Bridge by 2030 and its Transmission Capacities Adequacy**

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Abstract

In 2014 the European Union set a target to decrease the greenhouse gases emissions at least by 40 % by 2030 compared to 1990. This goal was set in the Paris Agreement as a step towards climate neutrality by 2050. In 2020 the Commission decided that it was necessary to set a more ambitious plan – 55% GHG reduction by 2030. This means a massive reduction of fossil fuels, especially coal and oil, and a massive development of renewable resources. However, such transition cannot be achieved immediately. Even though natural gas is a fossil fuel, it is considered the cleanest one and its importance is unquestionable. Given these facts, it is obvious it will have its part in the energy mix of Europe on its transition towards sustainable and clean energy, which is also stated by the Taxonomy. Considering natural gas a bridge to clean energy, it might seem that its consumption will increase, however, the European policy targets are not the only drivers. In this paper, an analysis of natural gas potential in selected Central-European countries was performed to create a model that describes the adequacy of transmission capacities until 2030.

Based on historical data analyses 4 groups of consumption were identified – households, industry, transport, power plants. In each of these groups, a regression analysis was performed to state relations on main drivers such as temperature, gas and electricity prices, season. These results were afterwards adjusted according to national climate plans to identify the future gas demand. Then a cross-border “entry-exit” flow model was created, where the flows were determined as linear combinations combined with consumption dependence. Afterwards the outputs were put together to create a base and other possible scenarios and state whether the transmission capacities comply.

Based on the results of the base scenario, some of the transmission capacities must increase (and will according to Ten-Year Network Development Plans), otherwise gas would have to be transported via different, longer route, and the prices would increase, for example for Italy, where now most of the gas entries from Austria. All the scenarios led to one common result. To guarantee continuous and secure gas flow, storage capacity will be a very important aspect and it is desirable to increase it. This fact could have already been noticed at the end of 2021 when the prices increased rapidly and at the same time, the storage capacities were almost emptied.

SDEWES2022.0101

Challenges of Renewable Energy Communities on Small Mediterranean Islands: Test Case of Ponza

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Abstract

Recently Italy has remodulated the incentives on PV plants to implement the EU clean energy transition strategy and its model of Renewable Energy Communities (REC). This shifted the focus from direct economical incentives to PV plants to a paradigm of incentives on self-consumption, to raise energy awareness in local neighbourhoods and mitigate the detrimental effect of a large number of small, medium and large PV plants disseminated across the country. In this paper, the REC model is tested in an extreme scenario, a minor Italian island without a power connection to the mainland, with a strongly seasonal energy load that peaks to 25MW during summer from less than 2MW during other seasons covered by Diesel gensets and the need for clean water supply provided via tankers. This is a typical scenario of minor Italian and Mediterranean islands. In the manuscript the implementation of renewable energy sources is investigated in a REC scenario. Results from time-dependant simulations carried out on pyRES, an in-house software for energy systems simulation, show the economical unfeasibility of the REC mostly due to the absence of a variable enough mix of prosumers and consumers. This changes if the community is asked to cover part of the energy load of a desalination plant (DES) with a total energy requirement of 1.8 MWh/year. The increase of self-consumption guaranteed from the DES allows to increase the net positive value of the community and results in major cuts in CO₂ emissions (60% of reduction of those associated with clear water supply from mainland and 10% for Diesel gensets) and fuel costs.

Energy system analysis 2

SDEWES2022.0121

The Management of an Energy System in the Realm of Energy Crisis and Strategies to Mitigate the Influence of Crisis, Examination in H2RES Energy Model

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Abstract

The energy system in Europe faces major challenges. Though, transition to renewable energy is under way, still a significant portion of energy is supplied from fossil fuels, mainly natural gas. At the second half of 2021, the supply of natural gas and consequently the rate of replenishment of the reserves has dwindled. The scarcity of natural gas has resulted in record high energy prices as well as the increase of goods prices. Especially hit are the industry sectors highly dependent on the natural gas such as petrochemical industry.

This research investigates the strategies to mitigate the crisis in the European Union energy system while at the same time ensuring low energy system cost and fulfilment of energy transition goals. The system analysis and simulations are carried out in H2RES model. H2RES model is a linear optimization program. It considers capacity expansion, decommission and unit commitment in the sectors of power generation, heating, industry, and transport sector.

Initial results display that the system opts for accelerated fulfilment of energy transition goals. Therefore, the dependency on the stable supply of natural gas is decreased. Also, the total cost of an energy system with restrictions is expected to be higher.

SDEWES2022.0224

Assessment of Optimal Location for Power to Methane Systems: the Case of Sardinia

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Abstract

An assessment of the optimal location for Power-to-Methane (PtM) facilities integrated with anaerobic digestion plants is carried out in this study. The PtM systems include an electrolysis section fed by photovoltaic (PV) power plants for the production of green H_2 , a biogas production plant and a biomethane reactor. Starting from the characteristics of 6 existing anaerobic digestion plants located in the south-Sardinia (Italy), this study aims to define location, number, and size of hydrogen generation units and biomethanation reactors and the required size of dedicated PV plants, to achieve the minimum production cost per volumetric unit of biomethane. Specifically, a comparison between Distributed and Centralized PtM systems is carried out. The results demonstrated that biomethane production costs of about 4 €/Nm³ is achieved with a Distributed PtM configuration by using 58% of PV annual energy. The biomethane production costs are further reduced to 3.72 €/Nm³ with a Centralized PtM system, with a percentage of electrical energy of 80% supplied by a PV plant. In addition, a reduction in biomethane production final cost arises from a centralized PtM system with combined transport of Liquefied Natural Gas and CO₂.

SDEWES2022.0262**Analysis of Revitalization Model Behaviour for Thermal Power Plants in Different Geographical Areas**

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Abstract

The implementation of renewable sources for electricity production into the energy portfolio of European countries is a priority task in last years, especially with current geo-political changes in mind. Even though coal is the fuel of the past we cannot put it aside from our use that easily. Firstly, because of the high fluctuation of electricity production from renewable sources and secondly, because of negative economic impact on the economy that change in electricity prices, when exiting the coal, might have. The paper will analyse the behaviour of the proposed revitalization model for the existing thermal power plants as part of critical existing infrastructure for supplying electricity to the grid. The revitalization model was developed in the scope of the Ph.D. research work and proposes the possibility to combine the conventional thermal power plants with renewable installations for electricity production. To the existing Rankine process, we designed the solar tower installation with a heliostat field, which enables electricity production based on solar irradiation. To that combination, we have also foreseen the additional installation for flue gas desulphurization. This combination of three processes is named the revitalization model for thermal power plants. Based on the computer model and energy market parameters, we tested the revitalization model for the pessimistic and optimistic scenarios. In the scope of the paper, we will analyse the performance of the proposed revitalization model for three different geographical locations – Berlin in Germany, Wuwei in China, and Hyderabad in India. Furthermore, we will present the response of the revitalization model, not only on the change in geographical location but also on the change of the additional parameters that implicate the overall performance of the revitalization model. That would be a change in the number of hour's effective sun irradiance, the local price of the supplied fossil fuel – coal, price of the electricity based on the country in which we choose the location and price of the emission coupons, if applicable. The results of the analysis will be descriptively, as well as graphically presented.

SDEWES2022.0276**Positive Impact of Red Soil on Albedo and the Annual Yield of Bifacial Photovoltaic-Systems in Ghana**E.M. Grommes^{*1}, U. Blieske¹, J.R. Hadji-Minaglou²¹TH Köln, Germany; ²University of Luxembourg, Luxembourg (*Eva-Maria.Grommes@th-koeln.de)**Abstract**

The rising energy demand and the low suitable areas for clean energy production demand more efficient energy technologies like bifacial photovoltaic (PV). Such solar modules can absorb irradiance from the front and rear sides, leading to a higher annual energy yield per module area than monofacial counterparts. The annual yield of bifacial photovoltaic systems is highly dependent on the albedo of the underlying soil. There is currently no published data about the albedo of red soil in western Africa. Having a closer look at the areas where bifacial PV systems can be installed, in West, East, and South Africa, red soil is the usual subsurface. Due to the recurrent energy deficit in the country and the expected growth of both monofacial and bifacial PV, in this study, Ghana is taken as an exemplary country for possible red soil impacts on bifacial PV. Considering a similar composition of red soil, the results are transferable to any other country with red soil. In this study, the impact of the albedo of red soil in Ghana on the energy yield of bifacial PV systems is analyzed. A bifacial PV simulation model (BifacialSimu) is created by combining the optical view factor matrix with an electrical output simulation. The view factor and one-diode model has already been validated with large-scale system data. For an exact simulation, the albedo of red soil is measured for the first time at three different locations in Ghana. The objectives of this paper are to publish and analyse the albedo of red soil and its impact on the energy yield of bifacial PV systems in Ghana as an exemplary country. The average albedo of any red soil is clearly determined as well as the measurement span including instrumentation uncertainty. The average albedo of red soil over three performed measurements in Ghana is $\alpha=0.256\pm0.025$. Considering these measured data, a state of the art bifacial PV system with 19.8 % average efficient modules in northern Ghana can reach an annual energy yield of 508.8 kWh/m² and a bifacial gain of up to 18.3 % in comparison to monofacial PV panels. To summarise, red soil in two out of three locations in Ghana shows higher albedo values than most natural ground surfaces and, therefore, positively impacts the annual yield of bifacial PV.

SDEWES2022.0324**Transient CFD Evaluation of the Impact of Environmental Conditions on the Performance of Urban Pavement Solar Collectors and Development of Intelligent Control Strategy**

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Abstract

Asphalt pavement is one of the most important urban features which has excellent heat-absorbing properties. A large amount of solar thermal energy can be absorbed and stored by the asphalt and released after sunset, which changes the urban microclimate and affects the building energy consumption. Some heat mitigation methods have been developed in recent years, “cool pavements” showed great potential in reducing the urban air temperature. Pavement Solar Collector (PSC) is a system that has a series of pipes with circulating water to absorb the heat from the asphalt, therefore, the heat from solar radiation can be transferred from the pavement surface to the bottom layer instead of released back to the atmosphere. By collecting, storing and utilising solar thermal energy, the urban heat island effect can be mitigated. The cooling effect provided by PSC has been confirmed in previous research, factors such as pipe configuration, embedded depth, circulating water temperature and velocity can affect the system performance. This work aims to investigate the PSC system performance under different weather conditions and system efficiency during the day by using Computational Fluid Dynamics transient simulations. Discrete Ordinate model and Solar-Ray Tracing were used to calculate the effect of solar radiation in the 3D simulation. Realistic weather data was imported into the model to obtain high accuracy results. The transient simulation method has been validated by several experiments. The PSC system operated after the asphalt slab was heated up for several hours to obtain higher efficiency. The asphalt temperature started to drop once the water circulated through the pipes. Based on the simulation conditions, the asphalt was heated up from 27°C to 49°C in the morning, and the temperature decreased to around 30°C in the afternoon. The inlet water speed velocity and temperature were optimised depending on the time and atmosphere temperature. Due to the transfer of heat from the asphalt to the water in the pipes, less heat would be released into the air at night and therefore, the urban heat island phenomenon would be mitigated. Future works will consider the cooling effect provided by the PSC system on the surrounding buildings and their energy consumption. The use of control strategies to improve the overall efficiency needs to be investigated.

SDEWES2022.0346**A Comprehensive Assessment of Cost-Optimal Heat Supply to New Low-Energy Building Areas in Sweden**

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Abstract

Buildings in Sweden contribute to a large share of energy use but low share of direct carbon emissions due to high market share of district heating (DH) based on biomass and heat pumps (HP). Urbanisation and population growth rises the need for construction of new building areas. Sweden has set stringent energy and climate goals by 2045 which asks for reduction of energy use in buildings. Consequently, the new building areas are built based on low-energy buildings (LEB) standards. These buildings need space heating during cold days and hot water. There are four main heat supply options to these areas: 1) individual heat devices, 2) decentralised DH (DDH), 3) connection to a nearby centralised DH (CDH) and 4) prosumers (combination of individual heat devices and a DH system). The aim of this study was to assess the system scale economy of the four presented heat supply options to LEB areas in a systematic way, and to determine the approximate thresholds for the cost-efficiency of the various options in a long-term. Further, energy system impacts of the heat supply options and the associated CO₂ emissions were assessed with a wide system perspective.

We developed and applied a dynamic energy system optimization model, i.e., TIMES, for calculation of the system cost. Our assessment was based on detailed local representation due to economies of scale and the diversity of local conditions and resource availability. In the model, we systematically combined three LEB areas with two urban areas and varied the location of the LEB areas in three different heat density zones of the urban areas in order to represent a wide range of conditions.

From the systematic analysis and model results, we identified that a low-temperature (LT)-DDH system in new LEB areas has the least cost of heat supply to LEBs if local LT and low-cost heat sources are available for the DDH production. Prosumers by investment in ground-source HPs and PVs can decrease the cost of the LT-DDH by supplying heat to the network in the LEB areas with plot ratio of above one. Stringent climate policy scenarios can further decrease the cost of the LT-DDH in LEB areas, reaching to the minimum system cost of 11.39 €/GJ among all the studied cases. A LT-CDH is the second heat supply option to LEB areas in the cost ranking order. The reason is both economies of scale and that a major characteristic of CDH systems in Sweden is the existence of low-cost DH production technologies. The model results also showed that the individual heat devices come in the last place of the ranking order.

Our results for CO₂ emissions impact of the various heat options, showed that CO₂ emissions of the power sector has strong impact on carbon neutrality of the heat options. The reason is that our assessment of the CO₂ emissions accounts for both the local CO₂ emissions and the emissions associated with electricity use in HPs.

SDEWES2022.0351

Thermo-Economic Analysis of a Low-Cost Greenhouse Thermal Solar Plant with Seasonal Energy Storage

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Abstract

This paper provides a numerical study of a thermal solar plant using a seasonal dual-media sensible heat thermal energy storage system for a greenhouse located in the South of Italy. The aim of the work is to assess the technical and economic performance of a low-cost pit storage system, made of gravel and water, placed under the greenhouse so save surface. The study provides an original analysis of the charging and discharging phases during one year of operation on the base of the real hourly heating demand and on real weather data.

A sensitivity analysis of the levelized cost of heat is carried on with respect to the solar-collector area and to the storage-pit volume. The analysis shows that a minimum-cost design solution exists. In this operation conditions it is possible to cover 97% of the heat demand with an estimated cost of 148 EUR/MWh.

SDEWES2022.0356

Estimating Potential Electricity Demand in Low-Income Countries: a Spatially-Disaggregated Stochastic Approach Illustrated in Sierra Leone

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Abstract

To design electricity access infrastructure in low-income countries, the future electrical demands of currently off-grid communities must be estimated. However, this is difficult, as off-grid communities have limited capacity to anticipate their future demands and little relevant empirical data is available. To tackle this problem, here, a demand estimation approach is developed which leverages existing large-scale socioeconomic data to estimate electricity demand in off-grid regions of low-income countries while accounting for intra-community and spatial diversity. A stochastic bottom-up estimation framework is implemented using the expected regional prevalence of appliance combinations from Multiple Indicator Cluster Survey data. This can be optionally calibrated based on the quantities of each appliance owned and regional wealth distribution. This approach is tested through a case study in Sierra Leone, which shows spatial variance in expected demands amongst similar communities in different provinces and better incorporation of intra-community diversity than alternatives such as tier-based estimation.

SDEWES2022.0490**The Impact of Spatial Representation in Energy Transition Modelling on System-Wide Energy Return on Investment**

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Abstract

Transition paths to zero-emissions power systems require flexible electricity generation options supported by stable grid interconnections and effective energy storage solutions. Detailed modelling of an interconnected power system can be challenging due to the complexity of the system and the associated computational burden to capture key characteristics. Currently, various simplifications are applied to overcome these challenges. However, the impacts of these simplifications are not known. This study provides a holistic approach to estimate its impact on the transition of the European power system from the perspective of energy return on investment (EROI) by using previously constituted four different spatial representation scenarios in the LUT Energy System Transition Model.

To achieve this, a broad technology-based cumulative energy demand database is constructed by applying same primary energy quality at the level of electricity. The outputs of scenarios are fed into a newly developed EROI model. Our findings reveal that EROI trends significantly vary due to the spatial structure of the model. In an isolated multi-node scenario, the EROI is decreasing from 18 to 11 during the period 2020-2050, generating the lowest EROI among other scenarios. As segregated 20 independent energy systems are linked by high voltage transmission lines, EROI values are increased by almost 3 points in an interconnected multi-node scenario by 2050. Disregarding the physical distances of the sub-regions and assuming one region, EROI values of the system reach a range of 20-24 by 2050. The above scenario results show the importance of a proper geographic representation of the energy system during modelling as the two extreme scenarios provide a large EROI deviation from the representation. The interconnected multi-node scenario may present near realistic conditions. A sensitivity analysis focusing on changes in the embodied energy requirements for fossil gas and oil indicates that the EROI value of the isolated multi-node scenario might go under 10, a value considered the upper limit of the net energy cliff. This reveals that fossil fuels maybe of high risk in the long-term as compared to renewables, also for the perspective of EROI.

Energy system analysis 3

SDEWES2022.0375

A Biomass-Based Polygeneration System for Historical Building: an Energy Analysis

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Abstract

Combined cooling, heating, and power systems (CCHP) are considered one of the most efficient energy systems since they have a less detrimental environmental impact, resulting in sustainable energy savings, and eventually less CO₂ emissions. An even higher advantage is possible when a renewable energy fuel source (e.g., Biomass) is used. The proposed study presents the energy modeling of a 100 kW_e capacity, biomass-based CCHP system retrofitted to a historical building, located in Perugia, Italy. Two well-known simulation software, ASPEN Plus, and TRNSYS are purposely integrated. In the first phase of the study, a wood biomass combustion-based externally fired gas turbine is modeled in Aspen Plus. In the later phase, the historical building, and the remaining components of the CCHP system are developed in TRNSYS. The transient system is modeled such that it fulfills the peak heating and cooling demand of the retrofitted building. The main components of the system are: a heat exchanger, storage tanks, a single-stage LiBr-H₂O absorption chiller, and a balance of plant components. A heat exchanger recovers heat from the gas cycle which is then utilized for heating and cooling of the end-user building, biomass drying, and domestic hot water (DHW) supply. A storage tank supplies direct heat to the end-user in winters and drives the absorption chiller in summer. The results of the model provide data on the performance parameters of different components of the CCHP system such as temperature, power consumption, and, energy profiles which leads to evaluating the overall energy performance of the CCHP system.

SDEWES2022.0396

Planning, Modelling and Optimizing the Integration of Renewable Energy in Electrical System of Emirate of Abu Dhabi

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Abstract

Energy transition is the process of moving from one source of energy to another one, taking the availability of resources into account. This process is not spontaneous; it takes time, and it requires good planning by countries and governments. In the Gulf countries, diverse measures of sustainable energy transition can be seen. There are projects in the areas of alternative resources, energy efficiency, and subsidy improvements.

Consider the United Arab Emirates (UAE). It is one of 10 largest oil producers in the world. It is estimated to have the seventh-largest proven oil and natural gas reserves worldwide. Abu Dhabi, one of the UAE's seven emirates, possesses 96% of those reserves. But the country is working to move away from economic reliance on hydrocarbon exports. In addition, the UAE has ambitious plans to incorporate renewable power, to diversify their energy mix. There could be multiple benefits from increasing the proportion of renewable energy in its electrical network: economic diversification, reduced reliance on price-volatile oil and gas, and the building of expertise.

This research highlights the importance of designing the integration of renewable energy into the UAE's sustainable energy transition. Its aim is to contrast and evaluate Abu Dhabi's generation sector over a ten-year period, during its conversion from a traditional gas system to a combination of gas and renewable energy sources. Using an optimization method as a Mixed Integer Linear Program (MILP), an energy planning program such as PLEXOS, and the real demand profile of Abu Dhabi, two main scenarios of the emirate's capacity generation growth are optimized, evaluated, and contrasted, using real data of power generation, transmission line and natural gas prices. A photovoltaic (PV) energy system and concentrated solar power (CSP) are modeled, and long-term planning was employed to distinguish between these integrations.

This work shows the effect of introducing renewable energy sources into Abu Dhabi's electrical energy system, in terms of carbon dioxide (CO₂) emissions, total cost of generation, and future capacity required. It also assesses the performance of the two scenarios, using a sensitive analysis that focuses on gas price volatility and generation efficiency. This research work calls for further studies into the optimizing of the electrical energy mix in the Gulf countries, to help in building a solid future for energy transition in the region.

SDEWES2022.0397**The Role of Energy Communities in Grid Electricity Balancing: a Flexible Tool for Electricity Deployment Optimization in Smart Grid**

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Abstract

In the last thirty years, a widely spread of green energy technologies with low initial costs led to energy production decentralization and an increase in electricity grid fluctuations. Thus, the unpredictability of renewable energy systems (RES) can affect problems in the electricity supply chain, such as voltage and frequency imbalances. For these reasons, the development of local energy communities with optimal electricity fluxes management is a promising action to minimize electricity losses by promoting the peer to peer (P2P) energy sharing.

In this paper, a suitable dynamic simulation model is developed and implemented in a MatLab tool. Here, the energy community and the final users are discretized into several control volumes for which different technologies are considered. The model implements suitable energy balances on different control volumes for single users as well as for the whole energy community. Such a tool is also able to assess the energy performance of different local energy communities, consisting of prosumers, consumers, energy storage systems, and electric vehicles. Furthermore, the model can investigate different solutions in terms of dispatching services for grid frequency regulation and optimizing distributed energy resources (DERs) exploitation. Another aspect worthy of notice is the capability in predicting electricity demand one day ahead. In this way, the model organizes renewable energy availability and relative energy storage systems for minimizing electricity grid interactions and flattening electricity demand to/from the electricity grid. Different objective functions in terms of energy, economic and environmental are also considered and implemented in the tool.

To show the capability of the developed model, a suitable case study is also presented. Here, an energy community consisting of 12 residential buildings, 1 office building, 125 m² of photovoltaic panels, 134 kWh of electricity storage systems, and 8 electric vehicles with 54 kWh of electric batteries is considered. Different electricity dispatching priority strategies are considered to find out the best configuration for maximizing renewable energy self-consumption. As result, an increase of renewable energy self-consumption from 34.8 MWh/y to 62.3 MWh/y is achieved, with consequential electricity saving of about 42.9 MWh/y and greenhouse gas emissions reduction about of 71.7 tCO₂/y.

SDEWES2022.0398

A Novel Methodology for Building Hourly Weather Data Files for Assessing the Energy Performance of Moving Systems Through the Dynamic Simulation Approach

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Abstract

This paper describes a new methodology for the development of hourly weather data files, useful for the analysis of the energy performance of moving systems (e.g.: ships, trains, cars, etc.). As it is well known, the climate conditions and the related hygro-thermal parameters (influencing the energy performance of moving systems) vary as a function of the position, speed, orientation of the system and of the related considered travel path.

The proposed methodology starts with the development of specific paths in suitable .gpx files. Subsequently, these .gpx files are processed in a new in-house developed subroutine written in MatLab environment, by which the geographic coordinates (characterizing the path) are obtained on the base of moving system speeds and considered path positions. Furthermore, new weather conditions data are obtained for each geographic location travelled by the moving system through suitable interpolations of TMY2 files data referred to existing weather stations. Finally, each geographic location of the path is associated with the interpolated hourly weather data, and through the developed subroutine a customised hourly weather file is obtained by combining the geographic coordinates of the considered path and the scheduled travel speeds.

To highlight the advantages provided by the proposed methodology, a suitable case study is presented. Here, a comparison is performed between the results obtained by the developed methodology and those of two different literature simplified approaches. Specifically, the case study refers to a modern cruise ship that travels three different routes: a cruise in the North Sea, a cruise in the Caribbean Sea and a cruise in the Mediterranean Sea. A 3D ship envelope is developed in the Google SketchUp and imported into TRNSYS environment via the TRNBuild tool. The heating and cooling loads in terms of transmission, ventilation, infiltration, and solar heat gain, are obtained for the three cruise paths and for the three different approaches. Consequently, it is highlighted how the computational cost-benefits for the correct consideration of the meteorological boundary conditions affect the reliability of the heating and cooling loads and demands assessment.

SDEWES2022.0428

Development and Tests of the Portable Power Supply System with Thermoelectric Generator

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Abstract

Thermoelectric generators are devices that harvest waste heat and convert it into electrical power. They may be considered either as an additional power source in the domestic sector, or power supply in off-grid objects (such as winter houses, shelters, etc.). This paper shows the development and tests of the prototypical Portable Power Supply system equipped with the specially designed and developed thermoelectric generator, a flue gas/air heat exchanger, and additional components such as the battery, controller, sensors, valves, etc. At this stage, the thermoelectric generator was equipped with low-price thermoelectric modules, resulting in lower output power than the theoretically available output power. This system can be powered by various types of fuel, depending on the requirements of the end user (including gas, oil, or biomass burners). Thermal energy generated in the system is used to heat air in the room, whereas generated electricity is stored in the battery and can be used to power the air fan and some low-power electric appliances. During the tests presented, the electricity generated in the thermoelectric generator was measured and conditioned by the electronic load, which allowed to simulate different operational conditions. Electrical power obtained during the tests was approximately 61.15 W. However, by installing more thermoelectric modules or replacing low-price modules with high-efficiency ones, this power may be significantly higher. In addition to technical aspects, also economic premises were included in the analysis. As calculated, the simple payback time related to the introduction of the thermoelectric generator to the Portable Power Supply system was approximately 14.7 years. On the other hand, increasing energy prices makes the potential economic benefits significantly higher than calculated.

SDEWES2022.0523

Influence of Power Grid Efficiency Variability on the Support Mechanisms for High Efficiency Cogeneration: an Italian Case Study

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Abstract

In Europe, economic support mechanisms have been developed to promote high-efficiency cogeneration systems because of their potential role in primary energy saving, network losses reduction, greenhouse gases emissions mitigation and energy supply security increase. Following the implementation of the Directive 2004/8/EC, in Italy new constructed or refurbished high-efficiency cogeneration plants are recognized the access to the White Certificates scheme, and they are allocated Type II Energy Efficiency Certificates proportionally to the energy savings provided with respect to separate electric and thermal energy supply. However, for the evaluation of the primary energy savings, constant parameters are adopted as reference values, and the average conventional efficiency of the Italian power grid is considered in relation to the separate supply of electric energy. As a result, although being capable of greatly affect the context in which the adoption of cogeneration systems is encouraged, the time variability of the electricity production mix and its effects on the power grid operation are undetermined. Therefore, to have a more accurate estimation of the feasibility and the profitability of combined heat and power production plants, this work aims at assessing the impact of using time varying power grid efficiency indicators for the evaluation of the primary energy savings due to the installation of two micro-cogenerators for polygeneration purposes in a multi-storey building. Unlike what the regulatory framework suggests, hourly-based power grid efficiency values will be used. The main findings have shown that the increased time resolution leads to greater energy savings and, in turn, to major economic revenues.

SDEWES2022.0567

E²Gem – Tool for Energy Analyses on Municipal Level

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Abstract

With the passing of the Austrian Renewable Energy Expansion Act in 2021, a concrete legal framework was created to drive forward the energy transition in Austria. According to the law, Austria's electricity consumption is to be covered by 100% from renewable sources by the year 2030. To achieve this ambitious goal, a transformation towards renewable energy generation is indispensable, both at state level as well as at the municipal level. However, Austrian municipalities often lack the necessary expertise to analyze their situation regarding renewable energy. Therefore, in this paper, the tool E²GEM, which enables energy analyses on a municipal level and helps communes identify their current position on the path to energy transition is presented.

In a three-step process, municipality-specific data on renewable potentials for the generation of electricity & heat, energy consumption of the economic sectors industry & commerce, housing, and mobility as well as the current renewable energy generation are collected and subsequently balanced. In this way, three key figures are determined: current degree of self-sufficiency through renewable generation, maximum possible degree of self-sufficiency through renewable generation, and the current percentage expansion of renewable generation. On the one hand, these key figures allow statements about the current and future contribution of a municipality to the energy transition, and on the other hand, they can be used to initiate targeted transformation processes at the municipal level. A case study carried out for a city with about 15000 inhabitants with local energy intensive industries showed promising potentials, especially of industrial waste heat. Regarding the percentage expansion of renewable generation, current rates are low. Full self-sufficiency is not possible for the study area.

Currently, complete analyses with E²GEM can be performed for the Austrian province of Styria, analyses of other provinces and economic sectors are expected to be available by end-2022.

SDEWES2022.0591**System Impacts of Heat Supply Scenarios to Low-Energy Buildings in Sweden**

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Abstract

Urbanization and population growth increase the demand for new buildings. Sweden has set stringent energy and climate goals for 2045. Consequently, new building areas are constructed based on low-energy building (LEB) standards. These buildings require space heating on cold days and hot water generally. The choice of heating technology affects energy systems far beyond the LEB areas. The local district heat (DH) systems, the heat sector, the electricity system, and the national energy system are impacted to various degrees. Thus, a system-wide perspective, rather than a focus on individual buildings, should ideally be considered for issues regarding heat supply in new LEB areas. In this study, we assessed energy system and system cost impacts of the heat supply options to LEBs in Sweden in the long term (by 2050) while also addressing the climate targets. We applied the ON-TIMES model, which is a dynamic energy system optimization model, with the perspective of the Nordic region's energy system. All energy sectors for each of the Nordic countries are represented in the model. The building sector has been represented in detail by an exogenously derived current heated area for single-family and multifamily buildings and divided into individual (having an individual heating system), decentralized, and centralized buildings (based on their connection to a corresponding DH system). We further developed the model by representing LEBs, centralized, and decentralized low-temperature DH (LTDH) systems in Sweden. We designed two scenarios of heat supply options to LEBs: 1) decentralized LTDH, 2) LTDH. We integrated them into the model either by limiting or not limiting the construction of LEBs in decentralized building areas, respectively. The results showed that energy flows and technologies in the heat and power sector depend on the choice of heat supply options to LEBs. These in turn affect the total cost of the entire energy system in Sweden as it fulfils its energy and climate goals. In this study we determined that at the national level, a LTDH supply to all buildings combined with a decentralized LTDH supply to LEB areas could lead to higher annual utilization of large-scale heat pumps (by nearly 30 PJ) in decentralized building areas and excess heat (by 52 PJ) for DH production while decreasing annual energy system cost by nearly 2 billion EUR (5%) and consumption of the electricity used for heating buildings (by 5 PJ, between 2040-2045).

SDEWES2022.0648

French Energy Transition Under Carbon Neutrality – Analysis Based on Systematic Modeling Approach

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Abstract

Global warming due to carbon emission linked with human activity has become one of the major concerns of human society. Under this environmental challenge, an increasing number of countries, including France, made commitments to reach carbon neutrality by 2050. It is thus necessary to design strategies to decarbonize the energy system, on both power/gas production sector and end-use especially buildings or transportation which represent large amount of carbon emissions.

To achieve the decarbonation, various RES solutions have been proposed from technology side, such as solar PV, wind park, renewable gas industry, hydrogen mobility. Our question of interest is the systemic interaction of these technologies in the dynamic transition to a low carbon energy system. Renewable solutions are very complementary, but such a systemic transition also creates new interdependencies and competition between renewable energy options in different sectors.

Our analysis covers future trajectories of the French energy sector to achieve carbon neutrality. We propose to investigate five core dimensions that will shape the adoption rate of different renewable solutions: biomass potential, carbon sinks, expansion rhythms of clean technologies, import strategies, and future demands. Our study will be based on TIMES-FR, a bottom-up technical economic optimization model of the entire French energy sector.

The results will be based on evolution of final energy balance of France till 2050. We will illustrate in detail the contribution of different types of RES for achieving carbon neutrality, under varied conditions. The results describe energy transition pathway on both national and sectorial level. We will as well present evolution of gas and electricity balance.

Energy system analysis 4

SDEWES2022.0137

Design and Optimization of Hydrogen Supply Network for Refueling Corsican Fuel Cell Vehicle Fleet

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Abstract

Green hydrogen is considered as a potential fuel for the future to make a significant contribution to clean energy transitions. This study presents a methodological framework for the optimal design of a hydrogen supply chain applied to Corsica island. The problem formulation is based on Mixed Integer Linear Programming (MILP) with a multi-period approach using the minimization of three objective functions, i.e., the total system cost, greenhouse gas (GHG) emissions and a risk-based index. Three optimizations based on each objective criterion have been considered. A complementary geographical approach is used by considering a Geographic Information System (GIS) to identify the hydrogen demand area and potential production, storage and distribution sites. The results provide an optimal configuration of the Hydrogen Supply Chain (HSC) with the size, type of technology and techno-economic parameters of the units involved (production, storage, transport, distribution) and their potential location. The novelty of this work is to present this optimal design evolution over a short time period considering the monthly fluctuation of hydrogen demand and energy availability while considering a long period (2050). The levelized cost of hydrogen obtained by minimizing the total cost of the system is 6.13 EUR/kg. This methodological approach can be used to explore appropriate future spaces and incentive mechanisms to boost the hydrogen economy in an isolated territory.

SDEWES2022.0603

Assessment of the Robustness of the European Gas System to Massive Gas Outages and Evaluation of the Effect of Increased Energy Efficiency on the Security of Gas Coverage in the Different Countries

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Abstract

Due to the current geopolitical situation in Europe, there is great uncertainty in covering energy demand in the winter months, especially in those countries that are dependent on gas from third countries. During 2021, gas from Russia accounted for a total of 38% of all consumption at European level. In situations of commercial, political and technical crises, Europe has cooperation and/or solidarity mechanisms capable of exchanging gas volumes internally, through the pipelines and infrastructures of the European gas system. This system did not work in extreme situations so new European regulations and infrastructures were developed. On the other hand, the European Council has defined a target of 32.5% energy efficiency by 2030, which implies reducing final energy consumption by 36% and primary energy consumption by 39%.

The aim of this paper is to simulate the European natural gas system in extreme situations and to see its weaknesses in terms of demand coverage. An assessment has also been made of the targets set in existing energy efficiency regulations and their effect on the coverage of future natural gas demand.

The document assesses the potential for energy efficiency improvements associated with European countries and the effect of such improvements on the reduction of natural gas demand. Once the efficiency improvement potential has been identified, the results of demand coverage in various scenarios of natural gas supply cut-off via pipeline are studied. The expected result reflects the study of the effect of the expected demand reduction, due to the improvement of energy efficiency, on the self-sufficiency of the natural gas network and the improvement of energy coverage to EU countries. To carry out the study

an evaluation of the current infrastructures is developed, the existing resources are optimized, and the independence of the system is quantified in relation to the current situation of natural gas consumption at European level.

The model proposed has resulted in improvements in the coverage of the demand of certain countries and has detected those ones with a system that is not robust enough to face extreme crisis situations. The main conclusions are that the natural gas system has improved considerably from 2009 to the present, and that in the event of massive gas cuts there is a real risk of not being able to cover the natural gas demand of several countries with a very high dependence on gas from Russia.

SDEWES2022.0619

Conditions for Sustainable and Democratic Electricity Systems

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Abstract

Currently, the electricity system in many countries is undergoing significant changes. More and more customers become interested in contributing to their own electricity supply. This was supported especially by the emergence of decentrally applicable technologies such as PV, small CHP and accompanying use of battery storage..

The major objective of this paper is to provide insights on how to bring about a competitive, sustainable and democratic electricity system with even higher shares of VRES.

Our method of approach is based on the principle of coverage of residual load (= difference between final electricity demand and generation provided by non-flexible electricity generation) on an hourly base over a calendar year based on assumed variable RES generation and development of the load profile;

The major results are: (i) Of core relevance is a pricing system in an energy-only market where the price signals provide information about scarcity or excess capacities at every point-of-time; (ii) to balance variations in residual load a portfolio of flexibility options is important such as: (i) Battery, pumped hydro and other storage; (ii) Technical demand-side management; (iii) Demand response due to time-of-use pricing. (iii) However, flexible power plants for capacity system adequacy will play a role in every system with and without regulated capacity payments.

The major conclusion of this analysis is, that it will be necessary to accept a paradigm shift in our understanding of the whole electricity system where no longer the generators are the centre but coordinating entities such as balancing groups respectively the supply companies. And finally we state that the evolution of such a creative system of integration of RES in Western Europe may also serve as a role model for electricity supply systems largely based on RES in other countries world-wide.

SDEWES2022.0620

Assessment of the Additional Electricity Demand to Decarbonise the Aviation Sector in Germany Until 2050 Based on Technology Diffusion MethodM. Khanra*¹, S. Prabhu²¹Fraunhofer ISI, Germany;
(*manish.khanra@isi.fraunhofer.de)²Fraunhofer UMSICHT, Germany**Abstract**

The hard-to-abate transportation sectors have considerable share in overall GHG emissions. In particular, aviation sector accounts for 2.5% of global anthropogenic CO₂ emissions and is expected to grow further [1]. Decarbonisation of such sectors is currently high on the agenda in the European Union and its member states. The emissions associated with aviation sector are anticipated to grow considerably in line with possible increase across Germany as well as Europe. Mitigating such emissions need deliberate efforts and planned interventions. Alternative fuels based on renewable electricity can have a key role in the transition towards CO₂-neutral hard-to-abate transport sectors. Production and synthesis of such alternative sustainable fuels is usually an energy intensive process which requires large amount of electricity and higher penetration of renewable energy sources in system. Most decarbonisation scenarios related to aviation sector towards 2050 does indeed point out the quintessential role of clean and low carbon energy carriers. In this paper, three scenarios has been analysed using developed agent based model to simulated the technology diffusion process considering economic as well as environmental factors. Model simulations gave multiple possibilities regarding use of fuels and technologies blends. Outputs of which are then compared with reference scenarios. Our findings shows that relative reduction in CO₂ emission with final reductions of roughly 40% and 60% for baseline scenario and scenario 2, respectively.

SDEWES2022.0623

Profitability of Demand Side Management Systems Under Growing Wind and Solar Shares in Power Systems

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Abstract

European power system is undergoing a major transformation through increasing wind and solar generation and expansion of transmission capacities. However, the capacity expansion of wind and solar capacities seem to outpace the transmission lines capacity expansion, thus creating a need for additional solutions to balance the variability. This article studies the profitability of demand side management (DSM) systems operating in the Northern-European power markets in 2025. We analyze the results with three key indicators: number of cycles/year, average income per cycle (EUR/cycle) and internal rate of return for the investment. The results show that the DSM system would be the most profitable (500+ cycles/year, 10+ % internal rate of return with 800 EUR/kW investment cost) in Denmark and Baltic countries. This is because of their role as electricity transit countries between electricity exporting Nordic countries and electricity importing larger Central European countries that still have a notable share of fossil fuels in their power systems (Poland, Germany, and UK). DSM systems were the least profitable (less than 100 cycles/year, internal rate of return below 5% with 800 EUR/kW investment cost) in Norway, Sweden, and France which have over 80% share of nuclear and hydro power with reservoirs. Sensitivity analysis shows that the profitability of DSM systems is more sensitive to unit specific parameters, especially larger storage size affecting the annual income more than 100%, than system parameters, such as wind power capacity.

SDEWES2022.0627

Study on Renewable Energy Investment Roadmap for Decarbonization of Manufacturing Companies

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Abstract

Decarbonization efforts are attracting attention around the world as a global warming countermeasure. Japanese companies, which are ahead of the rest of the world in setting decarbonization targets, should focus on incorporating them into more concrete plans and implementing them. In addition, because the environment for decarbonization has been highly uncertain in recent years due to rapidly changing international conditions, companies need to be flexible in their decarbonization efforts to respond to changes in the environment.

The objective of this study is to help companies develop the specific renewable energy (RE) investment roadmap needed to achieve their decarbonization goals flexibly.

Most previous studies on decarbonization planning have not looked at environmental uncertainty, conducted simulations for only a single year, or focused on large entities such as national or municipal governments. On the other hand, this study focuses on decarbonization in the corporate power sector and explores the time-series trend of optimal corporate RE investment under the assumption of environmental uncertainty.

After proposing an overall process for companies to develop their electricity decarbonization plan, two systems are proposed. The first system is a RE investment roadmap design system at a single site. Simulations are conducted for a single business site to search for the optimal RE investment roadmap for each business site that minimizes costs while achieving the target RE ratio. By changing input values such as price trends, the system can be used for scenario planning and estimation of the corporate environmental change risks. The second system is the decarbonization prioritization assessment system for multiple sites. It quantitatively evaluates each business site from two perspectives: potential CO₂ emissions reductions and the marginal cost of CO₂ reductions at business sites.

The case study validated the proposed systems with electricity demand data from a large manufacturing company. The proposed systems suggested optimal electricity decarbonization roadmaps for the target company. In addition, multiple scenarios were set for procurement prices to identify the impact of price fluctuations of procurement items on the subject companies' RE investment roadmaps.

SDEWES2022.0632

The Role of Flexible Heating Demand in the Danish Power Dispatch in 2050

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Abstract

The Danish power system will take a particular role in reaching the EU's goal of carbon neutrality by 2050, both as a renewable electricity producer but also as a transit country between its Northern and Southern neighbours. Already today, the Danish energy system leverages the flexibility potential from its heating sector, the importance of which might increase in the future with an increasing electrification of heat supply and potentially higher uptake of demand response.

In energy system analysis, demand response is not a direct control problem, where system aggregators set demand levels, but rather an indirect control problem, where consumers react to time-varying prices. However, modelling it as an indirect control problem can increase computational complexity and is difficult to achieve in most existing modelling frameworks.

The contribution of our study is two-fold: Firstly, we propose a novel method for integrating price-based demand response models in large-scale energy system models. Doing so allows modelling and analysing demand response realistically as an indirect control problem in country-scale energy systems analysis. Plan4EU is used to solve an electricity dispatch problem for Europe and demand response from district heating is simulated via a set of differential equations.

Secondly, this modelling setup is applied in a case study, where we analyse the role of demand response from the heating sector as well as heat storage in Danish power dispatch in 2050. Installed power generation capacities are the result of European transition pathways to net-zero computed via GENeSYS-MOD. We analyse the Danish electricity mix and electricity transit under varying configurations of demand flexibility.

SDEWES2022.0639

Sensitivity Analysis of Future Energy System Configurations with Regard to Resource Availability

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Abstract

In accordance with the goal of reducing CO₂ emissions by 55% until 2030 compared to 1990 values and achieving climate neutrality by 2050, future energy systems will rely on renewable energy sources. In such systems, demand-side flexibility technologies will be necessary to ensure required consumption and safe supply in conditions of variable production and times when it is not available. Accordingly, the task of energy planning requires special attention focused on modeling the system that will meet the goals of the energy transition and ensure stable operation, all while achieving the lowest possible system costs. Therefore, this paper uses a computer software for long-term energy planning, H2RES, developed at the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb within the INTERENERGY project. The program has the ability to model flexible technologies and changes in the availability of renewable resources over the years, which is an essential element in the development of the system in accordance with changing climate conditions in the future. Different scenarios of climate parameter changes for Republic of Croatia, which consequently affect the production from renewable energy sources, will be studied and the behavior of the system will be compared in scenarios of different availability while respecting the goals of energy independence from fossil fuels and the desired climate neutrality of Europe by 2050. Simulations are carried out for each year in the observed period, which is a departure from the usual open source tools and therefore it approaches the capabilities of commercially available tools.

Environmental policy and management

SDEWES2022.0030

Evaluating the Influence of Different Future Weather Data on Building Performance Simulations in Southern Europe

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Abstract

Climate change will have a great impact on the hottest climates of southern Europe, with more extreme temperatures according to the projections of the Intergovernmental Panel on Climate Change. The existing residential stock, obsolete and with low thermal and energy performance, will be extremely vulnerable to these future climatic conditions if an adequate retrofitting process is not carried out in a near future. Intervention strategies on this stock should not only be considered to meet current needs but also anticipate imminent global warming. Thus, it is necessary to apply climatic files that predict future conditions in the building performance simulations (BPS). There are several methods for forecasting climate change weather data that can be classified into two main groups: statistical and dynamical downscaling. Statistical downscaling, despite being a simplified approach, manages to provide adequate future weather data for comparative analysis in BPS significantly reducing computational times.

This research aims at comparing the results of using two different tools for generating future climate hourly data files based on statistical downscaling: Meteonorm and CCWorldWeatherGen, which are the most commonly used by the scientific community for BPS. The final objective of this comparative analysis is to discuss which tool implies more reliable results depending on the outputs object of study and the scale of the simulation model. For this purpose, two future weather datasets for different climate change scenarios (2050 and 2080) are generated for the city of Seville (Csa Köppen climate classification). Both are applied to the DesignBuilder models of a test cell, representing a typical bedroom, and a multifamily building, representative of the southern Spain housing stock. Values predicted for outdoor air temperature, relative humidity, and solar radiation are evaluated and compared, as well as the simulation results of thermal comfort, cooling, and heating demands.

The results for southern Europe show that both weather files have significant differences in predicting outdoor air temperature and solar radiation, and therefore the projection method selected for producing future climatic files has relevant effects on the future analysis of thermal comfort and energy demand. The global warming effect is more emphasized in the future climate conditions estimated by CCWorldWeatherGen, while more extreme events are observed in the ones predicted by Meteonorm.

SDEWES2022.0058

CO₂ Emissions and Global Value Chains Indicators: New Evidence for 1995-2018

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Abstract

The consequences of CO₂ emissions are one of the major problems worldwide, with serious socioeconomic and environmental implications. At the same time, the increasing trade openness and globalization have become important global facts, as countries are more connected and more interdependent as time passes. This especially true in terms of production: commodities are not entirely produced in one country, as several phases of the process are outsourced.

In this context, Global Value Chains (GVCs) have recently been one of the main representations of globalization, where main indicators are participation and position. Participation in the GVCs is a measure that determine, for each industry of each country, the weight of its value-added exports (embodied) over the total value added of each country. Position measures the distance of the production process of each industry of each country to final demand. Then, related to the position indicator, the more upstream is an industry, the highest is the use of intermediate inputs, so, the higher is the distance to final demand.

Many papers have analyzed the relationship between these two indicators over CO₂ emissions, finding positive correlation in most of them. However, these results seem to depend on the period. Thus, this work analyzes the effect of position and participation measures in the CO₂ emissions, during the largest period available: 1995-2018. This allows the identification of the possible structural breaks and to relate the different trends to different drivers. Then, better policy recommendations can be made.

This work employs a new dataset available since December 2021 and published by the OECD: Inter-Country Input-Output (ICIO) tables. The scope of ICIO tables is 1995-2018 and all tables consider 67 countries and 45 industries. The participation and position indicators are calculated for each sector of each country using these input-output tables. Once these two indicators are calculated, a fixed effects panel data is used to estimate their relationship with CO₂ emissions.

Preliminary results identify structural breaks in 2003, 2008 and 2012 and a positive correlation with participation in the whole period. Non-significant correlation has been found in the case of position.

SDEWES2022.0084

A Review of Economic Assessments of Drought Adaptation Measures in Agriculture

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Abstract

Due to climate change, the frequency and intensity of droughts are expected to increase. To improve resilience to droughts, proactive drought management is essential. Economic assessments are typically used to decide on the investments to make. Yet, the choice of both methods and scope of economic assessments influences the outcome, and thus the investment. This paper reviews actual economic assessments based on seven criteria for economic assessments as derived from the United Nations Framework Convention on Climate Change (UNFCCC). Through a systematic review, the methods used in 14 papers are evaluated. The results show that in practice, economic assessments rarely address all criteria. Applying a limited number of criteria reduces the scope and narrows the approach, possibly leading to the underestimation of related benefits. In order to improve the results of economic assessments of drought mitigation and adaptation measures, these criteria should be translated into practice.

SDEWES2022.0190

Evaluating How Ecosystem-Based Adaptations to Climate Change Influence Community Wellbeing in Pacific Islands

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Abstract

Climate change poses significant threats to the well-being and livelihoods of people and the ecosystems in many Small Island Developing States (SIDS). Adaptation solutions must counteract these threats while also supporting development in vulnerable SIDS. Suitable options need to ensure that connections between the social, economic and environmental dimensions of socio-economic systems are defined in a way that can support how decisions are made (and by whom) and how these can impact other parts of these systems. This is particularly important in many Pacific SIDS, where communities practice customary natural resource management and continue to rely on local natural resources. In this study, we model the anticipated impacts of climate change and the benefits of the ecosystem-based adaptation (EbA) approaches on community wellbeing in Vanuatu. To do this, we applied participatory and expert solicitation methods to develop a Bayesian Network model, which was designed to evaluate community wellbeing responses at four explicit spatial scales. The model includes both acute and chronic impacts of climate change, the impact of coral bleaching and the potential loss of Vanuatu's fringing coral reefs. The model predicts that all proposed EbA interventions will have a positive impact on wellbeing in all four locations to some degree, by either directly improving the integrity of Vanuatu's ecosystems, or by protecting these ecosystems as a positive spill-over of related actions. Significantly, it also predicts that if climate change exceeds 1.5 oC of warming, the costs of achieving the same level of well-being are increased

SDEWES2022.0191

Systems Approach for Examining the Fate of Sunscreen Derived Titanium Dioxide Nanoparticles in Swimming Pools

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Abstract

Swimming pool owners worldwide face the challenging task of keeping their pool water balanced and free from contaminants. However, swimming pool water (SPW) quality management is complex with the countless processes and interactions of interlinked system variables. For example, contamination with sunscreen residues is inevitable as users apply sunscreen to protect their skin from damaging ultraviolet (UV) radiation. Nanoparticulate titanium dioxide (nano-TiO₂) is one such residues that have received criticism due to potential human health and environmental risks. Despite ongoing research studies, management strategies of nano-TiO₂ in swimming pools are still limited. Therefore, this paper focuses on developing a multi-method approach for identifying and understanding interdependencies between TiO₂ particles and an aquatic environment such as a swimming pool. Given the complexity of the system to be assessed, the authors utilise a systems approach by integrating cross-matrix multiplication (MICMAC) and Systems Thinking techniques. The developed conceptual model visually depicts the complex system, which allows users with a basic understanding of swimming pool chemistry to comprehend the numerous cause-and-effects easily and be able to consequently identify leverage points that effectively change the dynamics of the system. Such systems-level understanding, and actions will help to manage nano-TiO₂ levels in an efficient manner. The novelty of this paper is the proposed methodology, which uses a systems approach to conceptualise the complex interactions of contaminants in swimming pools and the important pathways to elevated contaminant levels.

SDEWES2022.0376

Economic Climate Change Costs on the Regional Level – an Interdisciplinary Impact Assessment for Upper Austria

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Abstract

Anthropogenic climate change is affecting weather and climate extremes in all regions worldwide. Upper Austria will be affected by climate change primarily through increased temperature and intensity and frequency of precipitation, which will lead to direct sectoral and macroeconomic effects on the regional level. To quantify these, we choose an interdisciplinary framework, which combines meteorological forecasts with damage costs in macroeconomic simulations.

Future meteorological developments in Upper Austria until the end of the 21st century, utilized for the derivation of climate change indicators, are determined using data sets of the ClimEx project (Climate Change and Extreme Events). In particular, the temperature and precipitation developments of the IPCC scenarios RCP4.5, RCP7.0 and RCP8.5 were derived. Based on a set of climate change indicators, sectoral damages up to 2050 are monetarized for selected impact chains (wood production and pest infestation in forestry, reduced labor productivity and higher mortality due to heat, reduced yields in agriculture, changes in energy demand for space heating and cooling, additional costs for air conditioning as well as snow safety and shortening of season length in winter tourism). The damages are used as input for ex-ante simulation analyses which allow to quantify the macroeconomic impacts.

Depending on the scenario, the expected temperature increase in Upper Austria, compared to the reference period of 1980-2010, lies between 1.7 and 2.7°C in 2050. With respect to annual precipitation, a decrease between 17 and 27 mm is projected in 2050. This leads to average sectoral damages (from 2022 to 2050) between €202 million and €234 million per year. On the macroeconomic level, negative economic impacts through a decrease of the gross regional product between 450 and 537 million € per year and in employment of on average between 5,000 and 6,000 employees per year in 2022-2050 are identified. The results show (analogous to the development of climate change) an exponential increase of damages and thus of negative feedback loops in the regional economy, especially in the medium and long term.

In this respect, the study provides a basis for decision-making for the sectors of forestry, health, agriculture, space heating and cooling and winter tourism in Upper Austria and highlights the importance of considering region-specific climate change adaptation strategies.

SDEWES2022.0413

Sustainable Recycling of Paddy Straw Through Development of Short-Fibre Reinforced Composites: Exploring Gainful Utilisation of Agricultural Waste

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Abstract

This research focuses on the gainful utilization of agricultural waste by utilizing paddy straw for developing natural fibre-reinforced composites for multi-structural applications, including automotive and civil infrastructural interior applications. The experimental findings revealed that the density, prolonged water uptake, and thickness swelling of the paddy straw (PS)-polypropylene (PP) composites ranged from 0.8-1.12 g/cm³, 0.66-3.45%, and 0.42-2.31%, respectively, at fibre loading of 20-80 wt.%. The achieved maximum mean tensile and flexural strength was 28.69 ± 0.52 MPa and 49.73 ± 0.42 MPa, respectively, approximately 4.7% and 19% higher than neat PP composites. Significant enhancement in the bending (3.57 ± 0.93 GPa) and young's modulus (2.94 ± 2.31 GPa) were also achieved upon reinforcement. The impact resistance improved by 151% than neat PP composites with a maximum value of 2818 J/m². The mix-design of PS: PP ratio of 60:40 (wt.%) with the processing temperature of 180°C and pressure of 70 bar was found to be the best condition to achieve better physical, mechanical and thermal characteristics of the developed composites.

SDEWES2022.0479

Inventory of Timber in Finnish Residential Houses

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Abstract

The use of reclaimed wood-based building materials contributes to better material recovery, extending the life cycle of the materials and lowering greenhouse gas emissions. Significant efforts are still needed, however, to achieve this. Currently, there is no knowledge about the size, amount, and recoverability of timber and timber products after the first use. The paucity of such information does not allow reuse and recycling to be implemented. To better understand the potential of timber within buildings, this paper creates an inventory of timber used in the construction of typical building typologies in Finland by analyzing the technical documents of 20 typical houses and suggesting timber components that might be the best for reuse and recycling.

The results showed that most of the timber embodied in each house in terms of the volume comprises the following cross-sections (in mm × mm): '22 × 100', '20 × 100', '22 × 125', '40 × 125'. The '20 × 100' constitutes by far the highest volume in all case studies. In most cases, this was used as structural sheeting for exterior and dividing walls, making it unfavourable for reuse and recycling due to the use of as many as 40 nails per meter for their installation. The most favorable option for repurposing was '40 × 125' (when disassembled), which was mainly used for studs, top and bottom plates, and rafters. Upon disassembly, floor joists can be reused if their dimensions allow. Considering that the timber facades were painted with hazardous paints (e.g. asbestos-based paints), which pose a threat to the environment and human health, they were not found suitable for reuse and recycling.

The analysis showed that Finnish buildings contain timbers that could be reused and recycled. This highlights an opportunity and a need for the development of guidance on the principles and strategies for design for deconstruction and reuse. It was also determined that due to the design of these dwellings, it is currently uneconomic to extract the timber components intact, even if they could be reused or repurposed. By making only minor changes to existing design, construction, and demolition practices, significant possibilities for reusing and recycling may be generated, adding value to timber, and reducing the demand for virgin wood.

SDEWES2022.0518**The Role of Cobalt Supply for Lithium-Ion Batteries in the Achievement of the Sustainable Development Goals**L. Da Silva Lima^{*1}, L. Cocquyt¹, L. Mancini², E. Cadena Martinez¹, J. Dewulf¹¹Ghent University, Belgium; ²Freelance research consultant, Italy (*ligia.lima@ugent.be)**Abstract**

Electric mobility is becoming increasingly important for minimizing the effects of climate change and achieving a sustainable society. The demand for this technology and the raw materials it requires has increased significantly over the past decade and is expected to increase exponentially in the upcoming years. If, on the one hand, the rechargeable batteries used in electric vehicles support the transition towards carbon neutrality, on the other hand, the manufacture of these batteries may impose threats to the achievement of a sustainable society. The Sustainable Development Goals (SDGs) are the roadmap to achieve sustainability by 2030, but by analyzing the battery value chain, both positive contributions and negative impacts to the SDGs can be identified. In this study, the SDGs were used as a reference to assess the contributions and risks of cobalt supply for electric mobility (considering the use of electric vehicles in the European Union) and whether this technology supports the accomplishment of the SDGs. The main positive contributions and negative impacts assessed were associated with social aspects, but some environmental-related issues, such as water consumption, water quality, and greenhouse gas emissions were also evaluated. A Global cobalt supply scenario was defined (considering the most representative countries) and the socio-environmental risks and contributions to the SDGs were identified per supply chain stage. Although Europe has a limited role in the supply of cobalt for batteries, a hypothetical European scenario was also determined based on reported ongoing industrial activities related to batteries and their components in European countries. All the supply chain stages of both Global and European scenarios were investigated to identify positive and negative correlations with the SDGs. The results indicate that, although some SDGs receive positive contributions, like SDG 8 (Decent work and economic growth), SDG 11 (Sustainable cities and communities) and SDG 13 (Climate action), most of the identified correlations are negative, especially for SDG 3 (Good health and well-being) and SDG 16 (Peace, justice and strong institutions).

SDEWES2022.0608

Assessment of Hazardous Agrochemical Waste in Plastic Packaging by Terahertz Spectroscopy

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Abstract

Agriculture, one of the main economic pillars in Europe, is playing an increasingly important role in the environmental sustainability of non-urban regions. Today's agriculture still needs large amounts of agrochemicals to grow and protect crops. These agrochemicals are supplied in different types of packaging, most often in plastic bags or bottles. This plastic material is usually treated as hazardous waste as it contains residues of hazardous chemicals. There are specific waste management procedures for this type of waste. For such packaging to enter recycling processes and ensure a circular economy, it must first be decontaminated and separated from other packaging that does not contain hazardous residues. Terahertz technology is suitable for the detection and identification of residues of hazardous substances in plastic packaging. This paper presents the potential application of THz technology for managing hazardous plastic waste packaging from agrochemicals. It shows how hazardous chemicals in plastic packaging can be detected and identified by appropriate THz laboratory analysis. The results of this study showed that THz technology has the potential to be integrated into the agrochemical plastic packaging waste management system and contribute to reducing environmental pollution (soil, air, water) and improving public health.

Green economy, Regional planning, Social&education

SDEWES2022.0080

Comparative Technical-Economic-Financial-Environmental Evaluation Between Steam Cracking of Ethane and Catalytic Dehydration of Ethanol Processes to Obtain Ethylene

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Abstract

Ethylene is the precursor of a series of petrochemical products of interest and, due to its wide applicability, is considered one of the most important building blocks for the industry. 99% of ethylene production is via steam cracking, which is characterized by high CO₂ emissions and high energy consumption. This work presents a comparative evaluation of the ethylene production process via ethane steam cracking and the bioethylene production process via ethanol catalytic dehydration. For each process, eight capacities from 100 to 1,310 kt/year were simulated in Aspen Plus and scale factors, investment costs (CAPEX), operating costs (OPEX) and minimum selling price (MSP) of ethylene were obtained, in addition to their respective specific values. The economic evaluation results were then used to develop mathematical models that estimate capital and operation expenditures, as well as minimum selling price of each technology's main product, according to production capacity and prices for raw materials and carbon dioxide emission/capture. For the petrochemical process, the scale factor was 0.87 and the extremes of the economic and financial indicators were a CAPEX of 266 to 2,008 MMUSD (2,664 to 1,551 USD/t), OPEX of 67 to 627 MMUSD/year (666 at 483 USD/t), and MSP of 1,357 to 896 USD/t. For the renewable process, the scale factor was 0.78 and the extremes of the economic and financial indicators were a CAPEX of 169 to 1,010 MMUSD (1,690 to 771 USD/t), OPEX of 172 to 2,030 MMUSD/year (1,715 at 1,549 USD/t) and an MSP from 1,932 to 1,544 USD/t. Regarding environmental results, while the petrochemical route emits 1.2 t CO₂/t ethylene, the sustainable route captures 2.1 t CO₂/t bioethylene. For the economic and financial results of the petrochemical route, CAPEX results demonstrated that, despite higher yearly operational expenditures, carbon capture from consumption of renewable ethanol in the bioethylene process provides additional revenue, improving economic performance. For carbon prices ranging from 120 to 335 USD/t, lower minimum selling prices are obtained for bioethylene than for ethylene, depending on production capacity, green premium value and ethanol purchase price.

SDEWES2022.0104

Reviewing the Decision to Invest in Nature-Based Solutions from an Environmental Economic and Financial Perspective

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Abstract

Due to climate change, cities are facing major environmental challenges, like the urban heat island effect, loss of biodiversity and ecosystems, and flood risk. Nature-based solutions (NBS) harness the power of nature to adapt to and mitigate global warming's adverse outcomes. Yet, cities are confronted with barriers to the implementation of NBS. The benefits of NBS do not result in direct revenues or cash flows. Moreover, city budgets often do not have the required resources to provide for extensive urban infrastructure. Alternative ways of financing are therefore being sought, including value capturing, impact financing and crowdfunding via initial coin offerings (ICO). However, it is unclear whether such alternative financing affects the economic feasibility of the underlying investments. In the existing literature, there are several studies that apply economic evaluation techniques to analyze the feasibility of investments in NBS. However, there is no structured overview of how economic feasibility studies can encourage investment in NBS. To fill this gap, this paper examines how the economic feasibility of NBS is currently assessed, whether and how non-monetary benefits are addressed, as well as uncertainty issues, and to what extent policy measures are proposed to encourage investment in NBS. In doing so, we adopt a systematic review approach by applying the framework of Reporting Standards for Systematic Evidence Syntheses (ROSES). This framework allows for a structured, transparent, and replicable review of the scientific literature. We contribute to the existing literature by providing an overview of how current studies value non-monetary benefits, integrate flexibility and adaptive management options, and assess alternative financing instruments to capture the benefits of NBS and stimulate the investment decision.

SDEWES2022.0112

Including Geosystem Services for Sustainable Management of Natural Capital

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Abstract

Ecosystem management provides an integrated approach for sustainable management and protection of ecosystem services. However, the ecosystem approach fails to consider and represent the components, structures, formations, and processes resulting from the subsurface. The policies and governance on the exploitation of geosystem services are yet to match with rapid utilization and heavy reliance on geosystem services. It is not known if the increasing reliance and the rate of exploitation rate of the subsurface resources will allow for sustained use in the long term. In this article, the issue of sustainable scale is addressed for the exploitation of geosystem services.

A systematic literature review is conducted to understand the different terms of geosystem, geosystem services, and geodiversity. Furthermore, the existing methods to value geosystem services have been reviewed and analyzed under the context of sustainable management of the subsurface. The reviewed literature focuses on identifying, mapping, and analyzing the value of geosystem services. The findings suggest that the issue of scale has not been comprehensively tackled to inform on sustainable exploitation of subsurface. To bridge the shortcomings of sustainable management of the subsurface, theoretical formulations of sustainable scale in ecological economics are utilized to develop conceptual pathways for sustainable exploitation of the subsurface. A multi-functional perspective is derived from the conceptual pathways by applying it to the Campine Area in Belgium.

SDEWES2022.0335

A Conceptual Model for a Circular City

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Abstract

The importance and inclusion of cities in transforming the current standing of the economy in combating environmental and social dilemmas are on the rise. Simultaneously with the circular economy concept, a circular city concept emerged. There are several existing cities related concepts, such as smart cities or green cities, providing a good framework for future cities' development. However, these concepts have several limitations, discrepancies and gaps to be directly used for the circular city model. Thus, this paper addresses the deficiencies of the circular city model and focus on two specific issues: (1) firstly to identify crucial points and indicators that represent a city as circular and separate the circular city model from other similar city models and (2) secondly to incorporate those findings in conceptualizing a new model of a circular city by incorporating principles of Define-Measure-Analyze-Improve-Control process. Our methodology is based on the content analysis of a literature review of existing city models and indicators, using the Web of Science. We have used the review results to design a circular city model, using the Define-Measure-Analyze-Improve-Control process. The end model for a circular city depicts a holistic and circular approach. Each stage provides the needed steps for incorporating circular economy aspects into dynamic transformation of a city towards a circular one. This model eases the acceleration of cities' transformation and could provide a standardized form for policymakers and city legislative bodies.

SDEWES2022.0362

The Potential of Wind Energy Development in Poland in the Context of Legal and Economic Changes

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Abstract

The main topic of the work is the analysis of the development of wind farms in Poland. In addition, the aim of the publication is to assess the current development of wind energy compared to other renewable energy sources in Poland. As well as the comparison of the dynamics of development of this renewable energy source in Poland in relation to other European Union countries. The development of wind energy in Poland has been limited in recent years due to the legal regulations introduced in 2016. However, the current situation on the market of conventional energy resources and growing ecological standards may force dynamic changes in the legal solutions related to the possibility of building new wind farms.

This study was conducted and financed in the framework of the research projects: “Economic aspects of low carbon development in the countries of the Visegrad Group”, grant No. 2018/31/B/HS4/00485, “Socio-economic, environmental and technical determinants of the energy poverty in rural areas in Poland”, grant No. 2018/31/B/HS4/00048, granted by the National Science Centre, Poland, program OPUS, and “Economic conditions of energy storage in the context of the development of photovoltaic micro-installations in Poland”, grant No. 2021/05/X/HS4/01377, granted by the National Science Centre, Poland, program MINIATURA.

SDEWES2022.0474

Sustainability Integration in Supply Chain Management and Logistics Education in the Middle East

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Abstract

The global logistics industry grew significantly last decade, while logistics has become an essential part of the global business environment. Also, in the Middle East, the logistics industry plays a vital role in transportation development and urbanization. The Middle East logistics market is of significant size, and there is an increasing demand for adequate qualified people capable of managing the logistics systems and supply chains holistically and in a sustainable way. However, does logistic and supply chain education follow SDG goals, the rise of new trends and green technologies, or lag behind? This paper systematically analyses Middle Eastern countries regarding sustainability integration into higher education-related to supply chain, management, and logistics studies. It reveals enormous differences among countries and a lack of sustainability topics in most studied countries. Some countries are also significantly more oriented towards partial logistics challenges such as transport efficiency instead of sustainable supply chains, which are becoming one of the key challenges for the near future. Circular economy and corporate social responsibility are especially neglected. It was also revealed that sustainability integration in higher education is not directly related to sustainability scores and ranking of countries within the sustainability index.

SDEWES2022.0501

Modeling the Environmental Educational Video Materials: Rgb and Shot Length Analysis

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Abstract

In the era of social media and the dominance of video-based social media sites such as TikTok, short educational movies could serve as a powerful tool for the apprehension of environmental problems and the promotion of effective protection practices. According to System Theory, educational video can be observed as a complex system of various patterns of visual and acoustic codes that can be quantified and presented in the form of Ishikawa diagrams. Through the analysis of an award-winning educational short movie on environmental protection, this paper presents the development of models for educational movie production by combining theoretical concepts of message composition from communication theory with technical enhancements based on cinematics, psychophysiology and statistical methods derived from the simulation modeling. Analysis of the two technical characteristics of the movie: shot length and distribution of RGB color spectrum confirms explicated theoretical assumptions. Statistical analysis shows that technical transition points (represented by color equilibrium and inverse Gaussian distribution of shot length) correspond to the movie narration, color enhancements (peaks) are consistent with the elements of storytelling, and color patterns in the movie follow psychophysiological assumptions of the meaning of color, amplifying anticipated viewers response through unique distribution for each of the analyzed colors. Considering the acceleration of content production and the rising lack of focus of modern media consumers, the findings presented in this paper offer a useful tool for the development and production of educational and environmental video materials, its systematization, optimization, capacity to clarify complex environmental subjects and engage the various public.

SDEWES2022.0548

Climate Neutral Cities with a Gender Perspective: Assessing the Interaction Between Gender and Climate Objectives in Urban Policies

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Abstract

Gender studies have highlighted how policies and actions that are not drafted and planned with a gender perspective tend to produce a gender bias. Climate policies are not an exception. Measures to mitigate and adapt cities to climate change might lead to undesired outcomes regarding gender equality or, in contrast, may help to improve equality. Ideally, cities should prioritise actions that aim to reduce their carbon footprint but also help promote gender equality. We propose a Multicriteria Decision-Making Method to assess urban policies and relate them to climate and gender criteria. We describe policies for urban decarbonisation that have a non-negative outcome from a gender perspective, and compare their impact according to climate and gender criteria. To do so, we use a DEMATEL-ANP technique to determine how policies contribute to climate action and gender equality. Experts in the different areas and city planning respond to the DANP model by comparing and relating criteria and actions. Our results show which policies have a significant potential to reduce cities' carbon footprint and increase gender equality. Furthermore, comparisons are carried out to analyse on the one hand how the results differ when only gender or climate criteria models are considered, and on the other, how they differ depending on the expertise field. Regarding the former, we were able to conclude that the inclusion of gender criteria contributes to a more socially equitable decarbonisation.

SDEWES2022.0568

Visualization of Electricity Consumption Anomalies: End User Design Preferences and Triggered Emotions

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Abstract

Home Energy Management Systems (HEMS) show anomalies and unusual patterns of the electricity consumption of households, usually in the form of charts. Charts that show anomalies are very difficult to design in a way that is both comprehensible and visually appealing to users. However, visually appealing charts trigger positive emotions among the potential users, which in turn increases the intention to use HEMS.

Therefore, this study focuses on the visual appeal of different chart types as well as which emotions they trigger.

A two-part study was conducted to investigate this research gap. The first part of the study was an online experiment in which 626 participants had to rate different chart types of electricity consumption data. The participants were randomly assigned to one of three commonly used chart types (bar, line or rose chart) that showed anomalies concerning the energy consumption of a household. The participants had to indicate which chart type they preferred in terms of visual appeal.

The second part of the study was an eye-tracking study with 50 participants. The same chart types as in the first part of the experiment were used and participants had to complete three search tasks in one of the randomly assigned chart types. A facial expression analysis was also carried out within this experiment to analyze the emotions that are triggered by the different chart types.

Both experiments show that the line and bar charts are preferred in comparison to the rose chart. The line chart triggered the least negative and the most positive emotions and was rated the most visually appealing, followed by the bar chart. Bar and rose charts triggered more negative emotions in comparison to the line chart.

HEMS providers can utilize these findings to ensure long-term product usage and hence encourage users to adopt sustainable energy consumption behaviors.

SDEWES2022.0604

Towards Sustainable Entrepreneurial Education

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Abstract

“The future of the planet is in the hands of young people”; that’s what we often hear from our political leaders. This is particularly true today, due to the big changes we see happening in the world: extreme weather events, the pandemic and international conflicts affect the world economy. Young people have realized that they will need to be more active in the economy and society to ensure a better future for them and their children. Innovation through entrepreneurship is seen as one of the driving forces for the transformation the youth imagine in the world: try to make better or faster and create a more connected world. However, entrepreneurs often don’t consider the impact of their new technology idea on the planet: How will the use of my product impact the user’s carbon footprint? What resources are required to manufacture it and from where will they be sourced? What is the lifecycle of my product? How will it be discarded after its use?

Entrepreneurial education has an increasing place in Europe’s and the world’s HEIs, as we aim to inspire and nurture students to identify challenges in their environments and imagine adequate solutions. Inno-EU+ is an EIT HEI Initiative project, under the EIT Climate-KIC umbrella, which aims to increase the Innovation and Entrepreneurial capacity of HEIs across Europe. Seven HEIs (also members of the European University of Technology Alliance) and two Cleantech Accelerators make up the Inno-EU+ consortium, built with the aim of integrating the EIT’s knowledge triangle: Education, Innovation and Business creation. In the context of Inno-EU+, we have implemented the Climate Entrepreneurship Training, based on the content of the ClimateLaunchpad competition, in order to give to our students some basic entrepreneurial skillset and support them through the process of an early stage idea development program. During this training we aim to also make them think all the appropriate questions regarding the impact of their idea on the environment.

The mixed methods data collection we have conducted already shows a positive impact on the students’ entrepreneurial mindset. The improvement of their understanding of the climate impact of their ideas is an issue that is currently analyzed until the end of Inno-EU+ in June 2023.

Hybrid and electric vehicles

SDEWES2022.0216

Optimized Heavy-Duty Hybrid Powertrain Intended for a Future Articulated Forestry Tractor

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Abstract

Forestry vehicles have been increasingly equipped with hybrid electric power-trains in order to provide significant gains in fuel economy, and also to facilitate reductions in greenhouse gases emissions. Due to the fact that hybrid power-trains consist of two or more different energy sources, many questions in terms of power-train components sizing and energy management control are opened, and all of them have influence on the power-train purchase cost and operating efficiency. Therefore, this paper propose an combined optimization approach of powertrain components size along with energy management rules. The hybrid skidder powertrain components are optimized by parametric optimization algorithm with the aim to minimize their size while maintain comparable traction characteristics as conventional forestry vehicle. Optimal control rules are also optimized by recently introduced cascade optimization algorithm with the aim to reduce powertrain fuel consumption. The obtained optimization results are verified by a comprehensive computer simulations, and are also used to gain insights about the possible advantages of optimized powertrain in terms of fuel consumption reduction and related CO₂ emissions. The optimization results are also used to provide recommendations for design of a realistic (online) control strategy.

SDEWES2022.0235

Optimized Control Strategy of Hybrid Skidder Based on Realistic Operating Cycles

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Abstract

Increasing demands in terms of reducing the cost of running forestry machines along with the regulatory pressures for lower exhaust emissions encourages the usage of hybrid powertrains in field applications. Hybrid power-trains consist of two or more different energy sources, which leads to many open questions in terms of energy management control, which have significant influence on the power-train, efficiency, fuel consumption and consequently on the operating cost and emissions of greenhouse gasses. Therefore, this paper propose the optimal energy management control strategy intended to be used in hybridized articulated forestry tractor, also known as skidder. The proposed control strategy is verified on the previously developed skidder model by a comprehensive simulations over realistically recorded field data. The simulation results are used to gain insights about the possible advantages of proposed optimal control strategy in terms of feasible reduction of fuel consumption and related CO₂ emissions.

SDEWES2022.0253

Economic and Technical Analysis of a Hydrogen Refueling Station, in an Italian Scenario

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Abstract

In this study we will evaluate the characteristics of an Hydrogen Refueling Station (HRS) capable of delivering a daily quantity of hydrogen able to satisfy a fleet of vehicles / trains whose hydrogen needs are known. In particular, we evaluate the technical - functional aspects of a system capable of delivering hydrogen at a pressure of 350 and 700 bar, which are the present standards for vehicles. Besides, we assume that hydrogen is produced by electrolysis of water performed using electricity produced by a wind power plant, a photovoltaic plant or provided by the national electricity grid.

To estimate energy needs and storage systems, a numerical model is used to optimize the size of the wind farm and the photovoltaic system serving the Electrolyser and all the components of the HRS; this model will be capable of minimizing the volume of the tanks of storage and maximize the use of electricity produced from renewable sources. The location of the electricity production site is known as well as the wind and irradiation values. In particular, the chosen site is in Southern Italy, near Catanzaro Lido. The numerical simulation defines the peak powers to be installed for the two electricity production systems (wind and photovoltaic ones), as a function of the energy that can be produced for the chosen site in correlation with the needs of the HRS and the hydrogen storage limits. Then the model will evaluate the electricity to be supplied by the national grid. The study, known the characteristics of the HRS and of the two electricity production systems, will provide an economic analysis about the installation and operating costs (Capex and Opex), for an estimated life of the 20-year facility and assuming an interest rate of 4%. In this way, the price of hydrogen at the pump can be estimated (in € / kg). Finally, the study will provide the values of CO_{2eq} emissions per unit of mass of hydrogen produced.

SDEWES2022.0339**Generation of Synthetic Load Profiles of Electric Vehicles Based on Household Activity Profiles**

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Abstract

E-mobility is a major challenge for distribution network operators. The high power demand of electric vehicle charging wall boxes will increase the load in low-voltage grids in the future. In order to avoid grid overload, distribution system operators must develop suitable measures. Their development requires elaborate simulation environments which in turn create a need for realistic charging profiles of electric vehicles.

The goal of this work is to develop a charging profile generator for e-mobility. The charging profiles of a household are derived from activities of household members inside and outside the household in order to achieve realistic load timelines. Based on the study “Mobility in Germany from 2017” (MiD2017), the mobility behaviour of different types of households in seven different types of regions, such as metropolitan areas, regional cities, large cities, medium-sized cities, and rural areas is analysed and then categorised into different groups. For each simulation, the age of the inhabitants, size and occupational status of the households are recorded. Furthermore, the synthetic charging profiles are generated based on input parameters such as share of e-vehicles in the area, mobility behaviour of households, average battery capacities of e-vehicles, different charging behaviour of households, and average charging powers of wall boxes.

An existing load profile generator (Pflugradt, 2016 [1]) is used as the basis for related household profiles without e-mobility. It generates individual load profiles based on a behavioural model. These generated household load profiles are analysed and used as the base to generate charging profiles which are synchronised with the household load profiles.

The charging profile generator is implemented in Python. Figure 1 gives an overview. The generated profiles have a time resolution of one minute. A Constant Current Constant Voltage charging algorithm (Fasthuber, 2019 [2]) is implemented. Thus, a realistic charging behaviour of lithium-ion batteries is emulated.

Different scenarios can be created, which include worst- or best-case scenarios or scenarios corresponding to MiD2017. Thus, the average mobility behaviour of the respective region can be represented. The presented charging profile generator allows simulation based research for low-voltage grids in different regions with heterogeneous household types and corresponding mobility behaviour.

SDEWES2022.0355

Ecological Footprint of Electric Vehicles Considering Sector Coupling with Bidirectional Charging, Battery Recycling, and Second Life Usage

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Abstract

The transport sector is responsible for 23% of global CO₂ emissions (IEA, International Energy Agency, 2021a). In the European Union, this share is 25,8% (European Commission, 2021), and in Germany 19% (Umweltbundesamt, 2022). In the course of decarbonising all energy sectors, at least individual mobility is moving towards battery-electric vehicles (BEV). The BEV is in focus of the climate protection goals of various countries to contribute to the achievement of defined greenhouse gas reductions. To this end, countries are striving to achieve CO₂ reductions in their transport sector in order to counteract climate change in this area as well (Die Bundesregierung).

As e-mobility advances, its contribution to greenhouse gas emissions - and how it compares to conventional combustion engine driven cars - is a recurring topic of discussion. BEVs are repeatedly criticised in this context.

Calculations and comparisons are often made without taking the energy transition process into account and, on the one hand, assuming high emissions from the electricity sector both in battery production and during car operation. Secondly, only the mobility sector is considered and the possible services for the electricity sector are not considered. This publication presents a methodology for assessing the emissions of BEVs that considers the effects on the different energy sectors. In addition, the impact on the emissions of the usage of batteries in 2nd life as well as the usage of batteries from recycling processes is analysed. Finally, the impact of sector coupling with bidirectional charging on the BEVs emissions is discussed. The publication concludes with the results obtained using this methodology.

SDEWES2022.0484

The Development of the Electric Bus Fleet of Public Transport: the Evidence from Poland

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Abstract

The development of urban bus transport is currently one of the most important issues related to the improvement of the quality of life in Polish cities. The aim of the publication is to analyze the development of low-carbon city bus transport in Poland, with particular emphasis on electric buses. The paper analyzes the measures taken to limit the emission of harmful substances into the air by modernizing the electric bus fleet of public transport. The study also highlights economic constraints that adversely affect the development of the electric bus fleet of public transport.

This study was conducted and financed in the framework of the research projects: “Economic aspects of low carbon development in the countries of the Visegrad Group”, grant No. 2018/31/B/HS4/00485 and “Economic conditions of energy storage in the context of the development of photovoltaic micro-installations in Poland”, grant No. 2021/05/X/HS4/01377, granted by the National Science Centre, Poland, program MINIATURA.

Modelling for pollution avoidance and energy efficiency

SDEWES2022.0078

Cost Reduction and Effluent Quality Improvement for the Wastewater Treatment Plant by Optimization Based on Artificial Neural Network Models

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Abstract

Accurate models of the wastewater treatment plant (WWTP) are appreciated components of digital water and clean energy trends. The complexity of the WWTP bio-chemical processes lead to a challenging task for improving the plant performance. Artificial intelligence techniques are known to offer promising solutions for achieving this task.

In the current study, WWTP prediction models for a set of WWTP performance indices were developed using artificial neural networks (ANN). Several types of ANNs were considered: time-delay neural networks, recurrent neural networks, radial basis neural networks and generalized regression neural networks. Data used for the ANN model's development were obtained from simulations with an extended Benchmark Simulation Model No. 2 (BSM2), including the Activated Sludge Model No. 2d, considering WWTP influent and control variables. The outputs of the models are Effluent Quality Index and other energy performance sub-indices of the Overall Costing Index. Mean absolute percentage error (MAPE) at prediction was chosen as evaluation criteria of the ANN model's accuracy.

The investigations of both single and multiple outputs ANNs revealed good prediction accuracy, with MAPE values below 6. Two structures of ANN were further used for WWTP optimization of the two indices. The first structure consists of the best performing single output ANNs for each predicted index, while the second structure consists of the best multiple output ANN. The further use of ANN models for WWTP optimization, resulted in both reduced costs and improved effluent quality, succeeding also to diminish the computation time for WWTP optimization by more than two orders of magnitude. The ANN model-based optimization results showed comparable results to those obtained by optimization using the first principle model BSM2, hence validating the ANN training. The results obtained by the proposed ANN development methodology demonstrate the potential of ANN models for real-time implementations and their applicability in WWTP online plant optimization.

SDEWES2022.0119

Dynamic Simulation of Particle Deposition on the Blade Leading Edge of Film-Cooled Gas Turbine

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Abstract

Particle deposition on the leading edge was investigated in gas turbines numerically. The effects of inclination angle and blowing ratio on the deposition thickness of the leading edge are studied. Particles were released from the inlet of the computational domain, which is used to simplify a cascade in the gas turbine. The deposition thickness on the leading edge was determined using the double deposition model. Results show that the deposition thickness decreases with the increase in blowing ratio. The deposition thicknesses for 0°, 20°, 40°, and 60° inclination angles decrease by 7.82%, 6.84%, 7.44%, and 5.34% when the blowing ratio increases from 0.5 to 2.0 at 30 s. The deposition thicknesses with four inclination angles decreased by 6.79%, 7.24%, 6.79%, and 5.34%, with the increase in blowing ratio from 0.5 to 2.0 at 60 s. A region with deposition thickness coefficients below 0.3 is located on the side of the leading edge. The area of the region increases with the increase of inclination angle and blowing ratio.

SDEWES2022.0248**A Coupled Building Energy Simulation (Bes) and Computational Fluid Dynamics (CFD) for the Evaluation of the Exterior Convective Heat Transfer Coefficient and Energy Performance of a Multi-Zone High-Rise Building**

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Abstract

The increasing urbanisation in recent decades has led to the accelerated construction of high-rise buildings in major urban cities. This has prompted attention to the energy performance as well as the environmental impact of high-rise buildings. Tools such as building energy simulation (BES) support the energy-efficient design and optimisation of buildings. However, the convective heat transfer coefficient (CHTC) used in BES has been shown to be inaccurate by lots of studies. This is crucial for high-rise buildings with rooms or spaces having unique surrounding wind environments and microclimate conditions, which could impact the predicted energy performance. This study developed a BES and computational fluid dynamics (CFD) coupled model of a high-rise office building using EnergyPlus and ANSYS Fluent to understand the changes regarding exterior convective heat transfer coefficients (CHTC) as well as cooling energy demands at different building storey during a typical summer period. The information on heat transfer is exchanged during the co-simulation through a middleware Building Controls Virtual Test Bed (BCVTB) and MATLAB at each time step. The impact of different meteorology variables, including wind speed, wind direction, and dry bulb temperature, were investigated. Results indicated that the wind speed has a strong and positive impact on the average exterior CHTC. While the impact of wind direction on the exterior CHTC varies according to different storeys and building orientations. The differences between coupled model and EnergyPlus using the DOE-2 model of average CHTCs in different orientations clockwise from North to West are 38.42%, 52.00%, 74.04%, 55.47%, respectively, for the high-rise building located in Hong Kong. CHTC varies in sections along with the building height and is influenced by both wind speed and wind direction. Due to the differences in exterior CHTC, the calculated average difference in cooling load is 2.47% per storey.

SDEWES2022.0273**Kinetic Study of N₂O Decomposition in Pressurized Oxy-Combustion**G. Dai¹, X. Wang^{*1}, J. Zhang², H. Mikulčić³, H. Tan¹¹Xi'an Jiaotong University, China; ²Xi'an Jiaotong University, China; ³University of Zagreb, Croatia (*wx005@mail.xjtu.edu.cn)**Abstract**

Pressurized oxy-combustion is regarded as a promising carbon capture technology. During fluidized bed combustion, coal and biomass are prone to producing a large amount of N₂O. The Global Warming Potential of N₂O is 300 times greater than that of CO₂, so controlling N₂O emissions is critical to reducing greenhouse gas emissions. In this paper, The N₂O emission in pressurized oxy-combustion was calculated by CHEMKIN. The results show that in pressurized oxy-combustion, the time required to reach equilibrium is reduced. When compared to traditional air combustion, the complete decomposition temperature decreases as pressure rises, and in pressurized oxy-combustion, it can reduce by as much as 100 °C. As the pressure rises, N₂O decomposes more rapidly and is converted to N₂, NO and a trace of NO₂. When the CO concentration in the flue gas is high, the complete decomposition temperature of N₂O can be reduced to 700 °C. H₂O addition can also reduce the complete decomposition temperature of N₂O, while the decomposition ratio is not sensitive to H₂O concentration. Furthermore, the H₂O addition could result in N₂O converting to N₂ and only a trace of NO. The complete decomposition temperature of N₂O is reduced to around 800 °C in pressurized oxy-combustion, implying that low N₂O emissions can be achieved at conventional fluidized bed operating temperatures.

SDEWES2022.0296**Inter-Unit Transmission of Pollutants in Naturally Ventilated Buildings Adjoining a Street Canyon: a Parametric Study**

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Abstract

Air quality is an important determinant of human wellbeing, and poor air quality is a major environmental concern in many places around the globe. The recent pandemic has highlighted the infectious nature of airborne diseases, especially in dense urban areas. Indoor occupants were advised to ventilate their spaces naturally as it prevents built-up of pollutants and can generate better air quality as compared to mechanical mode. Most studies on natural ventilation have been limited to energy demand and sustainability. However, the risk of cross-transmission between closely located indoor units has not been dealt with in detail. It is paramount to understand the pathways of pollution transmission to design safer cities. Past studies have majorly investigated pollution dispersion in outdoor areas, while a few studies have investigated cross-transmission in isolated buildings. However, the street canyon represents a major share of urban features in dense cities characterised by extended built-up areas. The inter-unit spread of pollutants in this urban configuration has not been studied in detail and requires a thorough examination to understand its challenges and benefits.

This study aims to evaluate the inter-unit transmission of pollutants inside an idealised street canyon using 3D Computational Fluid Dynamics (CFD) modelling with a pollution dispersion model. 18 indoor units were modelled inside two buildings, on either side of a long street with a ratio of $L/H=10$. Average indoor pollution was modelled as point source emission inside the room. The numerical model was validated against experimental observations. A parametric assessment was conducted of the ventilation mode, canyon aspect ratio, wind speed and wind direction, to identify the role of urban and ambient conditions.

The analysis has identified that ventilation mode is responsible for establishing cross-transmission routes between a few specific units in the street. The contamination is aggravated under a higher aspect ratio and lower wind speeds. Contamination is usually higher in units with low ACH, and improving the airflow can reduce the concentration. Centre rooms are especially critical, as pollutants from the corner units are transferred to rooms in the centre. Future studies should look at investigating the influence of street intersections and building roof shape on the transmission and accumulation of pollutants in indoor environments.

SDEWES2022.0314**Thermo-Fluid Dynamic Analysis of the Air Flow Inside an Indoor Vertical Farming System**G. Agati^{*1}, B. Franchetti², F. Rispoli³, P. Venturini¹¹Sapienza University of Rome, Italy; ²Agricola Moderna, Italy; ³University "Sapienza" of Rome, Italy (*giuliano.agati@uniroma1.it)**Abstract**

Sustainability of resources in the food production system and in the agriculture sector is a key factor in the decarbonisation process we globally have to face. Controlled-environment vertical farm systems allow to optimize resources saving and lead to a continuous, safe and high quality production throughout the year. However, micrometeorological parameters need to be accurately monitored since the quality of the grown plants are strongly dependent on the surrounding air flow field. In the present work, the thermo-fluid dynamic behaviour of an indoor vertical farming system is assessed using computational fluid dynamics (CFD). Experimentally driven three-dimensional k- ϵ steady simulations have been performed in Ansys Fluent. Species transport model is also used to account for the relative humidity. In-field sensors measurements permitted to accurately set the boundary conditions of the problem and to validate the obtained results in terms of temperature and humidity distribution within the growing cell. The whole cell, consisting in 8 levels of tables where plants are grown, are here simulated in day conditions, i.e. LED lights heat sources are taken into account in the thermo-fluid dynamic air flow field. The full air ventilation and conditioning system is simulated. This includes two evaporators needed to cool down the air heated by the LED lights and two dehumidifiers aiming at removing the humidity released by the plants. Eight fans, placed on the top of vertical perforated balloons suck the air released by the evaporators and distribute it to every single growing table. Adopted methods and models are presented and discussed. Results helped in understanding the air flow main features. Air flow uniformity was evaluated by means of two dimensionless objective uniformity parameters, used to compare the velocity distribution with a target air speed and with the average table air velocity. A growing table efficiency index is defined by combining these two parameters. The analysis of these indices helped in enlightening critical differences in the fluid dynamic behaviour of upper and lower cell floors and demonstrated some deficiencies of the adopted ventilation system in providing uniform air conditions to all the growing tables. The comparison of the numerical results with measurements shows the ability of the numerical approach to characterise the thermo-fluid dynamic flow field of the indoor farming system in most of the domain. Well-calibrated CFD simulations demonstrated to be a reliable tool to control the air flow distribution in indoor farming systems, necessary to reduce the energy consumption and to improve the quality of the plants growth.

SDEWES2022.0563

Towards an Accurate Particle Motion Model Applicable to Simulation and Optimization of Biomass Suspension Burners or Boilers

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Abstract

The increased threats of climate change and fossil fuel depletion greatly stimulate large-scale widespread use of renewable energy sources. Biomass is the most abundant renewable energy source. Among all the biomass conversion technologies, directly burning biomass for heat and power generation is the most common and cost-effective route to turn biomass into energy. In existing biomass-fired power plants worldwide, suspension firing prevails, in which modelling plays a key role in better understanding and optimizing the combustors. However, the commonly used modeling routine does not adequately address the differences between coal- and biomass-firing, especially the significant impacts of large particle size and highly non-spherical shape of biomass particles compared to the tiny spherical coal particles.

In this paper, a new closed model, very different from the commonly used modeling routine, is developed and presented, which simultaneously solves the coupled translation and rotation of non-spherical particles. The model accurately reproduces the experimental data of cylindrical particles in a water flow. In order to further improve the accuracy and applicability, especially to simulation and optimization of biomass suspension combustors, new correlations of drag, lift and torque coefficients recently published in the literature, applicable to a wider range of particle and flow conditions, are revisited and summarized, which will be implemented into the closed model framework. From this, a closed model which can be used for model accurate simulation and optimization of biomass suspension combustors is expected.

SDEWES2022.0589

Suitability of Pod for Airflow Estimation in a Room with Multiple Unidirectional Air Diffusers

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Abstract

Although the computational power is increasing constantly, numerical modeling of turbulent and multiscale flows, as well as multiphysics and flow separation are still computationally expensive, requiring a couple of millions degrees of freedom, powerful CPU and hardware architecture. In the case of design optimization, flow control, or sensitivity analysis the problem of computational power becomes even more evident. Therefore, reduced order models (ROMs) are being extensively developed in the last decade. One of the most frequently used approaches to ROM generation is proper orthogonal decomposition (POD). It is used as the optimum between accuracy and the required amount of data for ROM generation. Nevertheless, the complexity of the problem significantly affects the accuracy of the POD approach. This paper aims to determine if it is possible to reproduce multi-species flow (CO₂ and air mixing) with POD and to what extent the number of input parameters affects the required number of simulations for the offline part of parametric ROM generation on the example of a room with two unidirectional inlet diffusers and two exhaust bar diffusers. The results of the reduced order model were compared with the CFD results in terms of accuracy.

SDEWES2022.0592

A Simplified Human Model for Experimental and Numerical Analyses of Ventilation Impact on Airborne Transmission

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Abstract

Current guidelines on control measures for preventing the spread of coronavirus show no consensus regarding the impact of ventilation on virus dispersion in a closed environment. Even though much research has been done to define this impact, the type of ventilation and airflow rates most appropriate for specific applications remain unclear. Several key aspects are crucial in ensuring the exactness and validity of the research: ventilation parameters, the airborne transmission modeling technique, and the focus of this study which is the human models. This paper aims to give practical guidelines for a simplified human model designed for experimental and numerical research. Here we show that a simplified human body geometry combined with a heat source can achieve an appropriate balance between feasibility and accuracy. The most important features of the human model are discussed and explained thoroughly, with the temperature stratification above the model of particular importance. We believe that the proposed guidelines contribute to better consistency and feasibility of further research and, consequently, lead to more suitable safety measures for the current and future pandemics.

SDEWES2022.0629

Low-Pressure Sprays Formed by a Two-Hole Injector Under Flash-Boiling and Cross-Flow Conditions

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Abstract

The flash-boiling phenomenon is already well known as a method to alter spray formation. When well prepared, this process provides enhanced liquid evaporation and intense atomisation, resulting in smaller droplets and making the mixing process faster and more uniform. On the other hand, in many practical devices, e.g. urea-SCR (selective catalytic reduction) aftertreatment systems, the liquid is injected into cross-flowing gas, and the group of small droplets is more likely to be dragged away by the cross-flow. This, in turn, may have a negative effect on the gas-liquid mixing process.

The vast majority of studies on flash-boiling sprays were performed in quiescent conditions, and the cross-flow hasn't been deeply evaluated. Therefore, the objective of this study is to investigate superheated liquid injections into cross-flowing air to understand the interaction between flash boiling and the cross-flow.

A series of experiments on low-pressure sprays formed at subcooled and flash-boiling temperatures in quiescent and cross-flow conditions was performed to analyse the cross-flow effect on the spray structures and the droplets' drift. The sprays and their drift were observed using high-speed imaging with global illumination. The results were analysed in terms of synergy between the flash boiling and the cross-flow. The experimental results were compared with the CFD (computational fluid dynamics) model predictions.

The experimental results showed that the interaction between flash boiling and the cross-flow in the case of low-pressure sprays is strong. Due to the substantial reduction of the unbroken liquid length and the droplet size, and thus the increasing importance of the aerodynamic drag, in flash-boiling conditions, the interaction between the cross-flow and the sprays is entirely different compared to subcooled injections. The model could accurately represent the experimental results, provided critical model-input data was initially measured experimentally.

Renewable electricity generation systems

SDEWES2022.0004

Environmental Impact of Hcpv Module Combining Space-Grade Solar Cells and Optical Micro-Tracking

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Abstract

To meet the growing needs of the market, the global energy supply system needs to be transformed due to limited resources of fossil fuels. To eliminate disadvantages and highlight the advantages of solar power systems, especially highly concentrated photovoltaic (HCPV) as hybrid technology has been developed. Concentrated photovoltaics system offers many benefits compared to conventional technology, e.g., relatively high conversion efficiency, reduction of the cost by replacement expensive components and elimination toxic materials, especially involving in solar cell production. HIPERION Horizon2020 project (<http://www.hiperion-project.eu/>) meets a challenge of breaking the efficiency ceiling of silicon panels. The main goal of the project is to deliver unique and highly efficient solar modules capable of providing real-time record of energy generation per m², between 50% and 80% depending on weather conditions. The goal is to be achieved through design a disruptive solar photovoltaic module, based on the planar optical micro-tracking, which concentrates sunlight on multi-junction solar cells on top of a conventional silicon backplane, integrated within a static frame. The technology is based on a combination of optics, space-grade solar cells and micro-tracking.

Rapid development of HCPV technology brings benefits mainly by increasing efficiency of systems, but also requires an environmental impact assessment. In the frame of the HIPERION project LCA analysis (Life Cycle Assessment) for new PV technology was performed. The goal of the LCA study was to determine the environmental impact due to HCPV panels production. In the LCA calculations the full module was adopted as functional unit. SimaPro version 9.00.49 and the recent Ecoinvent database was employed to perform the calculations. SimaPro contains several impact assessment methods, which are used to calculate impact assessment results. For the presented work the IPCC 2013 GWP 100a method was used. This method lists the climate change factors of IPCC with a timeframe of 100 years and expressed the LCA results in terms of kg CO₂-eq. Based on the performed analysis it was found that, the biggest load was generated by PV cells (58%), Poly(methyl methacrylate) (20 %), aluminium alloy (8%) and solar glass (3%). PV cells produced decisive contribution to the environmental load of the module: 114 kg CO₂ eq. (58 %), due to large amount of the materials covering 0.68 m² area of the module. Assuming energy yield, the emission of CO₂ g eq/kWh over the 25 years lifespan for the analysed module was determined for 16,8 to 22,9, depending on the location. The paper presents also analysis of environmental load for supply chain from Europe and from global market.

SDEWES2022.0120

Electricity Production and Storage System Using Parabolic Trough Solar Collectors and Transcritical CO₂ Brayton Cycle

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Abstract

The paper presents the results of thermodynamic analysis of a compressed carbon dioxide energy storage installation using isobaric carbon dioxide tanks. In the system, thanks to the use of the Parabolic Trough Collector system as an external heat source for the Brayton cycle, it is possible to produce electricity. The article presents the results of analysis for two sub-systems, i.e. Energy Storage Sub-system and the Parabolic Trough Collector Sub-system. These subsystems are integrated into one hybrid system. A thermodynamic analysis was carried out to determine the basic parameters of the installation, such as the electricity consumption during the charging period and the electricity production during the discharging stage. As part of the analysis, three cases of the system structure were examined, equal to the number of sections used within the expander. The analyzes allowed for the assessment of the impact on the basic thermodynamic indicators, including the efficiency of energy storage, such as parameters such as CO₂ storage pressure in a high-pressure tank, CO₂ pressure in a low-pressure tank, and CO₂ heating temperature supplying the expander sections. The analyzes were based on the models of two subsystems.

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Negative Emissions Power Plant Based on Flexible Calcium-Looping Process Integrated with Renewables

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Abstract

This paper proposes an innovative negative emissions power plant, combining the generation and storage of energy from biomass, photovoltaic, and concentrated solar power, capturing and recovering CO₂ through the production of H₂ or CH₄ as green energy carriers. The main features of the system are: i) large-scale energy production system with negative CO₂ emissions; ii) 100% renewable system based on biomass and solar energy with the possibility of integrating other renewables; iii) synergistic integration of processes and systems; iv) recovery of O₂ generated by photovoltaic-driven electrolysis within the process of partial biomass oxycombustion and v) solar-driven limestone calcination. A detailed model of the entire plant is developed to evaluate the integration of the process. The model performance is assessed on an hourly basis throughout the whole year. The results show an energy consumption associated with the capture process of around 3 MJ/kg CO₂ and green methane production of more than 7000 tons/year, which justifies the interest in the proposed negative carbon dioxide emissions power plant.

SDEWES2022.0295

Environmental Benefits for a Geothermal Power Plant with CO₂ Reinjection: Case Study of the Kizildere 3 U1 Geothermal Power Plant

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Abstract

Geothermal power plants (GPP) with high non condensable gases (NCG) content geothermal fluid have shown to be environmental impacting relating to their energy production, which could be critical if no corrective actions are achieved.

The GPP of Kizildere 3 U1, located in Turkey (Denizli) is taken as a relevant case study. The plant was commissioned in March 2017 and is a triple flash and a binary combined cycle plant with 99,5 MWe capacity. The GPP of Kizildere 3 U1 is intended to implement a new innovation consisting of NCG reinjection in the geothermal brine through a reinjection well to reduce the amount of NCGs released to the atmosphere.

In order to calculate the present environmental impacts which, the plant is incurring (baseline); and the potential reduction of environmental impacts which can be achieved by innovation (reinjection), a Life Cycle Assessment (LCA) calculation were developed. Primary data were collected for all the relevant stages of the energy conversion cycle and complemented where necessary with secondary data from other flash power plants studies.

The main results of the baseline environmental assessment show that the construction phase is the most impacting phase due to the materials used in the power plant building construction, electrical generation equipment and distributed machinery and infrastructures; the effects in the operation phase are dominated by the geothermal fluid composition. In this sense, the NCG reinjection system will prevent 877 to 4385 ton CO₂ annually of release of NCG to the atmosphere, which will reduce consistently the environmental impacts of the GPP plant.

SDEWES2022.0390**Co-Simulation Work to Assess Conventional Exergy Performance of a Hybrid Energy Generation-Vanadium Redox Flow Battery System**M.S. Yesilyurt¹, H.G. Ozcan^{*2}, H.A. Yavasoglu³¹Yildiz Technical University, Turkey; ²Bahcesehir University, Turkey; ³Yildiz Technical University, Turkey (*ozcanhuseyingunhan@gmail.com)**Abstract**

Renewables play a key role in achieving the sustainable development goal for energy that aims to ensure access to affordable, reliable, sustainable, and modern energy for all. Meanwhile, energy storage is widely adopted for renewables due to its intermittent nature. Among these, vanadium redox flow batteries (VRFBs) are a promising technology due to their superior features such as design flexibility, low cost, and indefinite lifetime. In this study, solar PV field-wind turbine energy generation (SWEG) with a VRFB system was assessed through co-simulated (TRNSYS integrated with MATLAB Simulink) works based on the conventional exergy analysis method. Due to the lack of an advanced VRFB model in the TRNSYS program, the battery model developed in the MATLAB Simulink environment was used. On the other hand, SWEG was modelled through the TRNSYS software package where VRFB was called by using the TRNSYS utility model. With the conventional exergy analysis, the exergy destruction rates of each system component (PV panels (PV), inverter/regulator (IR), wind turbine (WT), rectifier (R), VRFB and air source heat pump (ASHP)) were determined, therefore the irreversibility (loss in work potential) occurring in these components were identified. Based on the monthly obtained results, the improvement potential was found to be highest in ASHP having an exergy efficiency of 11.61%, followed by solar PV field (13.74%), WT (33.89%), VRFB (72.77%), R (91.11%) and IR (93.77%), respectively.

SDEWES2022.0395

Modeling and Simulation of a Floating Photovoltaic Unit of 500 kWp Installed on a Hydropower Plant Reservoir

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Abstract

Utilization of photovoltaic systems on water bodies offers an enormous potential for many countries worldwide. Actually, an interesting application considers their installation on hydropower plant reservoirs. The related term used nowadays is floating photovoltaic systems. One of the main benefits associated to them, is that through their contribution they open a path to the energy transition on a national scale. In the future, is foreseen that floating photovoltaic systems will offer their share and contribution on achieving targets related to the contribution of renewable energy on electrical energy generation. The utilized platforms are different on size, forms and design. There is very little data related to circular membrane units. In the present work the modelling and the simulation of a floating photovoltaic plant is carried out. The modelled unit is newly installed and has a peak power of 500 kW. It is a trial unit installed lately, which consists of a circular membrane. The PVSYST tool is utilized for this case study. The obtained results include the monthly values of energy injected into grid, energy at the output of the array, final yield, the reference yield, performance ratio. Also, the annual energy balance for the modelled unit is shown. The obtained results will be valuable to offer their contribution on the future predictability.

SDEWES2022.0526

A New Original Software for the Techno-Economic Analysis of Small Hydropower Plants

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Abstract

Project SMART (Strategies to Promote Small Scale Hydro Electricity Production in Europe) from the Intelligent Energy Europe (IEE) program, in which 7 institutions from 5 European states participate, pointed out the important barriers to the expansion of small hydropower plants (SHP) in Europe: the lack of suitable support methodologies and tools; the complexity of the legal/administrative processes to obtain concessions, and the economical/financial attraction of private investors. One of the main barriers is the lack of suitable methodology and tools (computer programs) able to create a clear view of the small hydropower potential in the given territory, as well as a complete techno-economic analysis for a certain location. Although, in the world, there are a certain number of computer programs for this purpose, which will be presented in the paper, but they are not able to take into account all the specifics of watercourses. A new original numerical tool (software) for the techno-economic analysis of small hydropower plants is developed and will be presented in this paper. In the software, the current knowledge and technical developments in the field of small hydropower plants are incorporated (e.g. the newest types of hydraulic turbines for small hydropower plants). The interface of the software is also designed to allow appropriate application. The program is very useful for experts in the field of small hydropower plants, but also much wider, for decision-makers, potential investors, and stakeholders. It will improve water resources management, disseminate opportunities to investors and increase the interest of stakeholders to invest in SHP, resulting in their wider use. The software will be tested in several locations for SHP in the Republic of Croatia.

SDEWES2022.0533**A Biomass Small - Scale Externally Fired Gas Turbine Plant for Distributed Generation of Electricity**E. Barić¹, Z. Guzović*², M. Barbarić³¹Zagreb University of Applied Sciences, Croatia; ²University of Zagreb, Croatia;³Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Croatia (*zvonimir.guzovic@fsb.hr)**Abstract**

The worldwide concern about global warming and the limited availability of fossil fuels have motivated the use of biomass for energy production. Biomass is a renewable source of energy. It includes forest and agricultural biomass, biomass generated during production processes in various industries or waste in the sense of municipal waste, water treatment and sewage sludge and the like, and it can also be grown on energy plantations (e.g. fast growing plants). It can be used to produce heat and electricity. Among the technologies for electricity generation from biomass, small Externally Fired Gas Turbine (EFGT) plants are receiving some attention as they offer the possibility of burning dirty fuels such as biomass in situ (great fuel flexibility). Externally or indirectly fired gas turbine means that hot combustion products do not come in direct contact with the turbine, which operates with a different working fluid; the flue gas thermal power is transferred to the working fluid through a high temperature heat exchanger. Hence, combustion takes place at atmospheric pressure without any need for fuel compression and injection equipments. The use of clean air as a working fluid simplifies plant maintenance and extends the life of the turbine. It also provides the flexibility of utilizing any type of biomass with or without the use of gasification process. The main issue of gasification process is the tar and particles contamination in the producer gas (PG) fuel after the gasification. This leads to the use of an elaborate and costly PG cleaning systems with high maintenance requirement, which could be entirely avoided by the use of externally fired gas turbine (EFGT) configuration. In the case of electricity production in higher power plants, it is not always possible to consider biomass as a cheap fuel due to the costs of collection and transportation. Therefore, it is expedient to install small-scale plants at the place where biomass is produced, for distributed generation of electricity (and heat at combined plants), for example in rural areas. On that way, the EFGT cycle attempts to combine the advantages of gas turbines (low operational costs, high lifetime and reliability, relatively high energy efficiency even at small size) and the capability of dealing with low quality biofuels. In the paper authors propose a small-scale gas turbine plant of 100 kW power with novel design of turbine with air as the working fluid. With the aim of achieving the best possible isentropic efficiency of the axial turbine and centrifugal compressor, as well as thermodynamic efficiency of the entire gas-turbine plant, turbine and compressor blades are shaped by innovative methods for shaping aerodynamically perfect blades, which will also be presented in the paper. The fuel is wood chips and the plant is intended for distributed production of electricity.

SDEWES2022.0542

Prospective Material Flow Analysis of a Local North Sea Offshore Wind Farm in Belgium

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Abstract

Due to the growing demand for sustainable and renewable energy, with the aim of reaching the 2030 Climate Target Plan, offshore wind farms have been suggested as a means of securing energy autonomy in the European Union (EU-28).

For the Belgian National Energy and Climate Plan, an 8GW offshore wind target was proposed as part of the EU Green Deal decarbonization strategy. However, with the decommission phases of the early offshore wind farms approaching and the lack of legal guidelines or precedents, inadequate end-of-life treatment can result in the loss of valuable or critical materials. On the other hand, a significant increase in the demand for raw materials is expected to meet the needs of new wind farm construction. This makes the mapping of material flows and introduction of circularity indices interesting from the viewpoint of EU self-sufficiency.

This work presents the case study of an offshore wind farm located in the North Sea, which was commissioned in 2010 with an expected lifespan of 20 years. Based on this case, a prospective material flow analysis could be performed, and material recovery rates were quantified. The main share (80%) of the installed mass originated from the scour protection, causing a prospective material recovery rate of 16%, as both the scour and part of the monopile are left in situ. The removed fraction (15%) has a recycling rate of 91%, with large disparities between components of the offshore wind farm.

Excluding the scour protection, steel makes up 84% of the offshore wind infrastructure. The monopile, transition piece, tower and bolt material can be recycled with little to no dismantling, covering 75% of the recycled content. Of all landfilled materials, 71% originated from composite materials (components such as blades, nose cone and nacelle cover). To conclude, a crucial indicator for this study was the overall material collection rate. The material recovery rate proved to be a valuable tool in guiding recycling and design targets to reduce the overall environmental burden of the offshore wind farm.

SDEWES2022.0562**A Comparative Study of Electric Self-Consumption Solutions for Energy-Intensive Industries**N. Nieto Aguirrezabala^{*1}, A. Rodriguez², L. Ochoa²¹IKERLAN, Spain; ²Ikerlan S.Coop., Spain (*nnieto@ikerlan.es)**Abstract**

Energy intensive industries (EIIs) are in the spotlight in terms of emissions, as they are one of the most pollutant agents. The European Union is implementing drastic measures, such as penalties for companies not reducing their carbon emissions by at least 45% by 2030. Industrial electric self-consumption based on renewable generation is one of the pathways to reach that objective combined with measures like energy efficiency, waste heat recovery or energy management.

Technological development and political campaigns favouring renewables have made the current price of a self-consumption installation much more affordable. It is increasingly natural to see solar panels on single-family homes, neighbourhood communities and other types of installations for private use, but there is still a long way to go in the industrial sector.

Industrial photovoltaic (PV) self-consumption differs from that in homes because of its energy generation potential as industry requires a greater volume of electricity for production processes. The investment required is substantial, thus, a tool has been developed to ease energy managers of EIIs on the selection of the most appropriate self-consumption solution. The tool performs a techno-economic analysis of industrial self-consumption solutions integrating PV plants, storage systems and auxiliary electricity generation from waste heat sources through an Organic Rankine Cycle (ORC).

The storage system is an energy resource providing the scenario under study with greater manageability, as it can be charged/discharged according to energy criteria (excess solar generation or the need to supply consumption) and economic criteria (price of electricity). For this reason, an operation strategy for the storage system has been designed and implemented in the tool adapted to changing operating conditions and aiming to maximize solar self-consumption.

The objective of this paper is to show the results obtained when applying the tool to an EII from the petrochemical sector. The profitability obtained from an industrial self-consumption solution is evaluated, providing a detailed comparison of 3 scenarios: a base scenario that considers electricity consumption from the grid, a scenario including local electricity generation from PV and/or ORC systems, and a scenario that contemplates, the generation sources with electrochemical storage applying an optimal energy management strategy for the controllable systems of the scenario.

Renewable energy resources 1

SDEWES2022.0024

Valorization of Corn Stover in Belgium to Second Generation Bioethanol: a Comparative Techno-Economic Assessment

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Abstract

Lignocellulosic biomass is the most abundant source of renewable biomass and is seen as a high-potential replacement for petroleum-based resources. The economic feasibility of the valorization of corn stover for the production of second-generation bioethanol in Belgium is studied. A comparative techno-economic assessment has been conducted, combining a meta-analysis on techno-economic assessments with process flowsheet simulations in Aspen Plus and data on corn stover availability in Belgium. In this analysis, the emphasis is on the comparison of different pretreatment processes, namely (i) dilute acid, (ii) alkaline, (iii) steam explosion and (iv) liquid hot water. The 2021 Minimum Ethanol Selling Prices are 0.93, 1.35, 0.98 and 1.05 EUR per liter of ethanol respectively for a separate enzymatic hydrolysis and fermentation plant with a capacity of 156 kilotonne/year of dry biomass. Plant capacity, fixed capital and operating costs are some of the key parameters that affect the MESP most. From the results it is concluded that there is limited potential for advanced ethanol production in Belgium under the current state of technology and therefore more R&D investments would be needed to make this technology economically feasible.

SDEWES2022.0028

Connected by Climate - Why Do Private Investors Purchase PV Panels?

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Abstract

Using a framework of multiple impacts, we investigate how households decide on the investment in photovoltaics on rooftops. On a large sample of 2,500+ respondents, we assess whether the broad range of multiple impacts can be aggregated into a smaller number of explanatory factors and how the investors differ across in their decision-making based on their sociodemographic characteristics. The factor analysis revealed that the identified 19 variables can be aggregated into five main decision-making explanatory factors: Economic, Hedging (financial security), Technical, Ecological, and Surroundings. While personal financial benefits are the primary motivation for acquiring PV plants, the investors consider the non-financial benefits to the same extent as financial ones. Additionally, the investors are not homogenous in their decision-making. The results show that younger homeowners put higher weight on ecological and technical factors. Higher-income respondents would be significantly less concerned about financial factors and the perception of the surroundings, but more concerned about technical, hedging, and ecological aspects. The settlement size did not prove to be a strong predictor of the structure of the decision-making. The results imply the need for diversified policy design across different groups of investors.

SDEWES2022.0054**The Monitoring of Transformation of Esters to Epoxides as Valuable Biomolecules**

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Abstract

Current issue is searching for renewable sources for production of various materials or energy, which are currently produced from crude oil. Triacylglycerides, contained in the vegetable oils, animal fats or waste frying oils, are one of the possible renewable sources and can be transformed to ester by transesterification. The other product is glycerol, which has many applications in chemistry, food and pharmaceutical industries. The esters are mainly used as a fuel (biodiesel), but can be transformed to epoxides, which have many applications. The epoxides can be used as (i) bio-lubricants in means of transport (additives to oils) or (ii) raw material for bio-polymers (as monomers), higher alcohols, olefins, glycols, polyesters and carbonates (reaction with CO₂, which is consumed). These chemicals are currently produced from crude oil. The epoxidation is a reaction of double bonds between two carbon atoms (in esters) with hydrogen peroxide to form epoxide group.

Therefore, the monitoring of epoxidation process (especially time dependency) is important because it allows to control the degree of epoxidation. Several monitoring methods are usually used, such as determination of iodine value, the epoxide equivalent weight, kinematic viscosity, or infrared spectroscopy. However, these methods are not able to determine the course of epoxidation in detail, they determine only the total decrease of ester content. On the other hand, the chromatographic methods enable to determine each single component of reaction mixture during time, i.e., esters with various degree of epoxidation.

The course of epoxidation will be determined by two chromatographic methods (gas with mass spectrometry detector and high-pressure liquid with refractometric detector) and the results will be compared mutually and with the results of other methods. During epoxidation, many intermediates (various steps of epoxidation) are formed, which will be identified and their dependency on time will be determined. Moreover, various esters with different composition of higher fatty acids will be used, i.e., with different amount of double bonds. The detailed knowledge of reaction course will allow to control better the epoxidation process and so reduce the reaction cost and raw material consumption. Therefore, the process will be more environmentally friendly.

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SDEWES2022.0056

“A Just and Clean Energy Transition: Insights from the European Regions”

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Abstract

The increasing political and social pressure in the fight against climate change and its consequences has led to the need for a change in the current energy model. Environmental objectives must be linked to economic and social objectives in order to achieve an energy transition process that is fair to the territories.

The infrastructures associated with renewable energies cause a series of socio-economic and environmental impacts on the territory. The main objective of this work is to evaluate the retrospective impacts that renewable energy installations have on the territory, in the short and long term. To this end, we will identify those European regions with the greatest installed capacity of renewable energies, evaluating the socio-economic effects that these installations have had on them.

From the methodological point of view, the Synthetic Control Method is applied to try to characterise the compatibility of economic, social and environmental objectives in the best possible way.

SDEWES2022.0062

Low Temperature Shutdown Frequency Consequences in Wind Farms in High Latitudes: the Influence of Global Warming

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Abstract

Wind energy is the fastest growing global renewable electricity generation technology. Many of the favorable areas for wind farm construction are in Cold Climates (CC) between middle and high latitudes. A region is in a CC, specifically in Low Temperature Climate (LTC), when it experiences periods with temperatures below the operational limits (IEC 61400-1 ed3). The objective is to analyse whether the study areas are LTC or not and their evolution along the last decades in the 1950-2019 period. The low temperature changes also affect the working hours of the wind turbine. For this purpose, a decadal trend of the annual shutdown frequency has been calculated at each grid point at the hub height. Results show that between the last decade and the first one the total area in different LTC regions has been reduced and, consequently, wind farms operational hours have increased resulting in a higher annual energy production.

SDEWES2022.0085

Techno-Economic Analysis on the Effects of Feedstock on Ethanol Production by Syngas Fermentation

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Abstract

The present study addresses the techno-economic analysis of syngas (CO/CO₂/H₂ mixtures) fermentation considering ethanol and acetic acid as reference products and two alternative feedstocks: C₁ rich off-gases and syngas from biomass wastes gasification. According to the recent literature and the current industrial practice, C₁ rich gases fermentation is a promising platform to biorefinery of biomass and valorisation of carbonaceous residues, the main advantage being that the whole carbon fraction of the feedstock is actually made by fermentable substrates (C₁ gases). Many microorganisms can metabolize syngas as carbon and energy source, but only a few are able to convert it into alcohols. CO can be metabolized by acetogens as single substrate and can be used both as carbon and energy source. CO₂ can be used as carbon source provided that H₂ is available as energy source. Acids and alcohol are the main products provided by acetogenic bacteria in fermentation processes and ethanol production has been scaled up to industrial applications using steel mill off-gases. The portfolio of products can be enlarged by genetic engineering of microorganisms, thus the syngas platform can offer a versatile strategy to support circular economy by renewables and wastes use.

SDEWES2022.0092

Development of a Reliable Simulation Framework for Techno-Economic Analyses on Green Hydrogen Production from Wind Farms Using Alkaline Electrolyzers

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Abstract

The present study investigates the feasibility of coupling the intermittent electric power generation from a wind farm with alkaline electrolyzers to produce green hydrogen. A physically accurate model of commercial electrolytic modules has been first developed, accounting for conversion efficiency drop due to modules' cool down, effects of shutdowns due to the intermittence of wind power, and voltage degradation over the working time frame. The model has been calibrated on real modules, for which industrial data were available. Three commercial module sizes have been considered, i.e., 1, 2 and 4 MW. As a second step, the model has been coupled with historical power datasets coming from a real wind farm, characterized by a nominal installed power of 13.8 MW. Finally, the model was implemented within a sizing algorithm to find the best combination between the actual wind farm power output and the electrolyzer capacity to reach the lowest Levelized Cost Of Hydrogen (LCOH) possible. To this end, realistic data for the capital cost of the whole system (wind farm and electrolyzers) have been considered, based on industrial data and market reports, as well as maintenance costs including both periodic replacements of degraded components and periodic maintenance. Simulations showed that, if the right sizing of the two systems is made, interesting LCOH (~4.5 €/kg) can be achieved even with current technologies. Bigger modules are less flexible but, by now, considerably cheaper than smaller ones. A future economy of scales in alkaline electrolyzers is then needed to foster the diffusion of the technology.

SDEWES2022.0115

Heat Absorption Intensification Methods in Linear Absorber - the Experimental Study in Simulated Solar Conditions

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Abstract

The utilization of solar radiation to obtain high-temperature heat can be realized by multiplying it on the illuminated surface by solar concentrators technologies. High-temperature heat with significant energy potential can be used for many technological purposes, e.g. the production of heat, cold, or electricity. The following paper presents the results of the experimental study, on the operation of the parabolic linear absorber in the parabolic concentrator solar system. The parabolic mirror with an aperture of 1 meter and a focal length of 0.25 meters focuses the simulated radiation onto a tubular absorber with a diameter of 1 inch which is placed in a vacuum tube. The investigation length of the absorber is 1 m. The installation is illuminated by the solar simulator, which allows to carry out tests under constant and repeatable conditions. The simulator consists of 18 metal halide lamps, with a nominal power of 575W each with a power reduction possibility. The paper presents results of heat absorption by the analyzed absorber, the comparison between coated and no-coated absorber, effect of using a twisted tape insert, the losses in the system and the pressure drops crucial for the optimization of the absorber geometry.

SDEWES2022.0434

Optimization of a Single Flash Geothermal Power Plant Powered by a Trans-Critical Carbon Dioxide Cycle Using Genetic Algorithm and Nelder-Mead Simplex Method

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Abstract

The usage of renewable energy, including geothermal energy, is expanding rapidly worldwide. The low efficiency of geothermal cycles has consistently highlighted the importance of recovering heat loss for these cycles. This paper proposes a combined power generation cycle (single flash cycle with trans-critical carbon dioxide cycle) and simulates in the EES software environment. The results show that the design parameters of the proposed system are significantly improved compared to the BASIC single flash cycle. Then, the proposed approach is optimized using the genetic algorithm and the Nelder-Mead Simplex method. Separator pressure, steam turbine outlet pressure, and carbon dioxide turbine inlet pressure are three assumed variable parameters, and exergy efficiency is the target parameter. In the default operating mode, the system exergy efficiency was 32%, increasing to 39% using the genetic algorithm and 37% using the Nelder-Mead method.

SDEWES2022.0527

The Influence of the Working Fluid on the Thermodynamic Efficiency of the Bottoming Organic Rankine Cycle and Turboexpander Design

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Abstract

The energy crisis caused by the reduction of fossil fuel reserves, dramatic fluctuations in their prices, as well as environmental problems due to global warming, are a challenge for the sustainable development of humanity. Therefore, in recent decades there has been a significant increase in interest in the use of renewable, medium and low-temperature energy sources such as solar energy, geothermal energy, biomass, thermal energy of the sea and ocean, and waste heat from various industrial plants and processes, e.g. petrochemical plants, exhaust gases from gas turbines and internal combustion engines. For the production of mechanical work at lower temperatures and pressures, the organic Rankine cycle (ORC) comes to the fore. Micro and small-scale ORC units for decentralized electricity generation have a special perspective. An important component of every ORC is the expander, which can be a volume or turboexpander. In the existing biogas plant, with internal combustion engine (ICE), the ORC as bottoming cycle (BORC) on ICE waste heat is installed. The BORC uses heat of exhaust gases and of cooling water of ICE. The paper will present the results of investigation of the working fluid influence as on the BORC thermodynamic efficiency and isentropic efficiency of turboexpander so design of turboexpander (number of stages, heights of stator and rotor blades, etc.). The following working fluids were investigated: R113, R123, R141b, Pentane and R601a.

Renewable energy resources 2

SDEWES2022.0142

Epoxidation of Methyl Esters of Various Vegetable Oils and Optimization of Reaction Conditions

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Abstract

A great challenge for humankind is to find a solution to an ever-rising energy and petrochemical consumption. One possibility represents vegetable oils (edible and/or non-edible ones), such as *Camelina sativa*. Oils can be transformed by transesterification, which is a reaction between triglycerides (present in oils) and short-chain alcohol (methanol, ethanol). The products are biodiesel (mixture of esters of higher fatty acids) and glycerol, which is further used in cosmetics, food industry, etc. Esters can be used as a raw material for other chemicals, such as epoxides.

Epoxidation is a reaction between unsaturated double bonds between two carbon atoms and oxygen (from peracetic or performic acid). The per-acids are prepared from hydrogen peroxide and formic or acetic acid and need to be synthesized in situ. There is a variety of epoxides applications, such as bio-lubricant additives, plasticizers and additives for PVC. Alcohols, olefins, resins and carbonyls can also be synthesized from epoxides.

The novelty and aim of this work is to show a difference of yield and properties of epoxidised methyl esters from various vegetable oils (sunflower, rapeseed, *camelina sativa*, linseed) under the same reaction conditions. Furthermore, an optimisation of epoxidation of common vegetable oils in Europe (rapeseed, linseed) was carried out and outcomes were evaluated by the statistical analysis. The relationship between reaction conditions and properties of epoxides, such as (i) iodine value, (ii) epoxide equivalent weight, (iii) relative conversion to oxirane, (iv) kinematic viscosity and (v) density was described. The formed models allow to synthesize epoxides of methyl esters, which are biodegradable and so replace epoxides formed from crude oil.

Acknowledgements:

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SDEWES2022.0176**Complex Aspects of Climate Change Impacts on the Cultivation of Perennial Energy Crops Under Central European Conditions**K. Vavrova¹, J. Knápek^{*2}, J. Weger³, D. Outrata⁴, T. Králík⁵, T. Humesova⁴

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Abstract

Given the acceleration of the decarbonisation process and the limited geographical potential for the use and future development of RES in Central Europe, biomass, e.g. in the form of intentionally grown biomass, appears to be a promising source.

The approach of growing biomass locally and then using it for energy has many benefits for improving the quality of the environment. In particular, increasing biodiversity and non-productive functions, reducing the overall CO₂ emission burden due to carbon sequestration during the growing period. However, the development of intentionally grown energy crops will be affected by the impact of climate change over the next decades. The main trends and impacts predicted for Central Europe by international and domestic teams of experts include: i) increasing frequency and length of droughts and extreme heat events, ii) increasing torrential rainfall and an increase in winter rainfall of up to 35%. The impact of climate change will be felt mainly in terms of water availability and balance on individual plots.

The paper deals with the results of long-term monitoring of yields of two promising energy crops -Miscanthus and short rotation coppice plantations on experimental plots. Miscanthus has shown during 13 years of monitoring that it adapts well to dry summers characterized by low rainfall ($\Sigma P = 350-450$ mm/year) and increasing annual daily temperatures (mean annual daily temperature $t \geq 10.5$ °C). Miscanthus can be recommended as an energy crop well adapted to the climate conditions predicted especially for the lowland areas of central Europe. Even for SRC plantations, the results of long-term monitoring of biomass yields so far show that there are at least two varieties in the range, Rokyta willow and Kaktu poplar, and one poplar clone J-105, which show solid yield parameters, namely 13.2, 10.8 and 9.8 tDM/ha/year, despite a significant decrease in annual rainfall and an increase in average annual temperature, respectively.

The paper deals with the modelling of the possible impact of climate change on biomass production of energy crops using a GIS model, where biomass yields are derived from soil and climate parameters of individual plots. Changes in the geographical distribution of energy crop biomass potential as well as other contexts such as non-productive functions and changes in the economic efficiency of crop cultivation are discussed using the Czech Republic as an example.

SDEWES2022.0194**A Spatial Site Selection Method for Pumped Hydro Energy Storage:
Case of Northern Queensland**

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Abstract

Pumped hydro energy storage (PHES) provides a viable storage solution for transitioning to 100% renewable energy generation. Nevertheless, the development of PHES solutions is complex, and many techno-environmental and socio-economic criteria need to be considered for each potential site location. Moreover, the numerous potential sites in a country require the development of a fast and comprehensive technique that can conduct pre-feasibility location suitability and viability assessment considering these various criteria. After a review of potential spatial analysis techniques and tools, a comprehensive GIS-based decision-making tool was formulated to identify the potential sites for the development of PHES in a fast and effective manner. At the same time, its application has been for the case of Northern Queensland (NQLD). In this current study stage, the focus was on the impacts of techno-environmental parameters on PHES site selection. Most of the data used in this research were derived from publicly available sources in a high-resolution format, such as Queensland spatial catalogue, global wind atlas, and SolarGIS. In addition, annual rainfall data was prepared using an I.D.W. interpolation technique in ArcGIS. The proposed GIS method was executed in ArcGIS 10.3.0. that narrowed down the potential sites from North, North-West, and Far North Queensland (FNQLD). More than 6479 watercourses across the study region were initially assessed. However, after applying various siting criteria and constraints, the model narrowed down 14 excellent sites for the focused three pumped hydro storage typologies, including naturally existing reservoirs, lakes, and greenfield land with excellent terrain characteristics. Far North Queensland acquired 7 out of 14 (50%) PHES sites in this study, followed by North Queensland (NQLD). Each detected site has a surface area equal to or greater than 1.0 km². The developed tool has implications for energy planning managers seeking to efficiently narrow down feasible PHES sites, which are essential storage enablers for transitioning to a zero-emissions economy.

SDEWES2022.0209

Design and Economic Analysis of the Highly Efficient Urban Wind Turbines

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Abstract

The small wind turbines installed in the urban environments represent the possibility of distributed energy production using renewable energy sources. As a part of the smart cities strategy, there is a growing interest in the wind turbine systems integration on the buildings or siting stand-alone wind generation turbines in the urban area. Vertical axis wind turbines (VAWT) have often been considered in urban areas, due to their ability to cope with turbulent wind. However, if a suitable location in an urban area, with favourable wind conditions, is initially selected, the horizontal axis wind turbines (HAWT) offer higher energy conversion efficiency for the same wind speeds. It has been shown that the use of a diffuser or other form of augmentation can increase the HAWT efficiency significantly above the Betz limit that applies only to a bare rotor in airflow. Nevertheless, the questionable economic viability of this concept is often mentioned in the literature, due to the requirements for additional material. This paper proposes the method for the design of highly efficient HAWT with and without augmentation. Additionally, the computational fluid dynamic (CFD) is used to obtain the power curves, and to compare the bare and the augmented wind turbines from the energy conversion efficiency point of view. Unlike previous research, this paper also considers the economic aspect. Based on the wind data for Dalmatian cities, the Levelized cost of energy (LCOE) of bare rotor and augmented turbine were calculated and used to conclude on the cost-effectiveness of using augmentation (ducts, diffuser) for HAWT. The presented results provide insight into the technical and economic aspects of using different design concepts of small-scaled HAWT for distributed energy generation.

SDEWES2022.0220

Investigation of Regeneration Cycles with Different Catalysts on Steam Gasification of Biomass

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Abstract

In this work, agricultural biomass was gasified in a three-zone tubular reactor in the presence of steam. During the measurements, at first, the effect of temperature in the 1st and 2nd reactor zone, as well as the impact of catalysts and steam/raw material ratio was investigated, later than the regeneration cycles of catalysts. In case of temperature, it can generally be mentioned, that at higher temperatures the amount of hydrogen, methane and carbon monoxide were increased, while decreasing can be seen in case of carbon dioxide and lighter hydrocarbons. For improving the synthesis gas and hydrogen yield nickel impregnated ZSM-5, Al₂O₃, CaO and Clinoptilolite were used as a carrier. In the presence of catalysts, the amount of lighter hydrocarbons was decreased, while the main goal in case of Ni/CaO and Ni/Clinoptilolite was the reduction of carbon dioxide. Besides, with the use of steam and proper temperature, steam gasification, methane formation, as well as methanation reactions can be shifted. Regarding the Ni/CaO, CaCO₃ can be formed from which in case of hydrogen surplus CO and H₂O can be resulted. It is important to be mentioned that in the presence of Ni/Clinoptilolite the amount of carbon dioxide was remarkably decreased owing to its high acidity and quadrupole moment.

In this work, agricultural biomass waste was gasified in a three-zone tubular reactor in the presence of steam. Firstly, the effect of temperature in the 1st and 2nd reactor zone, as well as the impact of catalysts and steam/raw material ratio was investigated, later than the regeneration cycles of catalysts. In case of temperature, it can generally be mentioned, that at higher temperatures the amount of hydrogen, methane and carbon monoxide were increased, while significant decreasing can be seen in case of carbon dioxide and lighter hydrocarbons. For improving the synthesis gas and hydrogen yield nickel impregnated ZSM-5, Al₂O₃, CaO and Clinoptilolite were used as a carrier. In the presence of Ni/CaO and Ni/Clinoptilolite the main goal was the reduction of carbon dioxide. During the regeneration cycles of catalysts, in most cases until the 3rd-6th regeneration cycles, no significant changes were identified.

SDEWES2022.0231

Co-Pyrolysis of Sewage Sludge, Biomass and Plastic Waste

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Abstract

The amount of annually generated sewage sludge is continuously increasing. For utilization of sewage sludge, the agricultural disposal is the most commonly used method. However, the agricultural utilization of sewage sludge is barely acceptable owing to its heavy metal content (e.g. zinc, copper, nickel, cadmium, lead, mercury, chromium) and harmful environmental and health effect. In addition to those listed, sewage sludge also contains other hazardous substances such as polyaromatic hydrocarbons, dioxins, furans, polychlorinated biphenyls, detergents, drug residues, body care products, synthetic steroids and pathogens. For the conversion and neutralization of organic compounds thermal or thermo-catalytic treatment (e.g. pyrolysis) looks a promising option, despite the fact that pyrolysis products have low heating value, and high oxygen and nitrogen content.

To improve the quality of pyrolysis products co-pyrolysis of sewage sludge with feedstocks containing lower oxygen or higher hydrogen is recommended. Therefore, in this study the co-pyrolysis of sewage sludge, biomass and plastic waste was studied in a TG-FTIR equipment. During the experiments, effects of the feedstock composition, temperature and heating rate were investigated to the decomposition process and the compositions.

Based on the results, it was found that raw materials have synergistic effects on each other in the co-pyrolysis. In addition, co-pyrolysis needs lower decomposition temperatures and less external energy requirements. However, finding the optimum of the feedstock ratio is essential.

SDEWES2022.0232

Slagging Characteristics in the Superheater Area and Aeams Distribution of a 30 MW Biomass-Fired Grate Boiler

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Abstract

The slagging on heating surfaces during combustion severely impedes the utilization of biomass fuel in grate boiler. Aiming at this situation, the slagging characteristics in the superheater area of a 30 MW biomass-fired grate boiler has been investigated. By the sampling of slags using air-cooled probes and the morphology and composition analysis of slag samples, the slagging mechanisms, including molten ash adhesion, alkali/alkaline earth metal (AAEM) condensation and viscous capture of ash particles, have been discussed. The results indicate that the severity of slagging in this biomass grate boiler is ordered as: mid-temperature superheater> high-temperature superheater> low-temperature superheater> furnace area. The slightest slagging in the furnace area before high-temperature superheater is attributed to the adhesion of molten ash containing silicates/ aluminosilicates. The slagging in high-temperature superheater is mainly caused by the condensation of aerosol particles containing K, Ca and Mg and dominated by Ca. The most serious slagging in mid-temperature superheater is dominated by K through condensation of KCl, formation of initial adhesive layer and capture of ash particles. The slagging in low-temperature superheater is slight due to little condensation of K/Ca sulfates and KCl. Since the slagging is mainly caused by K and Ca through condensation and viscous capture, it has been calculated that 44.6% of K and 35.7% of Ca in the feedstocks deposit on the heating surfaces during combustion, requiring more attention to not only K but Ca as well for relief of biomass slagging.

SDEWES2022.0237**The Conversion of Bio-Ethanol to Butanol by Mg-Al Mixed Oxides Dopped by Cu or Co**J. Malina^{*1}, M. Hájek¹, K. Frolich¹, J. Mück¹, J. Kocík²¹University of Pardubice, Czech Republic; ²Unipetrol Centre for Research and Education, a.s., Czech Republic (*jan.malina@student.upce.cz)**Abstract**

In recent years many renewable sources of many materials and compounds have been studied to replace fossil feedstocks. One of them is ethanol obtained from biomass by fermentation. Ethanol is possible used as raw material for conversion to higher alcohols, such as butanol and hexanol. The reaction (Guerbet reaction) is based on the condensation of two primary alcohols and has to be catalyzed by the bifunctional catalysts. Two series of the hydrotalcite-based Cu-Mg-Al and Co-Mg-Al metal mixed oxides are one of bifunctional catalysts and have been studied for Guerbet reaction. The Guerbet reaction is one of possibilities renewable raw materials use to obtain fuels, solvents, and raw materials for another reactions. Butanol can be used for example in varnishes production, fuel additives, solvents, and plasticizers.

Pure Mg-Al mixed oxides have great basic properties, which improve selectivity to butanol. The addition of transition metal can improve redox properties of pure Mg-Al. These properties are important for catalysis of Guerbet reaction. The reaction mechanism consists of four steps, and each step involves different type of sites: (i) dehydrogenation (redox sites), (ii) aldol condensation (basic sites), (iii) dehydration (acidic sites), (iv) hydrogenation (redox sites).

The successful preparation of Cu(Co)-Mg-Al mixed oxides, and presumed molar ratio of metals were confirmed. The amounts of reducible transition metal in mixed oxides were in wide range of total amount of transition metal. The acid-base properties showed great differences, mixed oxides with less transition metal content showed higher acidity and basicity. The Co-Mg-Al series showed better results in acid-base properties. The conversion of ethanol was increased with increasing amount of transition metals in metal mixed oxide. Butanol selectivity showed different course, catalysts with second higher transition metal content achieved highest butanol selectivity. Best results were achieved by series Cu-Mg-Al. Trends developed as expected to theory of Guerbet reaction. In other words, it means that (i) the conversion of ethanol was increased with increasing amount of reducible transition metal and (ii) the selectivity to butanol was increased with increasing amount of basic and acid sites.

Acknowledgement

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SDEWES2022.0497

A Joint Evaluation of the Wave and Wind Energy Along the West Iberian Nearshore

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Abstract

There is a growing interest in extracting marine renewable energy and contributing in this way to the green road towards a low carbon future. From this perspective, the Iberian nearshore represents a coastal environment with very high potential. In this context, the objective of the work proposed herewith is to perform a joint evaluation of the wave and wind power along the west Iberian coastal environment. The analysis is structured in two time intervals. The first is the 20-year period (2001-2020), for which the ERA5 wind data have been considered. The second 20-year period (2026-2045) corresponds to the near future and in this case, wind data provided by the climate model RCA4 (Rossby Centre regional atmospheric model, version 4) have been processed and analysed, corresponding to the climate scenario RCP4.5. (Representative Concentration Pathway). The same two periods have been considered for the evaluation of wave power. In this case simulations with spectral phase averaged model SWAN (Simulating WAVes Nearshore) have been performed. This wave modelling system was implemented for the entire North Atlantic basin and focused on the west Iberian coastal environment. Finally, the results also indicate that there is a good synergy between wind and wave power in the west Iberian nearshore. As a conclusion, the development of joint wind-wave projects along the west Iberian coastal environment represents a viable direction for the near future. Especially, the North western part of the Iberian nearshore has a very good potential both in terms of wave and wind energy.

SDEWES2022.0647

A Framework for the Design of Robotic Photovoltaic Cleaning Systems

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Abstract

Given the prominent role of solar energy among the other clean energy sources, the increase of photovoltaic (PV) systems efficiency becomes crucial. A problem that was recognized to degrade the performance of photovoltaic panels is related to the accumulation of dust (soiling) on their surface. In general, the common practice of manual cleaning of PV systems is not efficient. For this reason, it has emerged the need for automatic cleaning procedures. Automated solutions include integrated cleaning systems and robotized solutions.

From a robot design perspective there exist a plethora of issues to be considered, including its energy autonomy but also the employment of appropriate path planning and control methodologies. The available cleaning methods have to be assessed in regard to their suitability for a robotized solution and the corresponding operation parameters have to be optimized.

A monitoring system can assist in targeted cleaning beyond the scheduled routine cleaning operations. Towards that direction a suitable concept may integrate intelligent monitoring of a solar photovoltaic power plant using autonomous drones. An effective robotic cleaning solution can be further enhanced using other modern technologies including advanced image processing, artificial intelligence (AI), machine learning and internet of things (IoT).

The objective of this work is to provide a general perspective of the problem. The motivation for the development of robotized PV cleaning solutions is justified and the application requirements are identified. A general framework for the design of PV cleaning robots is established. Relevant works are reviewed, already proposed systems are categorized and research challenges are identified.

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SDEWES2022.0073

Geospatially Constrained Assessment of Solar Energy Sources in Poland

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Abstract

Since 2019, Poland has experienced a particularly rapid expansion of solar photovoltaic capacity. However, the considerable uptake in recent years has been mainly due to a cumulative growth in micro-installations or small-scale systems, which accounted for nearly 75% of the total installed PV capacity. The vast majority of new photovoltaic micro-installations were deployed to offset the electricity demand of private homes, with system capacities ranging from 2 kWp to 10 kWp. Although rooftop PV systems play a crucial role in addressing the present challenges of the power sector, it is expected that the Polish PV market will shift from micro-installations to utility-scale systems in the upcoming years. Consequently, there is a need for research on land eligibility and spatial distribution of renewable energy sources in Poland. In this context, the main aim of this paper is to (1) determine the major socio-economic regions and NUTS-2 regions with the highest share of land suitable for ground-mounted solar systems; (2) evaluate the spatial distribution of solar installations in Poland considering exclusion constraints (physical, environmental, sociopolitical); (3) investigate the effects of legislative changes related to the renewable energy sector on the spatial distribution of solar technologies. To address the objectives of this study, a model constructed in Python was employed to analyze the geospatial characteristics of the territory of Poland. By combining publicly available information and multiple high-resolution GIS datasets, this study contributes to the literature on the determinants affecting solar energy development of one of the most coal-dependent countries in the European Union. Moreover, it provides a comprehensive assessment of the Polish NUTS-2 regions with favorable resource locations to deploy utility-scale photovoltaic systems.

SDEWES2022.0240

Single-Step Drill-String Drive Active Damping Speed Controller Auto-Tuning Based on Closed-Loop Step Response Properties

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Abstract

This paper presents a control system design methodology suitable for the drill-string rotary drive for deep drilling applications. The active damping control system automatic tuning is performed by designing the drill-string parameter estimator which simultaneously calculates the drive resonance frequency and inertia using a single limited-duration closed loop experiment characterized by drive limit cycle oscillations. The design of proposed parameter estimator has been based on a suitable control-oriented process model of the torsional oscillator and utilization of a modified-mixer phase detector phase locked-loop (MMPD-PLL) equipped with adaptive second-order generalized integrator (SOGI) for the extraction of key features of the drive resonance mode. The rotary speed active damping system tuning is based on the so-called damping optimum criterion which guarantees a desired level of closed-loop system damping. The functionality of the proposed control system has been thoroughly verified by means of simulations, with the drill-string parameter estimator also being confirmed using the previously recorded field data to illustrate its robustness in the presence of realistic measurement noise.

SDEWES2022.0249

Optimizing the Geographical Distribution of PV Investments in the Iberian Peninsula

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Abstract

MOTIVATION.

Investments in PV energy have been very limited in Spain until recently. However, the sustained cost decreases of the technology have made it market competitive and opened new opportunities. The Spanish government has pledged to switch to a carbon-free energy system by 2050, improving the prospects for the deployment of this energy source. Then, PV energy auctions are held regularly.

Investments can be deployed at different geographical locations with varied generation/variability profiles. One aspect worth considering is the variability of its generation, and this research intends to identify optimal (geographical) combinations of power and variability for given investment amounts.

METHODOLOGY.

PV power data is available at hourly frequencies for every geographical location in Europe in the PV-GIS database. The data spans the years 2005-2020.

This research aims to identify geographical distributions of a given investment that optimize combinations of power generated and implied risk.

The Iberian peninsula shares a common electricity market and is the geographical area under study. A few specific locations are selected, scattered over the whole surface.

Risk can be analyzed with up-to-date criteria like Value at Risk and related measures, and requires estimation of the probability density functions of the PV supply in all locations.

RESULTS.

Several models at every location are being investigated. From the daily annual cycle, two types of hourly models can be built, a) a joint model for all 24 day/hours, and, b) specific models for every hour. Another approach is to model the hourly cycle over the year. The cycle can be modelled in two steps: a) estimate annual averages, and, b) estimate the cycle from there with a non-parametric kernel.

The database includes irradiance values of three kinds, plus temperature and wind speed values so that a regression model can be estimated. Both approaches can be combined as a further type of model. The available results show that both models capture the PV power hourly annual cycle closely.

Specific probability distributions can be estimated for every location from these models' residuals. Preliminary results show significant asymmetry and kurtosis, acceptably well captured by the Edgeworth-Sargan density, a convenient specification because of its analytical tractability.

CONCLUSIONS.

The results could be used to guide the public auctions for PV power. The next step would be integrating wind power into a joint global analysis. These research results could assist in the optimization of energy storage investments, and the choice between energy sources and their optimal locations.

SDEWES2022.0265

Tar and Metals Fate in Syngas Produced by Gasification of Prunings from Pabr (Plant-Assisted Bioremediation)

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Abstract

PABR (plant assisted bioremediation) is a remediation technique that involves the extraction of contaminants present in the soil thanks to the synergistic action of plant-microorganisms in the growth phase of specific crops. The prunings of such plants are considered contaminated so that their disposal is up for discussion. In this work traditional poplar pruning and PABR were compared in a large-scale gasification process. The biomasses were previously physically-chemically characterized and their metal content was determined in ICP-MS. During the gasification process, the syngas was bubbled into specific solutions for the sequestration of the metals and the tar present. The collected solutions were then analyzed in ICP-MS and in GC-MS. The residual ashes of the reactor and of the cyclone were also collected, in order to carry out a distribution and particle size analysis of the metal species. The study showed that PABR biomasses produce a syngas richer in heavy metals, but with an order of magnitude comparable to traditional biomass. In the ashes, on the other hand, the concentration of heavy metals has an order of magnitude up to 20 times higher in the case of PABR than in traditional biomass. This suggests that the energy conversion of PABR biomass into gasification processes allows to obtain a syngas comparable to that obtained from traditional biomass and allows to concentrate the pollutants in a reduced volume of ash. PABR biomasses also influence the production of tar, facilitating the formation of more compounds albeit at lower concentrations than traditional biomass. The particle size of the ashes and the distribution of metals in them is also related to the presence of high concentrations of metals in the biomass.

SDEWES2022.0341**Digital Twins for Marine Renewable Energy Applications and Open-Source Platforms**

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Abstract

Digital Twins (DTs) promise to bring innovation to new marine renewable energy applications utilizing modern technological advancements (sensors, predictive models, AI) and the existing Marine-Knowledge Framework (open-source platforms, clouds, etc.). A DT is a digital equivalent of a real-life object mirroring and predicting its behaviour and states over its lifetime in a virtual space. Using DTs as a central means for marine renewable energy applications and open-source platforms management enables the decoupling physical flows from planning and control. Consequently, marine renewable energy applications can rely on data offered and processed by open-source platforms to manage operations remotely, based on (near to-) real-time digital information, instead implementing direct observations and manual tasks on-site. DTs collect data at various points in each installation, utilizing the newly-introduced low-cost sensorics systems, synchronize, homogenize and transfer the data to a centrally-based hub and assimilate them into forecasting and machine learning models, aiming to optimize systems' performance and operation. DTs allow operators to intervene immediately in case of (expected) deviations and to simulate the intervention effects based on (near to-) real-life data. This paper presents critical aspects of the DT implementation risks and challenges in marine renewable energy applications and open-source platforms, by learning from marine observation system projects, where the DT is more widely employed. The DT applications and the existing marine-knowledge framework provided by the open-source platforms in marine observation and modelling systems are presented, and the main steps of developing a DT are discussed. The DT implementation three main steps, i.e., measurements systems, data harmonization and pre-processing, modelling, extensive data analysis and machine learning and optimization tools are identified. However, the DT implementation is associated with risk and high uncertainties, even in the space industries, where the DT is well established and at a higher advanced level than in the marine renewable energy industries.

SDEWES2022.0345

Pelletization and Torrefaction of Coffee Grounds, Chaff and Rapeseed Straw

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Abstract

Waste biomass pelletization is a suitable process for obtaining energy dense solid fuel. If the pellets are further processed by torrefaction, both their qualitative and energy parameters are changed. Therefore, the aim of this study is to investigate the effect of the torrefaction process on pellets made from coffee grounds, chaff from garden and rapeseed straw. Mechanical parameters such as pellet durability index, wettability index of the pellets, their water moisture resistance, hardness or specific and bulk density were determined for evaluation. Furthermore, pellet energy parameters such as heat of combustion, calorific value or elemental analysis were compared. Pelletization of the above mentioned waste biomass and torrefaction of the pellets were carried out on pilot plants. The first results showed that the torrefaction process for all samples increased the values of heat of combustion or carbon content values. The energy value of the pellets increases. The ash contents also increase with these values. The study thus shows an insight into the energy utilization of coffee grounds and chaff from garden compared to the results of rapeseed straw pellets for pelletization and torrefication process.

SDEWES2022.0352

Dynamic Simulation and Thermo-economic Analysis of a Power to Gas System Driven by Renewables

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Abstract

The global energy scenario shows that the integration of renewable sources in the energy production system is mandatory to reduce the environmental impact of the industrialized and developing countries. The global energy demand is rapidly increasing and a sustainable development may be achieved only using renewable technologies, which are not harmful for the environment. In this framework, solar thermal collectors, photovoltaic panels and wind turbines are very mature and efficient renewable energy technologies. Unfortunately, all these technologies are all affected by the unpredictability of the energy source availability. Moreover, solar systems are also featured by a significant energy production during the central hours of the day, due to the higher solar radiation. When these systems are connected to the local grid, they may cause an overloading of the power grid, during the peaks hours which may determine overvoltages, which are extremely dangerous for the grid safe operation. To this scope, power to gas systems were developed in the recent years, as innovative energy storage solutions. This technology converts the exceeding renewable electricity produced during the peak hours in a gaseous fuel which can be stored in suitable tanks. In particular, these systems include hydrogen production by means of electrolyzers fed by the excess electricity produced by photovoltaic panels. Then, the produced hydrogen is combined with carbon dioxide to obtain natural gas. The gas produced is an energy vector which is almost pure in methane and can be exploited as a useful energy vector. In the present work, a 3 MW solid oxide electrolyzer fed by a 3MW photovoltaic field is coupled with a biomethane production unit to produce further methane by means of a 2 MW methanation unit. The results of the dynamic simulation show an increase of 30% of the natural gas production from renewables. Unfortunately, the economic feasibility is poor due to the huge capital cost of the proposed technology.

SDEWES2022.0407**Anaerobic Co-Digestion of Sewage Sludge and Organic Fraction of Municipal Solid Waste: Focus on Mix Ratio Optimization and Synergistic Effects**

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Abstract

The utilization of municipal solid waste (MSW) and sewage sludge (SS) as a source of renewable energy is crucial in achieving sustainable and integrated MSW management. SS and organic fraction of municipal solid waste (OFMSW) can be anaerobically digested to produce biogas for energy. However, anaerobic digestion of specific substrates is challenging with respect of substrate characteristics. For example, SS is characterized by low organic load and presence of heavy metals, which inhibit microbial activity. Further it is poorly biodegradable and carbon to nitrogen (C/N) ratio is also low. On the other hand, OFMSW possess toxic substances like heavy metals and ammonia and has low pH along with lignocellulosic fraction with complex polymeric structure that are difficult to degrade. The problem of mono-digestion can be mitigated by co-digestion of these two major organic wastes because of their complementary characteristics. The objective of this study is optimization of mix ratio of SS and OFMSW based on biogas yield and methane content. The study also elucidates enhancement of biogas by analyzing kinetics of the process and synergistic effects associated with co-digestion process. The SS and OFMSW were collected and analyzed for pH, chemical oxygen demand, ammonia, alkalinity, heavy metals using standard methods. Different mix ratio of SS and OFMSW (0:100, 20:80, 40:60, 60:40 and 80:20, 100:0) at 5 and 7.5% total solids (TS) were evaluated for biomethane potential assessment (BMP) for 45 days based on BMP protocol. Biogas was measured using water displacement technique. All the ratios were analyzed in duplicate reactors. The biogas produced was characterized using COMBIMASS biogas analyzer. Further synergistic and kinetic analysis using modified gompertz and first order kinetics model was done to assess the synergism between these two substrates. It was found that the batch anaerobic co-digestion of SS and OFMSW resulted in an increase of biogas yield as compared to mono digestion of SS and OFMSW. Mix ratio of 60:40 of SS and OFMSW resulted in highest biogas yield of 782 ml/gVS and 755 ml/gVS added at TS 7.5% and 5% respectively. The methane content in the biogas ranged from 60-72% measured at 20th day and 45th day of batch experiment. As the SS ratio increased, the lag phase reduced for 60:40 mix ratio as well as it increased the hydrolysis rate constant indicating higher rate of biodegradation. The synergistic effects of co digestion process were evaluated based on co digestion impact factor (CIF). CIF value greater than 1.1 suggests a synergistic rather than an additive effect between two substrates. Mix ratio of 60:40 had highest CIF value of more than 2 indicating synergism between both the substrates. These findings demonstrate that co-digesting SS and OFMSW is a preferable alternative for harnessing renewable energy and managing organic waste in a sustainable manner.

SDEWES2022.0432**Thermography and Machine Learning Combination for Comprehensive Analysis of Dynamic Response of a Photovoltaic Module to Water Cooling**

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Abstract

Thanks to the high heat absorption capacity per mass and being not toxic, water is taken into account as one of the most efficient and environmentally friendly means for reducing the working temperature and enhancing power of a photovoltaic (PV) module. Taking this point into consideration, in this study, for a 50W polycrystalline PV module, experimental data during a one-year performance, including the images captured by a thermal imaging camera, is utilized to find its dynamic response to water flow cooling. Dynamic response refers to the module power improvement (ΔP) when water is applied and the system is in the transient condition. The recorded data is then employed to train an artificial neural network (ANN) for prediction of ΔP for any set of the effective input parameters, which are ambient temperature and wind velocity, as well as the irradiance and water flow mass flow rate. The obtained ANN is validated using the experimental data which has not been utilized for developing purposes, and after that, it is utilized to provide a comprehensive discussion about the impact of effective parameters on the system dynamic response. According to the results, for all the investigated cases, there is a threshold value for water flow rate (WFR). For instance, when solar radiation and ambient temperature are $1000 \text{ W}\cdot\text{m}^{-2}$ and 25°C , the threshold values for the wind speeds of 1, 2, and $3 \text{ m}\cdot\text{s}^{-1}$ are 0.004, 0.005, and 0.008 kg per second, respectively. Moreover, irradiance and wind velocity have great impacts on ΔP , while the ambient temperature is the least effective one.

SDEWES2022.0498

An Evaluation of the Expected Wind Dynamics in the Black Sea in the Context of the Climate Change

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Abstract

The work proposed herewith has as its main target to perform an analysis of the expected wind climate in the 21st century in the Black Sea basin. For this purpose, the wind fields provided by the RCA4 climate wind model are processed and analyzed. Three different Representative Concentration Pathway (RCP) scenarios are considered. These are RCP2.6, which assumes that the peak of the emissions was reached in 2020, RCP4.5, considering the peak in 2040 followed by a decline, and RCP8.5, according to which the emissions will continue to grow the entire 21st century. The study is structured considering two-time intervals, each of 40 years. These are the interval (2021-2060), denoted as near future (NF) and (2061-2100), which is considered in the present work as the distant future (DF). Furthermore, in order to have a basis for comparison the 40-year time interval (1980-2019) denoted as the recent past (RP) was analyzed as well. Two different parameters are followed in this analysis. These are the average wind power density and the maximum wind speed. The results indicate a moderate enhancement of the average wind power on the western side of the basin (in the range of 10-20%). The coastal areas from the western and north-western sides of the Black Sea were identified as being more energetic and appropriate for harvesting wind energy. On the other hand, a significant enhancement of the maximum wind speeds is expected in the Black Sea. Thus, the highest storms might be of hurricane type, both as regards the wind speed intensity and the cyclonic form of the storm

Renewable heat systems

SDEWES2022.0008

Optimization of Enterprise Activities in the Solar Collector Industry: a Case Study in Adana Province of Turkey

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Abstract

Solar collectors are systems that use solar energy as heat and are widely used around the world. For this reason, it is important to support initiatives for the production of solar collectors and to establish incentive policies. Turkey has significant solar energy potential. Adana is one of the most important cities in Turkey in terms of solar collectors. On the other hand, the lack of administrative and incentive mechanisms for the deployment and expansion of solar collectors limits the widespread use of solar collectors in Turkey. The aim of this study is to reveal the opinions of the industrial workers, define the current industry problems and identify possible actions by conducting semi-structured interviews with the solar energy systems industry currently operating in Adana. This study evaluated the solar collectors market using the qualitative analysis method for the first time. The results are an important guide for decision-makers as well as significantly enrich the literature.

SDEWES2022.0124

An Experimental Study of a Parabolic Trough Solar Concentrator with Two-Axis Tracking System Operating Under Poland Climatic Conditions

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Abstract

The parabolic-trough solar concentrating (PTC) systems are often considered as element of heat and electricity generation system in many regions of the world. The electricity production by this system is currently not competitive compared to photovoltaic installations, but heat production can be used in many applications where a higher temperature is required than can be achieved with flat plate collectors. Depending on the demand and potential, different variants of installations which utilize energy from PTC can produce heat, cold or electricity. There are many limitations related to the work of parabolic-trough concentrating system. Recognition of these limitations will allow the use such a system in selected application with appropriate efficiency. An experimental study of a parabolic trough solar concentrator installation with two-axis tracking system were carried out. This system is located at the Department of Power Engineering and Turbomachinery in Gliwice (Poland). Different variants of the system operation were considered. Measurement data were recorded during real weather conditions. The obtained results allow an analysis of the annual energy production in the PTC, based on solar radiation distribution and weather conditions for a given location.

SDEWES2022.0156

Exergy-Optimum Coupling of Radiant Panels with Heat Pumps for Minimum CO₂ Emissions Responsibility

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Abstract

This paper investigates the exergy-optimality of temperature-peaking heat pumps for minimum carbon dioxide emissions responsibility when coupled to radiant floor heating and solar photovoltaic-heat systems in buildings. It is hypothesized that heat pumps are not exergy-optimum when the embodied carbon dioxide of floor heating tube material as a function of tube spacing on centers is compared with the increase in the coefficient of performance of the heat pump as an inverse function tube spacing. The analysis also includes the dependence of the singular pressure losses as a function of the tube spacing. This paper shows that although optimum pipe spacing and pipe diameter may be found in terms of life-cycle analysis according to the first law of thermodynamics, a real root for optimum tube spacing for exergy-optimality is not available. Therefore, it has been concluded that a better solution is to eliminate heat pumps by using solar PVT panels in nearly-zero emission buildings with floor heating systems, especially in moderate climates.

SDEWES2022.0337

Consumer Purchasing Behaviour Towards Solar Water Heating System: a Case Study in Turkey

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Abstract

Renewable energy sources play a critical part in a country's economic development. Solar energy is one of these resources that has a positive impact on economic development. The solar energy sector in Turkey is in the development stage. The country has a high solar potential due to its location and annual sunshine duration. However, despite the enormous potential, awareness, and use of solar energy is not common in all regions of Turkey. The reasons for this situation can be associated with the high cost of solar energy, social impact, opportunity cost, and the inadequacy of government policies and incentives. Furthermore, according to Hofstede's cultural dimensions, the fact that people in Turkey are more likely to focus on short-term results may influence their solar energy system purchasing decisions. The goal of this research is to examine the water heating system, which is a type of solar energy system, in order to discover the elements that influence people's decisions to utilize these systems. For the first time, all influences on customers' purchases of solar water heating systems were assessed holistically in this study. In this regard, field sampling was applied and individual opinions from each region were collected in Turkey. The study employed a questionnaire, which is a quantitative research method. A survey of 651 people from seven different districts was carried out in Turkey. The study determines the factors which affect the consumer purchasing attitude regarding solar collectors and evaluates the results in terms of an organizational point of view. The study's findings serve as a blueprint for future research.

SDEWES2022.0394

Energy Estimation of Three Solar Water Heating Systems Under the Mediterranean Climate Conditions

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Abstract

Utilization of solar water heating systems has shown a tremendous increase in recent years. Their diffusion is related to the solar radiation potential, the energy demand and the target achievement that each country has foreseen for the utilization of renewable energy sources. In this work, the energy estimation of 3-solar water heating systems placed side by side is performed. Two of them are active systems and the third is a passive one. In these systems are utilized evacuated tube collectors with heat pipe and flat-plate collectors. With the aim to perform the energy estimation of the systems, the mathematical model is built. Experimental data obtained from their database are used. The recorded data for the three considered solar water heating systems refer to a 1-year time period. The graphs of the solar irradiation on tilted area of the collectors, temperatures, specific solar yields, system efficiencies are included. Also, even the energy balance for the considered systems are built.

SDEWES2022.0641**Strategy for Implementation of the Shallow Geothermal Potential in Cairo, Egypt - Outcomes of the Project Geothermal Energy Capacity Building (Geb)**

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Abstract

This paper was done as a part of the project Geothermal Energy Capacity Building in Egypt (GEB), funded by the European Union program Erasmus+, within the Key Action 2: Cooperation for innovation and the exchange of good practices (CBHE-JP - Capacity Building in higher education - Joint Projects). Five Egyptian universities (Cairo, Suez Canal, Ain Shams, Aswan and Egypt Japan University of Science and Technology), two Egyptian governmental/industrial bodies (New and Renewable Energy Authority and South Valley Egyptian Petroleum Holding Company), and three European universities (Bologna, Zagreb and Valladolid) are the partners in this project. GEB duration is 3 years, from the beginning of 2021 to the beginning of 2024. Within the project the investigation into applicability of exploiting shallow geothermal energy was done for a pilot site in Cairo. The pilot site is located within the premises of the University of Cairo and in relative vicinity of the river Nile. Since the climate conditions in Egypt are different than the ones in the northern Europe, heating and cooling demands also differ – as expected, cooling demands greatly surpasses heating demands. Therefore, implementation of borehole heat exchanger in such climate conditions would entail higher heat rejection rates into the subsurface than heat extractions. Given that river Nile aquifer is present covering almost entire Cairo area, strategy of using shallow geothermal systems is dependent on hydraulical parameters of the aquifer itself. This is due to the fact that groundwater flow of the aquifer can regenerate thermal conditions around the borehole field. Without the aquifer present, the sandy soil would quickly saturate with heat and the geothermal system would be extremely costly, compared to classical air source heat pump systems. This investigation will prove the real potential of the shallow geothermal energy for cooling in the Cairo city, but also for all of the major cities positioned on the river Nile banks, such as Aswan and Luxor. Hydraulic conductivity of the river Nile is the most important factor to make shallow geothermal energy application strategy. As a better alternative, direct groundwater production can also be considered (groundwater heat pump system) for this area. This paper will introduce numerous simulations of pilot project borehole field operation, according to real cooling and heating demands in Cairo.

SDEWES2022.0645**Experimental Investigation of Parameter Driven Defrost Cycle for Air-to-Water Heat Pump**D. Miše^{*1}, V. Soldo², L. Boban²¹Faculty of mechanical engineering and naval architecture, University of Zagreb, Croatia; ²Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Croatia (*dmise@fsb.hr)**Abstract**

Heat pumps have seen progressive growth in the number of installed units in recent years. The European Heat Pump Association (EHPA) reports a 34% increase in the number of units sold last year compared to 2020. As one of the pillars of the European Strategy 2030 and 2050 in moving away from fossil sources, the research and development of these devices are of great importance. Today, different types of units are used: air, ground, and water source heat pumps. Air source heat pumps dominate the market with both absolute number of sold units and relative change.

One of the main drawbacks of the air source heat pumps is reduced capacity in conditions of high relative humidity and low air temperature when the formation of ice on the surface of the heat pump evaporator occurs. Ice accumulated between copper pipes and aluminum fins reduces airflow and acts as additional resistance to heat exchange. With reduced air flow, the ice is unevenly distributed on the evaporator surface and efficiency is significantly reduced. That is why it is essential to control frost formation on the surface of the heat exchanger. Traditional defrosting techniques, which mainly consist of timer-driven defrosting cycles, stop the heating process for long periods or use too much energy, which significantly reduces the system's overall energy efficiency.

To overcome the existing problems of an inadequately timed defrosting process and increase the energy efficiency of the system, an improved defrosting system is tested in a psychrometric chamber, a closed room in which it is possible to maintain a consistent temperature and humidity and thereby to simulate the environmental conditions for testing the outdoor unit of the heat pump. The main parameter used for activating digital signals to reverse the process and go into the defrost process is the difference between evaporation and ambient temperature. Temperature difference increases over time due to the weaker heat transfer on the frosted air evaporator and in conducted experiments value is set to 20 K. The end of the defrosting process and the return to the heating mode is determined by the temperature of the external wall of the evaporator which is set to 35 °C. Initial experiments show that parameter driven defrosting reduced the energy for ice melting and evaporating water from the surface of the heat exchanger by up to 40% compared to timer driven system and resulted in up to 8% improvement in overall system efficiency.

SDEWES2022.0649**Defining Production Index Distribution for the Discovered Geothermal Brine Reservoirs in the Croatian Part of Pannonian Basin**M. Tuschl¹, T. Kurevija^{*2}¹Croatian hydrocarbon agency, Croatia; ²Faculty of mining, geology and petroleum engineering, Croatia (*Tkurevi@rgn.hr)**Abstract**

One of the important sources of renewable energy is geothermal heat. Its special feature of being independent 24/7 ensures stability and security of the system, either for electricity or heat production. Geothermal energy has a local character and is limited by the geological characteristics of each state. In the Republic of Croatia, the development of geothermal energy is closely related to the development of the oil industry, when geothermal deposits were discovered during oil and gas exploration. Considering the established temperature gradients in Croatia, there is a greater possibility of using geothermal energy, and for this it is necessary to evaluate its full potential and possibilities of use. The aim of this research is to determine the heat potential of the Croatian part of the Pannonian Basin System (CPBS), as a part of Croatia with exceptional geothermal potential based on high number of well data with confirmed water inflow that was analysed. In order to estimate the Heat in Place, the available data on the presence of inflow, temperature and porosity, as well as permeability and volume for each well/reservoir included in the assessment was considered. In geothermal reservoirs, one of the most important data besides petrophysical and thermodynamic data is the potential of the well, i.e. the maximum flow under certain permeability and porosity conditions. To define this, the methodology of IPR curves (Inflow Performance Relationship) is used to define the flow in a given reservoir at a given difference between the reservoir pressure and the dynamic pressure at the bottom of the well. The productivity index was made dependent on the permeability of each well, and the inflow in each well was risked using Monte Carlo for three main geological phases in CPBS, which subsequently influenced inflow and spacing between production and injection wells. The beta-PERT distribution for permeability is used in Monte Carlo simulation to determine the most likely values and produce a distribution that resembles the real probability distribution. As a result, geothermal potential was mapped according to obtained values of Heat in Place for entire Pannonian Basin.

Research, innovation and development

SDEWES2022.0308

New Design and Performance Analysis of a 3D-Printed Flowmeter

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Abstract

Industrial flow measurement is becoming increasingly important in terms of process optimization, safety, product quality and environmental protection. Media such as water, steam, air, natural gas and others are fluids whose control is very important and measurements must be performed consistently. It is also important that measurements are made with the highest possible accuracy and the lowest possible uncertainty. One of the methods of measuring a fluid flow is the measurement of velocity and dynamic pressure in several measuring cross-sections. Prandtl or Pitot tubes, which belong to the group of averaging flow meters, are used for this purpose. The use of averaging tubes to study fluid flows has many advantages over other measurement techniques (e.g. laser Doppler, vortex) like results repeatability, calibration ease, measurements stability, well-known and simple operating principle. Technological progress determines the search for the optimum flowmeter design (among others, the least invasiveness and the highest precision). Factors that are taken into account when designing new devices are: expansion of the application range, improvement of the total uncertainty, type of tested fluid, measurements in larger cross-sectional areas, generation of turbulence, which is related to the shape of the probe. The current technological possibilities make it possible to meet all design requirements in a very detailed way, especially with regard to 3D printing technology. 3D printing is a rapidly developing field for both plastics and metals. This technique makes it possible to produce objects of any shape very quickly and cost-effectively, which was previously extremely difficult, time-consuming and expensive. These techniques enable huge reductions in material and energy consumption during the production process from design through research to the finished commercial product. In this way they support cleaner production and sustainable development. This paper presents a completely new design solution for a flowmeter. Based on a review of the current state of knowledge and the identified problems, a new shape of the averaging tube was designed. An initial verification of the shape was carried out using CFD methods. A prototype of the flowmeter was made with 3D printing technique using PLA plastic. Flowmeter tests were carried out in laboratory conditions. The flow meter calibration station was calibrated using the secondary standard method. The study demonstrated the undeniable superiority of 3D printing technology over standard prototyping methods in the field of manufacturing fluid flow measurement devices. An particularly interesting finding is that printed flowmeters can be successfully used in rapid ad hoc measurements. That is, where there is no need to calibrate measuring devices.

SDEWES2022.0403

Towards the Characterization of a Developed Automatic Two-Phase Flow Control System Based on Image Recognition

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Abstract

Control valves for pneumatic conveying and processing of ground solids are one of the key devices in process engineering and industrial systems. They play an important role in controlling the flow rate of both gas and solid phases. However, due to the complex geometry and gas-solids interaction, accurate process control is challenging and crucial for assuring a sufficient flow regime. This paper conducted experiments on pneumatic dense phase transport using a self-developed airflow control valve feedback system and image recognition. The possibility of regulating the fluidization process based on visual data from an industrial smart camera was analysed. A decision-making system using a PLC was developed. Two-phase gas-solid flow in a vertical pipe was investigated by defining the flow regime based on a grey-level analysis of the image. The ability to effectively predict and automatically control the flow rate at different valve openings was investigated. The robustness of the developed automatic gas-solid flow control system to disturbances was investigated by introducing disturbances and studying if and how the system returns to equilibrium. An adequate control will ensure the desired two-phase flow regime and the efficiency of the involved processes.

SDEWES2022.0410

The Application of Thermal Diodes as Thermal Control Elements in a Caloric System Employing Solid-State Zero GWP Refrigerants

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Abstract

Caloric systems for heating and cooling are high efficiency energy systems employing solid-state zero GWP refrigerants exhibiting a caloric effect. Caloric effect is the answer by a material to an intensity change of a forcing field as a temperature rising or falling. Basing on this concept thermodynamic cycles can be exploited to realize heating and cooling systems that can be based on the Solid-to-Solid Heat Transfer (SSHT) mechanism employing thermal diodes as thermal control elements able to change their thermal conductivity because of an external stimulus. In this paper the potentialities of a system basing on thermal diodes and employing different magnetocaloric-effect materials as refrigerants are analysed through a 2D numerical model and a comparison in terms of energy performances is carried out. The SSHT system is devoted to controlling the heating of electronic circuits. The novelties introduced in this work are: the possibility of optimizing the dimensions of both the block of caloric refrigerant and the thermal diodes to optimize the heat transfer reaching high values of working frequencies; a comparison among the energy performance given by a SHHT thermal-diode caloric system for cooling employing different solid-state caloric materials that, at the best of our knowledge, has never been analysed before.

SDEWES2022.0515

Quantitative Strategies for a Sustainable Future: a Roadmap Analysis

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Abstract

Roadmaps provide an outlook on the future and estimate how specific plans and measures can contribute to reaching certain targets in the future. They are used to support policy and identify required measures to be taken. Despite this important policy-supporting role, the outline and structures of roadmap studies is very case dependent and no generic structure of what a roadmap study should include is available. In addition, their prospective nature makes it important not only to look at technologies in a static way but also to include a prospective perspective on technology development.

This study reviewed ten recent roadmaps in the context of sustainability. Based on this review, a general framework for roadmap studies is provided, categorizing the different measures according to what kind of scenario is included (f.e. baseline); what kind of changes are implemented (f.e. consumption reduction); what kind of effect is being modelled (f.e. indirect or direct); what kind of technologies are included (f.e. technologies still in development); and what kind of estimations are used (f.e. based on historical trends). In addition, also the use of learning effects to model how technology performance changes with cumulative adoption, was assessed.

The results showed that where scientific publications often consider learning effects on the environmental or economic product level, the roadmaps focused more on improvements in the technical component level. The transition towards renewable energy was included as an indirect event in the background by almost all roadmaps. However, the global warming impact of this future energy mix was assumed to be zero, which disregards the impact of material extraction and waste management required for renewable energy. It is therefore recommended to also incorporate the impact of the material footprint of the renewable energy transition when discussing future scenarios. All the included measures can be related to the circular economy strategies, although the targets of all roadmaps primarily focus on minimizing climate impact. This illustrates how circular economy strategies act as a means to an end, although this is not acknowledged by the roadmaps themselves.

SDEWES2022.0522

Multilayer Flexible Plastic Packaging: Circular Transition Through Incorporating Design for Recyclability

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Abstract

The flexible plastic packaging market is expected to grow robustly due to its lightweight and high flexibility; however, closed-loop recycling of traditional flexible multi-material multilayer packaging is challenging and not yet implemented today. In ensuring the circular transition for this material, design for recyclability, therefore, is among the key aspects.

Through Life Cycle Assessment (LCA) and more specifically the European Product Environmental Footprint (PEF) methodology, the innovative multilayer mono-material flexible packaging (OPE/OPE/PE laminate) was investigated in comparison to the current multilayer multi-material one (PET/Al/PE laminate) regarding environmental sustainability. The three following life-cycle stages: material production, laminate processing, and end-of-life (EoL) treatment of packaging waste were considered while other stages: packaging, storage, distribution, and usage were excluded. The foreground data of laminate processing were provided by the packaging producer while that of the two remaining stages and the background data came from the LCA databases (mainly Ecoinvent v3.8). Moreover, Circular Footprint Formula, developed by the European Commission, was implemented. This formula defines the rule to allocate the environmental burdens and benefits of material and energy recovery between e.g., the supplier and the user of recycled materials. It means that the current market situation and quality losses of mechanical recyclates were taken into account.

The analysis firstly showed that the innovative mono-material laminate, either recycled or incinerated with energy recovery, obtains a lower net environmental impact compared to the current multi-material one. A clear benefit of recycling over energy recovery was also noted for the innovative laminate. Moreover, the material production (i.e., plastics, barriers, adhesive, and solvents) was identified as the environmental hotspot but induced a significantly higher impact for the current one while the laminate processing obtained a similar impact between the two packaging options. Generally, one should pay attention to (i) selecting more environmentally friendly materials (i.e., plastics and barriers), and (ii) designing a higher recyclable packaging structure, e.g., mono- instead of multi-material. A comparable functionality between the current and innovative packaging, however, should be kept in mind.

SDEWES2022.0525

Thermal Energy Storage as a Way to Improve Transcritical CO₂ Heat Pump Performance by Means of Heat Recovery Cycles

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Abstract

Electrification of the heating sector is one of the main targets of energy transition towards a more sustainable, efficient and less polluted future. Heat pumps are considered more suitable devices than electrical heaters or fossil-fueled boilers, but common refrigerants are responsible for ozone layer depletion, worsening the greenhouse effect. Natural refrigerants, such as CO₂, show comparable and even better performance than HFCs while minimizing negative aspects. This paper presents a model of a water-heater CO₂ transcritical heat pump in a particular configuration, which increases the overall COP (Coefficient Of Performance) just by introducing a TES (Thermal Energy Storage). The thermodynamic cycle is divided into two separate phases: after heating the TES (charging), warm water is later used as heating fluid in the evaporator to increase CO₂'s evaporation temperature and pressure, consequently reducing the compressor's work. As water temperature progressively decreases, discharging cycles help improve total COP. The case study refers to dairy processes and points to a more straightforward and cheaper way to improve the cycle efficiency than current ones, such as ejector expansion systems or double compression.

SDEWES2022.0594

Development of Electric Hybrid Drive of Forest Tractor – Skidder

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Abstract

Growing demand for forest machines that cost less to operate, along with regulatory pressures for lower emissions, increase manufacturers' interest in developing electric and hybrid drives compared to traditional hydraulic and mechanical ones. While pure electric drives of forest machines meet a lot of bottlenecks (costs of the electric components, battery durability, duration of charging, size of batteries which could ensure enough energy for 8 h working time), electric hybrid drives offer a favorable solution for the propulsion of forestry machinery in terms of lower fuel consumption and improved efficiency.

Among all forest vehicles, specialized forest tractors (skidders), so far, has not been considered a forest vehicle with hybrid drive capabilities. A skidder is a forest articulated self-propelled vehicle for pulling trees or parts of trees. In most countries of southern Europe, the use of skidders equipped with forest winches are the most common technique for timber extraction

The first goal of the research is to develop methods for measuring the energy consumption of skidders at different operating tasks and under different field conditions. Research was performed on skidder Ecotrac 140V (from Croatian producer Hittner Ltd.) during timber extraction in mountainous terrains in Lika County. Skidder was equipped with measuring device WIGO-E (Telematic Data collector) gateway with integrated GPS system which ensured collecting and storing data from sensors and motor computer via CANBUS and data transfer with GSM to Web platforms. Also, a fuel flow meter was installed on the skidder.

Data on fuel consumption (mL), position (travelling route), detection of winch work, engine rpm (min-1), engine torque (% of max), throttle position (%), engine temperature were measured with sampling frequency of 5 s. Besides, skidder load volumes per cycles and slopes of tractor paths were constantly measured.

The paper shows the skidder's energy consumption per day, work cycle and individual work procedure with regard to the size of the load, the slope of the tractor path and the direction of movement based on overlapping and merging all measuring data.

Using mathematical and simulation models of the drive with defined operating cycles obtained by measurement, the structure of the hybrid drive and the dimensions of the elements of the hybrid drive (internal combustion engine, electric motor, batteries, control unit) are determined and presented in the paper.

Research, Innovation, Nano and micro

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Investigation of Film Cooling Enhancement Using Comb Plasma Actuators

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Abstract

This paper proposed a novel comb plasma actuator (CPA) for active flow control. The effects of the CPA on the tip and the CPA on the root are investigated to improve film cooling effectiveness. Results show that the CPA on the root increases the size of counter rotating vortex pairs (CRVPs) and the agminated body force of CPA on the root toward the wall center arches the coolant air away from the wall. Whereas the scale of anti-counter rotating vortex pairs (Anti-CRVPs) induced by CPA on the tip is larger than that of CRVPs, which significantly weakens the coiling effect of mainstream on coolant air. Compared with plasma off, wall-averaged film cooling effectiveness increases by 90.9%, 108.9%, 87.2% and 38.0% under blowing ratios of 0.25, 0.5, 0.75 and 1.0. In addition, wall-averaged cooling effectiveness increases by 58.7%, 108.9% and 115.0% when applied voltages are 6 kV, 12 kV and 24 kV. The diffusing body force of CPA on the tip increases coolant air distributions along the spanwise direction. When blowing ratio increases from 0.25 to 1.0, spanwise film cooling effectiveness increases by 62.3%, 103.4%, 164.6% and 150.5% on average.

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Investigation of Vapour Film Formation on Nanolayer Surfaces to Reduce Drag on Marine Vessels

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Abstract

Although electric vehicles are becoming a viable solution for urban transport, in the areas of maritime sectors vehicles still do not find alternatives to fossil fuels. Since most studies are argued that the performance, fuel consumption, and energy losses are strongly influenced by the drag force, therefore, it is intended to improve the surface properties of moving bodies against the water, and hence reduce drag. For these reasons, new technological solutions to reduce drag reduction on marine vessels by combining together compliant surfaces can be expected. Towards a ground-breaking solution in the drag reduction for marine vessels, developing a new concept, where two-phase flow generation (boiling crisis [1]) solutions would be used in a complex way together with compliant surfaces. The research was focused on testing activated aluminium in second-degree boiling crisis processes. The Leidenfrost phenomenon [2] was achieved at a water temperature of 60 °C and a sample temperature of 580 °C. It has been observed that as soon as the Leidenfrost effect disappears, intense generation of hydrogen bubbles occurs, but not, as previously thought, in the case of the generation of a stable layer of film steam. The results obtained raise new hypotheses for the investigation of the conditions for the generation of hydrogen gas when the tests are carried out in water saturated with sodium hydroxide.

SDEWES2022.0617**New Hybrid Materials Based on Carbon Nanotubes and Metal Alloys**

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Abstract

Storage the hydrogen in the solid materials is safe and effective way to store energy. This type of cell can be used both for stationary and mobile equipment. The main requirements for modern materials for hydrogen storage in the automotive industry are: high gravimetric density, easy absorption / desorption of hydrogen at normal temperatures and pressures, low price of materials and their ecological safety. Conventional hydrides, such as LaNi_5H_6 and derivatives of zirconium and titanium alloys are commonly used in hydrogen storage systems have the storage capacity of less than 2% by weight of hydrogen. Four major groups of suitable materials include: a) carbon and other materials with high surface areas (nanotubes, graphite nanofibers, zeolites, etc.); b) H_2O -reactive chemical hydrides (NaH , LiH); c) hydrides complex (LiAlH_4 , NaAlH_4 , etc.), borohydrides amine (NH_3BH_3); d) alloys and intermetallics. Hydrides of rare earth metal (R) and transition metal alloys (T) are very well researched. These materials show good kinetics, but capacity and desorption temperature are low. On the other hand the hydrides complex of the lithium alloys have enjoyed in recent years, large attention as materials for energy storage in the future. The hydrogen content is achieved in accordance with the literature value of 18% mass for LiBH_4 . However, these compounds only desorb hydrogen at a temperature about 600°C . Large prospects in the process of sorption / desorption of hydrogen and therefore solving of this problem are lightweight multicomponent lithium alloys and carbon nanotubes.

Scanning electron microscopy

Tescan Vega 3 SBU scanning electron microscope (Tescan, Brno, Czech Republic) with EDS analyzer.

Fourier transform infrared spectroscopy (FTIR)

FTIR Nexus Nicolet spectrophotometer (Madison, WIS., USA) within the range of $4000\text{--}400\text{ cm}^{-1}$.

Electrochemical investigations

The functionalized MWCNT were introduced in LiPF_6 solution in propylene carbonate. The resulting paste was applied on the working electrode of the cell, and then tightly closed. The second electrode (cathode) was made analogously by grinding LiCoO_2 alloy. The third electrode was the reference electrode (metallic lithium). Experiments were performed at 25°C .

Conclusions

Modification methods of metal alloys by MWCNT used by our group provide the possibility to use functionalized MWCNT in devices powered by electricity. Preliminary tests have shown a very positive influence of d- and p-electron elements on the corrosion resistance and extension of the life of hydrogen storage materials. Our proposed test procedure (synthesis - the phase composition - crystalline and electron structure and the properties of absorption and catalytic) will allow to select the most optimal configurations of hybrid materials for practical use. Since the main goal of the project is to obtain new materials from the point of view of their practical use.

SDEWES2022.0618

Sulphur and Seleno Derivatives of Nanotubes as Electrode in Batteries

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Abstract

Lithiated transition metal oxides are of great interest for fundamental studies and practical applications such as positive electrode materials for rechargeable lithium-ion batteries. In comparison to commonly used LiCoO_2 electrodes, LiNiO_2 is cheaper and has a higher energy density (20% higher by weight), but is less stable. The phase relationship between NiO (NaCl-type), $\text{Li}_x\text{Ni}_{1-x}\text{O}$ (disordered NaCl), $\text{Li}_{1-x}\text{NiO}_2$, and LiNiO_2 (α - NaFeO_2 -type) was described by Kanno et al.. In the industrialized world, the development of energy resources (e.g., oil, natural gas) has become essential for agriculture, transportation, waste collection, information technology, and communications that have become prerequisites of a developed society. The forecasts for energy needs make it necessary to look for new alternative sources of energy for environmentally friendly batteries. Currently, a very promising solution is to store energy using cells composed of ternary systems such as alloys and composites. We have developed lightweight alloys and intermetallic compounds. Lithium alloys (Li-Me-O) can be used as electrodes in batteries.

Based on the literature and study results described in the our paper, we continued modifications of the multiwall carbon nanotubes (MWCNT) with thiophosphoorganic and selenophosphoorganic salts along with simultaneous evaluation of their effect on electronic properties of the MWCNT.

Functionalization of halogenated carbon nanotubes

Syntheses of MWCNT containing a covalently bonded substituent based on nucleophilic substitution reactions of halogenated carbon nanotubes with anions containing a stereogenic heteroatom.

Scanning electron microscopy

Tescan Vega 3 SBU scanning electron microscope (Tescan, Brno, Czech Republic) with EDS analyzer.

Fourier transform infrared spectroscopy (FTIR)

FTIR Nexus Nicolet spectrophotometer (Madison, WIS., USA) within the range of $4000\text{--}400\text{ cm}^{-1}$.

Electrochemical investigations

The functionalized MWCNT were introduced in LiPF_6 solution in propylene carbonate. The resulting paste was applied on the working electrode of the cell, and then tightly closed. The second electrode (cathode) was made analogously by grinding LiCoO_2 alloy. The third electrode was the reference electrode (metallic lithium). Experiments were performed at $25\text{ }^\circ\text{C}$.

Conclusions

Modification methods of MWCNT used by our group provide the possibility to use functionalized MWCNT in devices powered by electricity. Introduction of phosphoorganic salts into the structure of MWCNT increases the stability of work with simultaneous increase in performance and life span of the cell. However, phosphoorganic salts with smaller cation provide broader opportunities in the commercialization of such systems, because there is no effect of excessive competition between cations in terms of charge transfer.

SDEWES2022.0628

Investigation and Improving the Environmental Friendliness of Fishing Vessels Through the Network of Fishermen and Scientists

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Abstract

Energy efficiency and environmental performance of ships are key factors in marine sector. Introducing different technical and operative measures, focused on achieving higher environmental friendliness of vessels through emission reduction and fuel consumption monitoring, has increased the need for cooperation between industry and scientific institutions. The fishing industry has a long tradition, and even today the procedures are based on simple operations developed a long time ago. New regulations and environmental measures, which mostly concern the improvement of fishing operations, are often complex and require calculations to ensure sustainability, minimize operative costs and enhance marine protection. Fishermen have a lot of knowledge and skills in the operational part of fishing, but the application of alternative technologies requires detailed analysis and calculations that they cannot carry out by themselves. On the other hand, scientists assess the environmental influence of vessels at different levels of complexity and accuracy, obtaining technical data and assuming operative profiles, but they do not have the direct experience to qualitatively assess all the necessary parameters that affect the operational properties of vessels. In order to resolve the aforementioned shortcomings, cooperation between fishermen and scientists is highly important. During the cooperation, the fishermen provided data on fuel consumption in real-time, explained the problems they face while fishing and presented the difficulties they face when trying to apply new regulations. Scientists collected these problems and created a database that helped them during the analysis of fishing vessels and their environmental impact. The calculations explored numerous possibilities for the implementation of alternative technologies, which include new regulations and enable fishermen to make a profit. The initial phase of creating the network involved two universities, two fishing cooperatives and 12 vessels. With further work, efforts will be made to expand the network, in order to connect the entire fishing fleet of Croatia with its scientific institutions.

SDEWES2022.0631

Optimisation of Mixing System Design for Heavy-Duty Diesel Engine SCR Aftertreatment System

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Abstract

Despite electrification and hybridisation trends in the automotive industry, Diesel engines still play an important role, especially in heavy-duty applications. Due to more and more restrictive emissions limits, aftertreatment systems have come for good as a solution for emissions reduction. One of the most common approaches to reducing the nitrous oxides in Diesel exhaust gas is selective catalytic reduction (SCR) catalyst using ammonia from urea-water solution (UWS) as the NO_x reducing medium. A proper UWS dosage and mixing are necessary to provide the high efficiency of such a catalyst. However, not only the uniformity of ammonia is important. The solid urea deposit needs to be prevented as it reduces the aftertreatment system performance, and there is a risk of system damage. The design process of each aftertreatment system is challenging as there is no universal approach to exhaust system aerodynamics.

This study shows the optimisation process of a commercial heavy-duty system design. As the mixing length is sufficient, the uniformity of ammonia at the SCR inlet is not an issue. However, the urea deposit risk was the key challenge in that design. During the validation tests, the initial version of the system, despite a high uniformity of ammonia distribution, led to a solid deposit formation around the injector. Further development was focused on reducing the deposit while maintaining the high uniformity of ammonia distribution. The iterative process of design development using CFD analysis allowed us to improve the mixing process and reduce the wall film generation and deposit risk. The injected UWS mass balance was analysed, as well as the flow distribution along the mixer. The mixer was tested under various flow conditions to improve its performance in a wide range of engine operating points.

The results showed that the improvement of UWS mixing with hot gas stream reduced the risk of wall film generation on the system walls and solid urea deposit formation.

Smart energy systems 1

SDEWES2022.0027

A Multi-Agent Co-Optimization of a System-Of-Systems for a Profitable, Sustainable, and Resilient Circular Supply Chain of Multiple Conventional and Crypto Products

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Abstract

Alongside encouraging investment in green energy systems, the market increases the energy-intensive products of the new era. Profitability is the primary goal of all businesses, but sustainability is the main hindrance to that. Efficient integration of multi-carrier and multi-product networks not only aids sustainable development but also justifies financing in green systems as a result of analyzing the crypto products and weighing their merits and downsides in cross markets. Optimization of systems by concurrent consideration of design and operation over their life cycle would have a critical role in fulfilling the goals of the Paris Agreement in mitigating climate change. Furthermore, new technologies are emerging in addition to available multigenerational systems and energy hubs. However, conventional approaches of systems engineering cannot adapt to these innovations for the lack of systematic self-improving. A System-of-Systems (SoS) approach has recently been put forward as a resilient remedy due to its inherent diversity, efficiency, adaptability, and cohesion. Here, a circular supply chain model of power, cooling/heating, freshwater, hydrogen, and crypto products is developed to be delivered to a novel multi-agent co-optimization model considering the water-exergy-carbon-cost nexus. The SoS is redesigned by investing in new technologies or modifying its architecture by means of manipulating production modes, distribution and generation plans, storage facilities, external connections, and demand management of a given problem. For this, a multi-agent Reinforcement Learning (RL)-based co-optimization algorithm discovers a solution by learning and improves the decisions as the agents cooperate. The results showed that the models could determine the near-optimal operating schedules of the SoS by maximizing the green profit objectives. The demand management increased the resiliency while controlling the energy consumption of crypto products in the new holistic design and operation co-optimization model by balancing both supply and demand sides.

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SDEWES2022.0263**Dynamic Simulation of a 4th Generation District Heating Network with the Presence of Prosumers**T. Testasecca^{*1}, P. Catrini¹, M. Beccali², A. Piacentino¹¹University of Palermo, Italy; ²Università degli Studi di Palermo, Italy
(*tancredi.testasecca@unipa.it)**Abstract**

It is estimated that in the European Union buildings' space heating accounts for 40-80% of the total primary energy consumption and, considering the achievement of the Sustainable Development Goals, its decarbonization plays a fundamental role. According to the "Heating" report by International Energy Agency in 2021, District Heating Network (DHN) is identified as a promising technology for the decarbonization of urban areas. Indeed, this technology could allow for the integration of heat produced by renewable energy sources, cogeneration plants, and the exploitation of waste heat available from industry or data centers. Moreover, it is also recognized that DHN could help solve issues related to grid stability in case of electricity surplus from renewable energy sources via power-to-heat technologies and thermal energy storage. In this context, each consumer of the network could become an energy producer during the day (briefly indicated as "prosumer"), thanks to the surplus of renewable thermal energy produced in-locu. However, to be supplied by thermal energy available from prosumers, DHNs should be operated at lower temperatures than conventional networks (i.e., 85°C). These are the main features of 4th and 5th DHN generations, characterized by a temperature lower than 60 °C.

During these years some models were proposed to simulate the operation of DH systems. However, there is a lack of studies focused on the dynamic simulation of these networks. Indeed, the increasing presence of prosumers will require accurate dynamic modeling of DHNs to monitor the changes induced in the thermohydraulic variables of the network. The developed model could not only be used to monitor the operation of DHN, but also to develop cost-effective operation strategies. In this respect, this paper aims at developing a DHN model in TRNSYS environment. The study focused on a ring-shaped network serving a cluster of 10 residential buildings located in Southern Europe. A network with a centralized CHP and a supply temperature of 85 °C is considered as the "Base Case". Some alternative scenarios are proposed based on the presence of prosumers along the network and a decreased temperature. The model will allow for monitoring the main thermohydraulic parameters of the system (e.g., pressures, temperatures, flow rates, etc.) and to calculate the achieved primary energy saving during DHN operation. Results obtained for the different scenarios will be then compared and discussed.

SDEWES2022.0297

Real-Time Monitoring of Windows Using a Computer Vision-Based Detector for Reducing the Building Energy Demand

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Abstract

The interaction of occupants with window openings can significantly affect the air change rate and the energy heat loss from ventilation. During unfavourable conditions, the use of natural ventilation can then lead to significant heat loss and thermal discomfort. This is even worsened by occupants leaving windows open unintentionally during heating periods. With the increased awareness of the impact of occupancy on energy use and advanced control strategies, more researchers are focusing on occupant-centric strategies. An example of this is the use of sensors that can monitor the usage of building spaces and controls which can automatically adjust according to the actual requirements of the space. Various techniques have been introduced to monitor or sense windows' status (open/close), and much recently, computer vision-based techniques have shown great potential for monitoring various objects and activities in building spaces. For example, it can simultaneously monitor occupants and their interaction with the windows, providing more information for the control systems and building users or operators. This study introduces a vision-based approach for the real-time detection and recognition of the windows' opening and closing. The study will take an in-depth look into the performance of the detection model, in particular, the influence of data curation, labeling and training employed. This includes exploring the impact of the types of detection responses selected, the types of images used, the dataset size, and how the images were proposed before training the window detection models. Four types of window detectors were formed and were evaluated based on the detection of a set of windows within a case study building, which will help seek the best, most accurate detection and recognition window opening status detector. The different detection model development strategies provide detailed comparisons for energy consumption. The study showed that the detection model performance could ultimately impact the control and coordination of an HVAC system with occupancy and natural ventilation, which play a significant role in reducing energy consumption and improving comfort and indoor air quality.

SDEWES2022.0344

Blown Plate Heat Exchanger in Cabinet Cooling System

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Abstract

In a surface heat exchanger, the heat transfers from hot fluid to cold fluid through the separating solid wall. The heat transfer areas of surface heat exchangers are usually constant when it is performing in energy system. Similarly, fixed plate heat exchanger is applied in electronic cabinet cooling system. In this paper, a novel approach to vary the heat transfer area of surface heat exchanger is proposed. A blown plate heat exchanger is introduced for cabinet cooling system. And, the thermal performance of the blown plate heat exchanger and fixed plate heat exchanger are compared. For the same Reynolds numbers the thermal performances of the blown plate heat exchangers are the same with fixed plate heat exchanger. The blown plate heat exchanger with all mixed plates has the best thermal performance, the temperature reduction of hot air is arrived 15.185 K, when the maximum temperature difference is 20 K.

SDEWES2022.0422

Energy and Economic Assessment of a Reverse Osmosis System Based on Trigeneration System with Wind Turbine, Photovoltaic Field, and Biomass Steam Cycle

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Abstract

Progressing global development causes depletion of earth's resources on a large scale. In order to solve this problem, renewable energy sources have been used for many years, also combined in the so-called hybrid systems. Among other issues, the need for drinking water is a growing problem. The existing solutions for the production of drinking water mainly focus on the use of fossil fuels in reverse osmosis or thermal systems. The aim of this study is to propose a solution enabling the production of drinking water and allowing to match the electrical and thermal load of the user using a self-sufficient hybrid system based on the biomass-fired steam cycle, wind turbine, photovoltaic panels, and an adsorption chiller.

In the proposed system, renewable energy is used to match the energy load of a homestead and a load of a reverse osmosis system. If production exceeds the load, power is directed to the grid, which is used as virtual storage for electrical energy. Moreover, the thermal energy recovered by the steam cycle is used to match the user's thermal demand by means of a storage tank supplying the user directly during the winter, and driving the absorption chiller during summer.

The proposed system is modeled and dynamically simulated by means of Transient System Simulation software. The dynamic operation of the system and the energy and economic performance of the system are assessed in the paper. The operation of the system is presented on a monthly and daily basis, while the global performance parameters of the system are reported considering a one-year period.

SDEWES2022.0473

User-Oriented Design of Energy Data Platforms

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Abstract

Our fossil-fuel based energy system is to date challenged by the need to reduce greenhouse gas emissions to achieve a decarbonized energy system, and by the increasing trend of digitalization, which opens various new opportunities to design a sustainable energy system. The ongoing smart meter roll-out provides temporally available energy data on individual households. Different smart services and products provided by energy supply companies and other companies in the field of energy management offer new ways to educate consumers, to manage production and consumption, and to strengthen the role of renewables. However, whilst the increasing availability of data, and even open data, has led to new services in terms of open data platforms in other domains, like e-governance, such offers remain scarce in the energy sector. In addition to data-driven energy efficiency and innovation, such open data platforms have the potential to create collective value in the form of information transparency and system change.

In a representative survey conducted in July 2021 (n= 700), we therefore investigated the overall acceptance of an open energy data platform, and specifically addressed what features potential user would prefer with a Conjoint experiment. Which characteristics of the components of an open data platform such as operator, type of use, contact partners, motivation, privacy or comparison options do Austrian households prefer? Preliminary results suggest that end users would prefer that such a platform would be operated by a public institution, and they see a benefit of said platform for themselves rather than for optimizing energy planning on a local level or for the national energy system overall. Moreover, the provision of information as well as the possibility to compare energy data with other households are considered as very attractive by end users. This information on key design features can provide a decisive indication for the establishment of an energy open data platform.

SDEWES2022.0597

Integration of an Rsoc-System to Industrial Processes

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Abstract

In our research we are focusing on the integration of reversible Solid Oxide Cell systems (rSOC-Systems) to industries. This system can work as electrolysis cell as well as fuel cell. The fuel cell operation furthermore has the advantage, that methane from the gas grid can be used to produce electricity. In this ways the rSOC-System can provide a part of the flexibilities, that will be necessary in our future energy system with a high share of volatile renewable energy sources. In this work the aim is to improve the understanding of the rSOC-System and the effects of an integration in industrial sites. We explain the coupling possibilities to industries together with the operational behaviour of rSOC-Systems. For deriving the results, we used literature studies as well as simulation models for the system. From the generated insights, conclusions for the application of the system understanding and its integration are drawn. Finally, an outlook for further works is given for which this work provides a basis to start from.

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SDEWES2022.0041

Application of Optimal Energy Management Strategies in a Microgrid Using Different Energy Pricing Profiles

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Abstract

Microgrids generally use photovoltaic production and battery storage system for supplying electricity to different types of loads such as building and electric vehicles (EV). Such microgrids need to be controlled in order to operate efficiently. Several energy management strategies (EMS) of increasing complexity have been developed. The most advanced rule-based control (RBC) strategy considers several parameters such as photovoltaic forecasting and battery degradation, thus improving the operation of the microgrid. The price of energy has an important impact on energy exchanges planning in the microgrid. Four price profiles are used: peak and off-peak electricity prices in France, constant pricing, dynamic electricity pricing that reflect variations in electricity demand and production and an electricity tariff considering the additional electricity production costs in no interconnected island area as Corsica. The impact of energy pricing profile on the EMS performances is analysed. The most complex RBC strategies conduce to the highest gain regardless of the tariff profile, varying from 3595 to 5329 € for a whole year. The highest gain is reached with dynamic electricity pricing. With this tariff, the use of an optimised RBC allows an increase of the gain of about 49% in comparison with a simple auto consumption strategy. With the three simplest RBC, a significant number of power cuts is observed (up to 138 for one year). The inclusion of PV production forecasting and the consideration of battery degradation in the decision tool improves the efficiency of the EMS strategy.

SDEWES2022.0448

An Optimization Model for the Scheduling of a Multi-Energy Microgrid

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Abstract

A methodological framework for the optimal scheduling of a multi-energy microgrid with electricity, heating, and cooling energy demands has been developed in this work based on advanced mixed integer programming techniques. In particular, the microgrid consists of several technologies and resources, including micro combined heat and power units, gas turbines as dispatchable generators, renewable energy sources, energy exchanges with the main grid, heat pumps, electric chillers, chiller boilers, as well as flexibility providers such as energy storage systems, electric vehicles, and demand response. A salient feature of the proposed framework is the consideration of the contribution of all those flexibility resources in the ancillary services provision of both microgrid's and main grid's requirements, providing an additional income for their operation and enhancing the grid operation. The model outputs highlight the importance of incorporating the ancillary services market as a revenues component of the microgrid and the fact that the participation of various resources in both energy and ancillary services markets influences the microgrid's scheduling plan. The services provided by the flexibility resources play a vital role in the overall cost reduction. System operators and aggregators can utilize the methodological approach to identify optimal scheduling and investment strategies.

SDEWES2022.0485

A Deep Learning Approach for Spatiotemporal Energy Demand Prediction

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Abstract

With the urbanization and economic growth in the global world, energy consumption in cities is increasing rapidly and with more sophisticated behavior, threatening future energy safety and efficiency. Unexpected fluctuations in energy demand can put enormous pressure and uncertainty on energy production and distribution, and even cause the entire energy system to collapse. Although considerable effort has been devoted to estimating the trend of energy demand by socio-economic or data-driven methods, most of them give a statistical number, but do not provide finer details and, therefore, are not intuitive. In this paper, we propose a novel deep learning-based approach to predict energy demand by taking into account both spatial and temporal information in a coordinated manner. We model the spatiotemporal problem of urban energy consumption as a two-dimensional dense prediction problem and use Conv-LSTM to encode spatiotemporal information of urban energy consumption. We validated the effectiveness of the proposed method using real-world electrical consumption data. The approach is significant for the planning and operation of urban energy management systems, which can potentially improve the efficiency of conventional power generation and ensure the safety of the energy supply.

SDEWES2022.0537

Renewable Energy Communities in the Industrial Sector: Energy, Economic and Environmental Assessment of an Italian Case Study

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Abstract

As part of the Clean Energy Package, the European Renewable Energy Directive of 2018 and the Internal Electricity Market Directive of 2019 defined innovative configurations of end-users to develop renewable energy sharing system, self-consumption, self-production and also prosumers figure such as Renewable Energy Communities. In addition to residential consumers and local authorities, also small and micro-enterprises are encouraged to join these energy sharing organizations, in the light of the optimisation of demand side management ensured by multi-users. Therefore, this work is aimed to evaluate the outcomes deriving from the implementation of energy sharing and collective self-consumption schemes in the industrial sector through the constitution of a Renewable Energy Community in the industrial area of Benevento (in South of Italy). An office building and the industrial wastewaters consortium treatment plant have been selected as initial members of the configuration by using a photovoltaic plant to supply electric energy load. The data about users' electric energy consumptions were obtained from the real bills, whereas the photovoltaic plant producibility was estimated using Homer Energy Pro software. Successively, an energetic, economic, and environmental analysis has been performed to assess the positive outcomes in terms of primary energy savings, users' renewable energy self-consumption and energy self-sufficiency increase, operation costs reduction and greenhouse gas emissions mitigation.

SDEWES2022.0550

Barriers to Demand Response in the Commercial and Industrial Sectors – an Empirical Investigation

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Abstract

To address the challenges arising from the expansion of renewable energies and the increasing electrification of energy demand, Demand Response (DR) is seen as a promising tool to match consumers' electricity demand with available supply. Its rationales include financial benefits (e.g., electricity cost optimization), as well as addressing technical constraints (e.g., local grid congestion). Despite high theoretical DR potentials identified in scientific literature, adoption of DR in the industrial and commercial sectors is still a long way from reaching these potentials. Therefore, this study explores the barriers to engaging in DR, as well as the importance of these barriers. To this end, we conducted 20 semi-structured interviews with experts from industrial and commercial companies as well as national industry associations from various sectors in Germany, such as the paper industry or the retail sector. An initial analysis has revealed numerous potential barriers, and differences emerged in both how often barriers were mentioned and how relevant they were considered to be. The most commonly cited barriers include fear of reduced product quality, interference with up- and downstream processes, management of human resources, and costs that are difficult to quantify ex ante. Even though some industrial companies have recently started to participate in DR programs in Germany, our results suggest that the heterogeneity of production processes and facilities may explain the reluctance to engage in DR. While some of the most predominant barriers could be overcome with further information and enough (human) resources within an organization, external incentives and regulations may need to be adapted to facilitate DR uptake as well. Inspecting the identified barriers, as well as the underlying motives and fears can help decision-makers to devise strategies in order to assist industrial and commercial consumers in participating and providing DR.

SDEWES2022.0616

Optimization of Energy Systems Through Multi-Agent Reinforcement Learning with Risk Mitigation

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Abstract

With the ever-growing need for carbon neutralization in the wake of continued acceleration of global warming, reducing reliance towards non-renewable energy sources, and further development and optimization of energy systems has become ever so important. However, since such next-generation energy systems incorporate multiple, often fluctuating components such as photovoltaic (PV) power energy supply and demand profile, optimization of complex energy problems through traditional mathematical means have proven to be a struggle. In light of this, we proposed an AI based approach to solving the energy optimization problem under uncertainties, with algorithmic and learning capabilities, in the form MADDPG (multi-agent deep deterministic policy gradient) reinforcement learning algorithm. A case study was then introduced, where a three-factory, formulated as three learning agents, under one PV power supply system was optimized with the goal of learning an operation schedule that minimizes energy usage incurred by the three agents. The schedule learnt by the algorithm was validated by the schedule suggested through mathematical means, before being applied to a more complex optimization problem. In addition, risks of following an operation schedule deduced by an optimization algorithm of an energy system with highly uncertain factors such as PV power output cannot be ignored. Consequently, we proposed the preparation, and implementation of varying numbers of PV power supply scenarios to conduct a scenario-based risk-mitigation during the learning process for the MADDPG agents. Our results indicated the MADDPG algorithm is able to conduct effective optimization and scheduling of energy systems with uncertainties by effectively extracting the common feature among all PV-cell supply scenarios.

Smart transport systems and policy

SDEWES2022.0021

Evaluation of the Shift to Electromobility with an Input-Output Model: Scenarios and Impact of the Electrification of the Powertrain for Passenger Cars in Spain and the Relationship with Other Regions

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Abstract

The decarbonization of transport is a goal for many countries and in particular for the EU zone, showing its commitment with the European Green Deal. At medium-term, this goal is focused on the electrification of the powertrain for passenger cars. It involves a change in the supply chain for production that could be significant for the countries with a high weight of the traditional automotive industry, such as the case of Spain, where 11% of the GDP comes from this industry. There is a forecasted shift from the sector of traditional automotive parts (combustion engine and associated parts) to the electric sector, where batteries and electric components will be the major part of the powertrain. This shift can have an important impact on the economy and moreover social effects. In this work, we simulate scenarios to evaluate changes in the car industry from the ramp up of the EV market both in Spain as in the European Union and the rest of the world by using an environmentally extended multiregional and multisectoral input-output model. This model represents the whole economy and the relationship between the regions and sectors, so the effect of a change in the supply chain for production or in the demand can be calculated. The results show significant impacts on employment and economic indicators for the scenario in 2050, when the share of electric vehicles is expected to increase up to a relevant level. The model enables also to evaluate the environmental impact and adding it to the operational vehicle emissions.

SDEWES2022.0046

A Proposal of Zero-Emission Tug in South Korea: the Economic and Environmental Effects

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Abstract

This study presents the results of economic and environmental analysis for two types of zero-emission ships (ZESs) that are actively discussed in the shipping industry as the most probable carbon-free solutions to meet the strengthened environmental regulations. The two ZESs studied in this manuscript are the ZESs using only energy storage system (All-ESS) and the ZESs with fuel cell and ESS (FC-ESS) hybrid system. Recently, IMO (international maritime organization) started to discuss the fuel's entire lifecycle greenhouse gas (GHG) emissions, including the well-to-tank (WtT, also known as upstream) emissions and the tank-to-wake (TtW, also known as downstream) emissions. In addition, the target ship was a tug operated in South Korea. The optimal capacity of the ESS for each proposed system was determined by an optimization tool. The capital expenditure (CAPEX) and operational expenditure (OPEX) during the total lifetime of a ship were estimated from the economic analysis. And total GHG emissions of the fuel's entire lifecycle were calculated for the environmental analysis. The results showed that all proposed systems bring higher costs than the conventional MGO-fueled system, however, they have lower total lifecycle GHG emissions. Among the proposed systems, the All-ESS system has the highest cost for a ship's lifetime, however, it has the lowest GHG emissions for fuel's lifecycle. In the case of the FC-ESS system, economic and environmental analysis results vary depending on the combination of the FC and ESS power generation. Also, the results highlighted that the electricity or hydrogen-based system should reduce GHG emissions from its WtT (upstream) process to realize the genuine ZES.

SDEWES2022.0063

Environmental and Economic Consequences of the Electric Vehicle Penetration in Spain and Europe: a Dynamic CGE Analysis

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Abstract

Automotive industry is crucial for the economy of Europe, being a major producer of vehicle components and cars worldwide. Inside Europe, Spain is the second largest producer only after Germany. Nowadays this industry is subjected to a deep transformation due to electrification, which is driven by environmental and economic objectives contained in the European Green Deal. The expected increase in the market of electric vehicles (EV) versus the decrease in internal combustion engine vehicles (ICEV) implies a significant change in supply chains for production and consumption of the corresponding energy sources (electricity versus petroleum based products). In order to evaluate the economic implications of this transition, a computable general equilibrium (CGE) model has been built. This model is based on the environmentally extended multiregional input-output (MRIO) matrix of 2016 for the worldwide economy and evaluates the impacts up to 2050 from a dynamic perspective. The use of CGE enables to relax restrictions of Leontief model by defining substitution elasticities that reflect the relationship between the sectors implied in the electrification transformation. Different scenarios of household energy demand and fiscal policy are defined, establishing also market factors for labour and capital. The model calculates the impact on different aspects of the economy of the regions of interests together with the impact in environmental indicators for production.

SDEWES2022.0215

A Review of Challenges and Emerging Technologies for Increased Energy Efficiency, Safety and Sustainability of Railway Transport

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Abstract

The paper presents a detailed review of state-of-the art technologies for the future development of smarter, safer and greener railway transportation systems. Firstly, the paper presents a comprehensive overview of current challenges in railway transportation, followed by emerging propulsion technologies that are key for sustainable transportation, such as those based on alternative fuels, hydrogen fuel cells and energy storage technologies for kinetic energy harvesting and bridging power applications. Secondly, emerging information and telecommunications systems based on long term evolution and 5th generation new radio networks suitable for railway applications are presented and the role of industrial internet of things is discussed. Finally, the use of wireless communications and remote sensor networks is investigated in the context of increasing the availability of key information about the transportation infrastructure under varying weather conditions for the purpose of improved transportation energy efficiency and safety, along with information technologies needed for the future implementation of Industry 4.0 concept in railways.

SDEWES2022.0217

Control Variable Optimization for a Diesel Electric Hybrid Locomotive

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Abstract

Nowadays, railway vehicles are being increasingly equipped with hybrid electric power-trains in order to provide significant gains in fuel economy and reductions in greenhouse gases emissions. Since hybrid power-trains are complex electromechanical systems, optimal energy management is crucial in order to achieve minimum possible fuel consumption. Having this in mind, this paper proposes an optimised real time energy management control for a diesel electric hybrid locomotive based on optimal results of dynamic programming optimization algorithm. The goal of the optimization is to minimize the fuel consumption subject to battery state-of-charge constraints and physical limits of different power-train variables. The final optimization result, expressed in terms of optimal battery state-of-charge reference (target) is used as an additional input to the state-of-charge controller of the real-time energy management system, and the resulting simulation analysis shows clear gains in terms of fuel savings of the locomotive equipped with the hybrid power-train over the conventional one.

SDEWES2022.0392

A Novel Dynamic Simulation Tool for Railway Stocks Energy, Economic, and Environmental Performance Assessment: Analysis of the Role of Ventilation in Enhancing Indoor Air Quality

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Abstract

The energy consumption in the transport sector is constantly growing. Such a growth, from 1990 to 2018, has been equal to the 100% in the EU-13, and the recent predictions see the transport sector far from stopping growing, which in turn implies a remarkable energy consumption increase in the next decade. In this context, the railway sector weights for a non-negligible share in terms of energy use, being accountable for up to 280TWh_{el} per year worldwide. In this framework, the HVAC system energy consumption share is proven to be not negligible and accounts for up to 30% of the total energy demand on board (depending on the considered train). Given all of this, and considering the remarkable growth that the railway sector is experiencing, increasing interest should be played in enhancing the railway sector energy efficiency. To reach this goal, there is a proven need for mathematical tools capable of dynamically assessing rolling stocks' energy performance, in order to predict the convoys' energy demand and to take suitable actions aimed at improving their energy efficiency. To this aim, this paper presents a novel dynamic simulation tool for railway stocks energy, economic, and environmental performance assessment. The tool, developed in openstudio environment, is capable to take into account the weather solicitation linked to the actual train path (function of the convoy location and orientation). To show the capabilities of the developed tool, a novel case study referred to an existing medium-distance train is presented. For the considered train, ventilation strategies for IAQ enhancement have been tested for three diverse European climates by obtaining interesting energy, economic, and environmental results.

SDEWES2022.0415

Machine Learning-Based Method for Leakage Localisation of Crude Oil Pipelines

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Abstract

In accidents involving oil leaks, the calculation of pipeline leakage is a crucial element in estimating economic losses. It is therefore important to study the leakage localisation method of oil pipelines. Based on machine learning theory, a pipeline leakage predicting model is developed to solve the problem of leakage localisation. Large amounts of the crude oil pipeline leakage data generated by SPS are used to train the leakage predicting model with multiple machine learning algorithms. As a result, a model for calculating leakage of pipelines is developed that accounts for the changes in friction coefficient and specific heat capacity of crude oil with temperature. To calculate the coupling of pipe flow and leakage, the non-steady-state pipe flow regularity after leakage is combined with the outflow regularity at the small hole. The model of the Sinopec Dong-Huang oil pipeline is built based on the SPS software, and the "Qingdao 11-22" pipeline leakage and explosion accident is simulated. The simulation results show that the average error of leakage location is less than 35 m compared with the real accident data. The results can verify the reliability and high accuracy of the proposed machine learning method.

SDEWES2022.0417**Adaptive Control of a Parallel Plug-In Hybrid Electric Vehicle Tuned Based on Dynamic Programming Optimization Results**J. Soldo^{*1}, I. Cvok², B. Škuĝor³, J. Deur³

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Abstract

Increasing legislative and market pressures on reducing emissions drive the development of electrified vehicles. This includes plug-in hybrid electric vehicles (PHEV), which for the time being circumvent drawbacks of the fully electric vehicles, such as high vehicle and charging infrastructure cost, limited driving range, and long charging time. PHEVs achieve this by combining an internal combustion engine and one or several motor/generator machines supplied by the electrochemical battery chargeable from the grid. To maximize the efficiency of such a complex powertrain configuration, design of an optimal energy management control strategy is required. Due to high variation of road load-related operating conditions, it is generally of interest to design an adaptation rule for the optimal control strategy.

This paper deals with the design of an adaptive control strategy of a PHEV-type bus with parallel (P2) powertrain configuration. The adaptive control strategy is based on the previously developed optimal control strategy, which combines a rule base (RB) controller and equivalent consumption minimization strategy (ECMS). The adaptation is based on scheduling of most-relevant RB+ECMS parameters with respect to on-line monitored driving cycle statistical features. The adaptation law is derived from dynamic programming (DP)-based control variable optimization results, which are obtained by using a computationally efficient quasi-static backward-looking model, whose accuracy is enhanced by accounting for the powertrain transient effects (such as those occurring during gear shifting and engine switching events). Comparative simulation results obtained by using the backward-looking model and more accurate, fully transient forward looking-model demonstrate that the adaptive control strategy achieves consistent fuel savings when compared to the existing, non-adaptive strategy.

Storage

SDEWES2022.0003

Performance Prediction and Optimization of a Three-Layer Thermocline Tank Using Response Surface Method

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Abstract

The connection between the independent and dependent parameters of the thermocline thermal energy storage tank system used in concentrating solar power plants is shown in this work using a predictive model based on the response surface method (RSM). MATLAB software was used to figure out and calculate the two-phase transient dispersion-concentric current numerical formulas. Furthermore, RSM is used for single and multi-objective optimization to recommend the best control factor values for various optimization purposes. The selected operating factors include charging cut-off temperature, discharging cut-off temperature, charging cycle inlet temperature and molten salt mass flow rate. For response factors, including charging time, discharging time, overall efficiency, and recovered energy are considered. The analysis of variance (ANOVA) test and perturbation analysis are also applied to evaluate the suitability and statistical of the model. According to the results, to minimize the charging and discharging time, and to maximize the overall efficiency and recovered energy, simultaneously, it is recommended to select the charging cut-off temperature of 0.671, discharging cut-off temperature of 0.394, charging cycle inlet temperature of 565 °C and the molten salt mass flow rate of 100 kg/s, based on the proposed method in this study.

SDEWES2022.0042

Electrochemical Preparation of Cu₂O/cu Layer and its Application for Galvanostatic Charge-Discharge Test

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Abstract

In the present work, we first deposited a thin layer of Cu₂O on Cu foil substrate using anodic oxidation technique. Then, we tested its electrochemical performance as a cathode in lithium battery. The X-ray diffraction analysis showed the formation of a copper oxide (Cu₂O) layer with a cubic structure and space group of Pn 163" > m. The electrochemical properties of Cu₂O/Cu as cathode material for lithium-ion battery was measured by Galvanostatic charge-discharge test. In the first cycle, the determined maximum discharge capacity was found to be 674.58 mA h.g⁻¹, after that (50 cycles). it becomes 425. mA h.g⁻¹, hence the high stability. Thin layer copper oxide (Cu₂O) materials have attracted the attention of the scientific community as new generation cathodes in lithium battery, because of its excellent properties such as good conductivity, low price, high discharge capacity, good electric contact and big electrode/electrolyte interface. As a result, by decreasing charges and the environmental impact caused by massive use of fuels in the production of electricity, this might bring a significant improvement in the field of battery charging.

SDEWES2022.0214

A Parameter Estimator-Based Approach to Constant-Current/constant-Voltage Charging of a Lithium-Iron-Phosphate Battery Cell

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Abstract

This paper presents the design of a constant-current/constant voltage charging control system for a battery cell using the so-called cascade control system arrangement with the superimposed proportional-integral (PI) controller commanding the battery charging current reference to the inner current control loop. The superimposed control level is realized as a voltage double feedback loop, combining the battery terminal voltage limitation with the open-circuit voltage estimation for precise control of the battery state of charge (SoC). The battery cell open-circuit voltage is estimated using the battery equivalent circuit model within the so-called System Reference Adaptive Model (SRAM) approach, whose convergence criterion is shown using the Lyapunov stability theory. The superimposed voltage control system design is based on the damping optimum criterion which provides analytical tuning rules for the voltage limiting and state-of-charge controllers. The proposed concept of the battery charging control has been verified by means of simulations using the experimentally-obtained model of a lithium-iron-phosphate (LiFePO₄) battery cell.

SDEWES2022.0274**Energy Storage and Production by Integrating Thermo-Chemical Energy Storage Systems Based on Calcium Oxide**A. Carro^{*1}, R. Chacartegui², C. Ortiz³, J.A. Becerra Villanueva¹¹University of Seville, Spain; ²University of Sevilla, Spain; ³Universidad Loyola Andalucía, Spain (*andrescarro@us.es)**Abstract**

Energy storage is a key factor in developing renewables-based electrical power systems. Different types of renewable energy sources and associated power production systems are differently adapted to each type of storage system, depending on their characteristics. In recent years, thermochemical energy storage systems have emerged as an alternative to molten salts for energy storage in high-temperature CSP plants. Among the most developed is the TCES based on calcium looping, which has been tested in a relevant environment. A few steps behind is the one based on calcium hydroxide, which has been tested at the laboratory level. The two systems present different technological challenges that could be solved by integrating the two thermochemical storage technologies with a synergic effect. This work analyses their combination applied to CSP, taking advantage of the synergies of both technologies based on abundant, low-cost, non-polluting raw materials. The calcination reaction from calcium carbonate provides calcium oxide. In the integrated system, the calcium oxide can follow two paths, carbonation at temperatures above 700°C or hydration reaction at temperatures above 400°C. An adequate integration and operation strategy allows for optimising the heat exchange profiles at different temperature levels. The calcium hydroxide dehydration reaction would close the process, with benefits in calcium oxide activation. The system has an overall efficiency similar to those based on the calcium looping, above 40%, but with higher flexibility for optimised operation and integration within specific applications.

SDEWES2022.0379

A Novel Comprehensive Equivalent Circuit Model of an All-Vanadium Redox Flow Battery

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Abstract

Grid-scale energy storage systems have gained popularity as hybrid renewable energy systems have grown in popularity. Vanadium redox flow batteries (VRFBs) are a promising energy storage technology due to their design flexibility, low manufacturing costs on a large scale, indefinite lifetime, and recyclable electrolytes. However, the majority of equivalent circuits developed for flow batteries make numerous assumptions and thus do not accurately reflect the actual battery characteristics. Electrical equivalent circuits with high accuracy are required to analyze systems using VRFB and to perform realistic calculations.

In this paper, the proposed sophisticated battery model identifies both the steady-state and dynamic characteristics of VRFB. Additionally, the inherent characteristics of the flow battery are considered, such as shunt current, ion diffusion, and pumping energy consumption. Furthermore, simplified charge transfer resistance (CTR) is taken into account based on electrochemical impedance spectroscopy (EIS) measurements results. The simulations conducted in the MATLAB Simulink environment using the proposed model are presented. Using experimental data, the developed model was validated.

SDEWES2022.0598

Borehole Heat Exchangers and Energy Storages – Geoenergetics Considerations Based on Przemyśl Gas Field Wells

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Abstract

Adapting crude oil infrastructure for geothermal energy extraction after its primary purpose has been served is becoming an increasingly popular solution, as it reduces the costs of drilling a new borehole and the costs of liquidating the old well. The paper discusses the changes in the design of oil&gas wells that can contribute to better operational parameters when adapted for geothermal purposes. One of the most important parameters of a geothermal energy extraction well is its heating power. It can be increased by selecting the appropriate properties of the materials used for piping and cement slurry for given geological conditions. Wells in good technical condition can be adapted to borehole energy storage. The types that seem most suitable for energy purposes are gravity borehole energy storage and pressure borehole energy storage. Especially the former can significantly contribute to the operation of smart grids. The weight placed in the borehole serves as storage when it is on the surface. The storage is discharged when the weight is at the bottom of the well. Numerous weights in a single well can be present. The paper presents an example of using the wells of the Przemyśl reservoir for the storage of heat or electricity. The surface of photovoltaic panels, which in the conditions of sunlight in the Przemyśl region will produce an appropriate amount of energy for daily storage, was determined. The conditions of the demand for heat and electricity in Przemyśl were described.

SDEWES2022.0605

Techno-Economic Analysis of a Novel Rock Bed Storage: Analysis for Power to Heat and Heat to Heat Applications

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Abstract

The heat demand of the industrial sector accounts for around 25-30 % of Europe's final energy consumption. In order to meet the ambitious decarbonization goals set forth by the European Commission by 2050, it is important to design future integrated energy systems based on the low cost and environmentally friendly thermal energy storage, coupled with solar collectors, electric heaters, or heatpumps which will increase the renewable penetration and provide flexibility. To achieve that, it is important to evaluate the techno-economic feasibility of possible scenarios, which could serve as a possible benchmark to decide which configuration is suited for a specific case. This study aims to provide an analysis of LCoH (Levelized Cost of Heat) for two configurations of heat storage against the benchmark of gas boiler for a given heat demand data from food & beverage industry. These two cases are given as follows;

- Thermal storage coupled with electric-heaters powered by renewable electricity (Power to Heat).
- Thermal storage coupled with solar collectors (Heat to Heat).

The thermal storage used in the analysis is novel vertical airflow rock based packedbed using air as a heat transfer fluid developed at DTU Energy and the solar thermal collectors are developed by Absolicon Ab. Both the configurations can cater the heat need upto temperatures of 200-250°C. The optimization of the system and calculation is performed in MATLAB by using the data experiments and simulation tools such as Modelica and COMSOL Multiphysics.

The results show that both configurations are feasible depending on the geography and the end goal. As the application of proposed storage for heat-to-heat use for industrial use can help to increase the solar fraction using solar thermal collector, thus displacing more CO₂ emissions. Whereas, the configuration of storage for Power-to-Heat can provide flexibility in operation during the peak hours, thus providing more energy savings.

SDEWES2022.0613

Cloud Battery System for Centralized Deployment and Decentralized Control of Storage Batteries

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Abstract

Growing global environmental awareness, including the SDGs, has led to calls for the introduction of renewable energy. Its profitability and stability can be improved by introducing storage batteries. There are four possible approaches to installing these storage batteries, depending on whether the deployment method is decentralized or centralized, and whether the control method is decentralized or centralized. In the past, these four approaches of deployment and control methodologies have been developed for computing resources. Following the centrally controlled centrally deployed supercomputer, the decentrally deployed decentrally controlled personally owned PC, and the centrally controlled decentrally deployed grid computing, came the centrally deployed decentrally controlled cloud-based data center. A similar pattern of development is expected to come for storage batteries. Much research has been conducted on storage batteries, including grid storage batteries that are centrally located and centrally controlled, P2P power trading that is distributed and decentralized, and VPP (Virtual Power Plant) that is distributed and centrally controlled. However, very little research has been conducted on the central placement and decentralized control of storage batteries. This paper proposes the Cloud Battery System as a new approach to central placement and decentralized control of storage batteries. The cloud battery system maintains the advantages of P2P power trading, such as the ability to reflect user preferences, and has the following merits: 1) storage battery capacity can be effectively utilized, 2) storage batteries can be easily introduced with little financial burden, and 3) power loss during recharge and discharge can be reduced. In this paper, as a case study of the cloud battery system, multiple scenarios with different conditions were simulated, and indicators such as RE ratio, total power charges, and required storage battery capacity were measured. As a result, the verification was conducted under different conditions such as RE power source configuration, simulation period, and demand shift, etc. In most of the verification results, it was found that the required storage battery capacity could be reduced by 10 to 40% by using the proposed method.

SDEWES2022.0644

Research Challenges and Innovation Opportunities for Energy Transition: Mid to Long Duration Energy Storage and the Role of the European Innovation Council

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Abstract

The Green Deal sets ambitious goals for the EU climate neutrality by 2050, pursued also by the 'Fit for 55%' package that increases the EU targets of renewable energy share by 2030 to 40% and by the Repower EU action that specifically addresses the increase of energy prices, the dependence from fossil energy outside EU and the transition to a more affordable, secure and clean energy system. The development of interconnected, sector coupled, or flexible energy systems is crucial to achieve these targets and in particular to enable high penetration of intermittent renewable energy and address the spatial and temporal mismatches between generation and demand. In this context, the possibility to (i) store thermal (heat and /or cold) and/or electrical energy at low cost, high density, high charging/discharging efficiency and enhanced durability (to address temporal mismatches), and (ii) transport this energy in the form of one or more energy carriers which are system integrated, safe and cost competitive (to address spatial mismatches) is a key enabler for a fully decarbonized energy system. Energy storage also enables smart demand response strategies and energy efficiency options, such as waste heat recovery or heating / cooling supply chains optimization, in industrial, commercial and residential sectors. This presentation aims to report on emerging researches and innovation landscape related to mid to long term thermal and electrical energy storage, which originates from the experience gained by EIC Programme managers in energy systems. An overview of key research challenges and policy priorities in this field, such the minimization of the use of critical raw materials, the facilitation of process and system integration opportunities and the combination with demand side management strategies will be provided in the presentation. An overview of most promising innovations funded by the European Innovation Council will be presented.

Sustainability comparisons and measurements 1

SDEWES2022.0006

Life Cycle Assessment of Geothermal Plants Targeting the Lower Carboniferous Limestone Reservoir in Northern Belgium

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Abstract

Decarbonizing the heating sector is essential for combating global warming. Geothermal energy is considered to be a low carbon energy source that can provide a reliable alternative to fossil fuel heating. However, the successful development of geothermal energy plants is strongly dependent on the site-specific geological conditions. Only a few studies have investigated the environmental burden of deep geothermal heating (DGH) by means of Life Cycle Assessment (LCA). Despite the increasing interest on DGH in Belgium LCA studies focusing in this area are missing. In this study we investigate the environmental impacts of deep geothermal heating (DGH) in Northern Belgium by means of Life Cycle Assessment (LCA). We define three scenarios depicting current and future DGH development. We use, primarily, site-specific data derived from the already developed VITO DGH plant and from exploration activities performed in the area. Additionally, we employ global sensitivity analysis (GSA) to assess the variability of the impacts and identify the parameters introducing the largest variability. Our results show that the environmental performance of DGH plants in Northern Belgium falls in the range reported for DGH plants in Europe. Regarding the global warming impact, the already developed plant shows higher impact compared to the European average, although still considerably lower than alternative heating sources such as natural gas. Future development is expected to cause even lower impacts. The well development and the electricity consumed to run the pumps dominate the impacts, causing more than 80% of the global warming and toxicity impacts. The GSA shows that the environmental impacts of DGH in the area can vary widely. The largest part of the variability is introduced by uncertainty regarding the plant capacity, capacity factor and pumping needs. Future LCA studies on DGH in Belgium should consider the time-parameter and the evolution of the processes causing the largest impact through time. Also, they should endeavor on acquiring accurate estimations for the plant capacity, capacity factor and pumping needs.

SDEWES2022.0023**From Laboratory to Pilot Scale: a Life Cycle Assessment for the Conversion of CO₂ into Chemicals by Plasma Catalysis**

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Abstract

Carbon Capture and Utilization (CCU) is gaining attention as one of the key technologies to help reach net-zero emissions. The utilization of CO₂ can replace the use of fossil resources in production processes and it can support the transition to renewable energy systems by enabling energy storage in chemicals or fuels. The development of a CCU production route that does no longer rely on fossil fuels, can be of particular interest in the chemical industry. Nevertheless, the commercialization of CCU is impeded by several barriers, e.g. high investment costs, technical risks during scale-up, or high energy requirements. Moreover, the public has revealed their concerns about CCU merely being a tool to lock in the use of fossil resources. To evaluate whether a particular CCU route contributes to the abatement of emissions, the environmental impacts have to be mapped over the entire life cycle. In this study, the environmental performance of a new CCU technology is evaluated: the plasma-catalytic conversion of CO₂ into syngas. Plasma catalysis is a chemical CO₂ conversion route, that combines the high reactivity of the plasma with the selectivity of the catalysts. Despite its ability to enable CO₂ conversion at ambient conditions, the technology is still relatively immature. The novelty of this study is that it explores the environmental hotspots already at this early stage, while adaptations can still be made to the technology's design, and that different designs of the technology are assessed. Hence, a Life Cycle Assessment (LCA) is performed for various designs of the plasma catalysis. Plasma catalysis is still an emerging technology (laboratory-phase), but the technology's impact is modelled and evaluated at a future phase (large-scale production) in the LCA. Different plasma catalysis designs are compared, to analyze how the use of different catalysts or feed ratios influences the environmental impacts. The results of the LCA provide insights into the environmental impacts of different plasma catalysis designs. These observations can help to make the design of the technology itself more sustainable, already at an early phase.

SDEWES2022.0036

Life Cycle Assessment of Spanish Spirulina- Should We Bet on Artisan and Local Superfoods in Favor of the Environment?

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Abstract

In response to the urgency of finding solutions to the global challenge of the diet-environment-health trilemma, the so-called superfoods have gained prominence in recent years. These products commonly stand out for their particular nutritional value, presenting an interesting food option to prevent diseases and fight against food insecurity. However, this work proposes to go beyond these nutritional characteristics and consider foods as 'super' also taking into account their environmental performance. Unfortunately, there is still a great deal of uncertainty in this area of knowledge.

For this reason, the present study aims to provide a breakthrough by developing the Life Cycle Assessment (LCA) of one of the most popular superfoods, spirulina. The methodology, based on the LCA guidelines, includes the definition of a cradle-to-grave approach, the compilation of inventory data from a production company in Spain, and the evaluation of a wide range of impact categories addressing resources depletion, water and energy consumption, global warming potential and other indicators related to environmental degradation.

The main outcomes will be two-fold: On the one hand, the environmental impacts of Spanish spirulina, both fresh and dried, will be quantified, identifying the weaknesses of the system and proposing opportunities for improvement, enabling the promotion of a more sustainable food sector. On the other hand, the environmental benefits or disadvantages of its local and artisan production and consumption patterns will be analyzed, allowing to determine the suitability of adapting superfoods to different geographical areas and providing a scientific basis for stakeholders' decision making.

SDEWES2022.0213

Urban Macrostructure-Based Well-Being Assessment for Sustainable and Resilient Cities

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Abstract

Well-being is a critical element of the 2030 Agenda for Sustainable Development Goals. It follows from the complexity of the concept of well-being that its measurement requires complex, multivariate methods that can analyse the physical, mental state, economic, social, and environmental aspects together.

It is not enough to carry out settlement-level analyses to make cities and human settlements inclusive, safe, resilient, and sustainable. Still, it is also necessary to understand the patterns within settlements. This work aims to present how indicators related to urban well-being can be estimated based on GIS-based multi-layered urban macrostructure.

The road network, points of interest, green spaces, vegetation, etc., are used to estimate urban well-being parameters such as noise level, air quality, light pollution, and health-related impacts, supplemented by climate models to assess urban resilience and sustainability.

The proposed method is suitable for the joint assessment of positive and negative impacts. A composite well-being indicator has been developed to support well-being-based decision support and urban planning based on the proposed variables.

SDEWES2022.0321

Applying Partial Least Squares-Structural Equation Modelling for Developing a Whole-System Wastewater Bench-Marking Model Considering Factors from Remote-Environment

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Abstract

One of the most critical services for the society is wastewater collection and treatment. Maintaining a sustainable efficient service is challenging and yet crucial for protecting the environment and preserving the social wellbeing (Keenan, 1996; Lofrano & Brown, 2010). However, the wastewater industry is further impacted by several issues worldwide, insisting for a rational wastewater management and knowledgeable decision making. This is important to ensure meeting the Sixth Sustainable Development Goal (SDG), that is to ensure the availability and sustainability of clean water and sanitation for all. Such issues are related to fluctuations in population and other demographic factors, as well as other factors relating to water bodies and air pollution. Consequently, governments should continuously revise their strategies and consider service efficiency in light of expected future challenges and changes.

Nevertheless, delivering a sustainable economic service with reduced associated costs and reasonable utility tariffs would ensure an optimal system performance and service accessibility. This in turn will have a positive impact on social and environmental sustainability. Given complex cost and performance interactions between collection and treatment processes, regulators should not consider these processes in isolation but should adopt a whole-system benchmarking model while taking into consideration such interactions. Moreover, as location specific operating characteristics can significantly affect the location and size of sewage treatment works, and hence the characteristics of the wastewater transportation network, it is important to develop comprehensive benchmarking models that account for these factors. Accordingly, this research focusses on developing a whole-system benchmarking model that takes into consideration the effect of interactions and location specific operating characteristics. Specifically, Partial Least Squares Structural Equation Modelling (PLS-SEM) is adopted as a multivariate approach, given its applicability in estimating complex models, and thereby allowing for simulating the inherent complexity. Moreover, this technique allows for modelling and simultaneously analysing causal relationships and indirect effects. The model will then help in defining costs determinants and finding costs elasticities, in addition to exploring the location specific factors that significantly affect overall-system costs.

SDEWES2022.0334

Boosting the Sustainable Mexican Energy Transition Through the Photovoltaic Performance Assessment in Mono and Polycrystalline Silicon Modules Using Actual Data and Free Access Simulation Tools

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Abstract

Photovoltaic systems are among the most popular renewable energy technologies transforming solar energy into electricity for different applications. Despite its popularity, the massive adoption is still facing considerable challenges in developing countries. Performance assessment parameters such as performance yield and performance ratio help provide a mathematical account of the expected energy output. In this work, the photovoltaic yield of two technologies has been evaluated following the procedure for measuring and characterizing the long-term energy performance of PV Systems in buildings reported by NREL[1]. For this study, photovoltaic systems of monocrystalline silicon (c-Si) and polycrystalline (pc-Si) silicon, 10 kWp each, were installed in Tepic, Nayarit, México. The measured Average Incident Global Solar Irradiation for the installations site is 5.86 kWh/m²-day, reaching up to 8.02 kWh/m²-day during spring months and minimum values of 4.29 kWh/m²-day during the winter season. This work aims to compare the PV performance of two different technologies of commercial photovoltaic modules based on their electrical parameters. The annual energy production and cost of energy of grid-connected PV Systems will be present for both technologies. The calculus of Performance Ratio leads to evaluating the PV system performance as a metric normalized by PV system capacity and incident solar irradiation, as present in this work. This work would establish the long-term performance records that enable monitoring trends in energy performance as a strategy to make synergies to achieve a Sustainable Mexican Energy Transition.

SDEWES2022.0495**Circular Economy Indicators Based on the Matrace Model**

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Abstract

Circular Economy (CE) and its strategies can prevent the depletion of earth's limited mineral resources, which are vital for maintaining modern human society. In CE, the ultimate goal is to keep the materials in a useful state for as long as possible while minimizing the hibernation and losses such as dissipation to the environment. Therefore, appropriate indicators that can keep track of these aspects of CE are essential to measuring its true performance. However, current indicators have different limitations, for example, most of them are static and do not include the temporal perspective.

The objective of this work is to advance the estimation of indicators that can capture the circularity of materials across different cycles and over a broad time horizon.

This study combines the results of the MaTrace model (Nakamura et al., 2014; Godoy León et al., 2020) with the indicators proposed by Moraga et al. (2021). The MaTrace model is a prospective dynamic material flow analysis. Godoy León et al. (2020) applied it to study the flows of cobalt embedded in eight applications: portable batteries, mobility batteries, catalysts, hard metals, intentionally dissipative uses, magnets, superalloys, and others. The study was done for the European Union (EU) over a time horizon of 25 years. The work of Moraga et al. (2021) is a micro-scale study, where two indicators were proposed based on the in-use occupation, with a focus on material embedded in a single product. These indicators are the In-use Occupation ratio (UOR) and the Final Retention in Society (FRS), which measure the circularity of materials by quantifying their conservation in the useful state. These indicators were adapted and estimated from the MaTrace results of cobalt. The indicator UOR represents the fraction of cobalt that stays in the useful state in the EU for each application, throughout the assessed time horizon. The indicator FRS represents the fraction of cobalt that is still in the useful state at the end of the time horizon. Both indicators take into account: (i) losses such as export, recycling process inefficiencies; (ii) conservation of cobalt in the hibernation phase; and (iii) the complex supply chain of cobalt. Of the eight applications, portable batteries show the lowest UOR and FRS values, and catalysts the highest values for both indicators.

The proposed indicators expand the perspective of existing conventional macroscale indicators. The conventional indicators are limited in their capacity to capture the circularity of materials and provide snapshots of material conservation in time. The indicators estimated here can consider technological uncertainties with the interests of future generations and capture circularity of material over time and across different product cycles.

SDEWES2022.0503**Accounting for Socio-Environmental Impacts Through the Integration of Ecosystem Services and Life Cycle Assessment**

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Abstract

Anthropogenic activities are causing various kinds pressures on our ecosystems, for instance negatively at a global level (e.g., accelerated climate change) or at a more local level (e.g. reduction of pollination), or positive for activities dealing with restoration or nature conservation. Some environmental sustainability assessment methods are promising in the sense that they can account for part of the positive or negative effects. For instance, life cycle assessment (LCA) is a standardized quantitative tool to estimate the environmental burden of products (goods and services) mainly at the global level from a lifecycle perspective (ISO, 2006), i.e. covering all the stages of a product's life, from raw material extraction through materials manufacture, distribution, use, and end-of life. The areas that are usually being protected (AoP) are our natural resources, human health and ecosystem health. A second method is ecosystem services assessment (ESA) which is a methodology designed to improve our understanding of the benefits provided by local ecosystems, those are called ecosystem services (ES). According to the ES cascade framework of Haines-Young and Potschin (2010), ES are supplied through ecosystem functioning, which is a result of the complex interactions between the biophysical structures and processes of the system. When ecosystem functions are altered, it leads to changes in the delivery of regulating, provisioning and/or cultural ES which eventually changes the benefits for humans. In this study, a conceptual integrated ES-LCA model is developed to address the gap of having a comprehensive sustainability tool. Whenever local ESA studies are available, they can be combined with LCA results through the use of several monetary valuation techniques whereby the ES are linked to AoP. However, as performing ESA studies is data- and time-intensive, it is not always possible to have results of ES changes for each life cycle process. Therefore, new LCA midpoint impact categories are proposed and characterization factors are developed to link land occupation and transformation to changes in ES, expressed in monetary values as it is based on the Ecosystem Services Valuation Database of de Groot et al. (2021). These two ways of ES-LCA integration provides a valuable improvement to the state-of-the art with regard to socio-environmental life cycle impact assessment of human activities. This work was financially supported by VLAIO grant number HBC.2019.2903.

SDEWES2022.0509

Process Level Circularity Performance in a Life Cycle Perspective: Environmental Impact, Change in Resource Quality, and Material Retention as Costs and Benefits

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Abstract

Classical life cycle analysis (LCA) helps to quantify environmental impacts of following a particular production pathway, and to further compare alternative production systems for identical functional units. One common outcome from LCA is hotspot analysis, in which major contributing processes to overall impact are identified. However, this fails to capture changes in resource quality induced by different processes in the life cycle. Additionally, depending on which impact categories are used in the study, material efficiency of the system might not be captured in an LCA. A deeper understanding of (material) efficiency and resource quality within the life cycle are both critical in the ongoing circular economy transition.

In this work, we aim to quantify trade-offs in quality-efficiency-impact space for individual processes within the context of a product life cycle as a form of cost-benefit analysis. Further, we develop a visualization tool which captures these three dimensions to provide a holistic picture of process circularity performance.

Data for a simple plastic packaging product life cycle with two alternative waste treatment scenarios were collected including mass yields for each process step, compositions of natural resources, raw materials, intermediate products, final products, and waste fractions at input and output of each process step, and mid-point life cycle indicators attributable to each process step (Global Warming, ReCiPe 2016 Midpoint (H)V1.04). As a proxy for resource quality, available composition data were mapped to a list of 37 materials and a statistical entropy value was calculated for each material mixture through the life cycle. These two indicators are plotted against the cumulative global warming impact up to that stage in the life cycle. The most significant mass losses in the production chain are due to un-recovered oil in the oil well and mis-sorting of waste at end-of-life (EOL). Mechanical sorting and distillation steps show the greatest performance as quality improvers in the life cycle. Mid life cycle steps, including polymerization and forming, show high mass efficiency and do not significantly compromise quality, but still have a significant contribution to overall life cycle impact. Looking at the slope of any given line segment through the life cycle gives a metric for how much cost is incurred for a given change in quality or mass retention.

This approach augments traditional hotspot analysis by also assessing the benefits of a given process step. Future work might include looking at a wider range of process steps across different product life cycles to look for patterns in behavior in quality-efficiency-impact space.

This work was performed in the framework of the Catalisti clusterSBO project WATCH (HBC.2019.0001 "Plastic waste to chemicals"), with the financial support of VLAIO (Flemish Agency for Innovation and Entrepreneurship).

Sustainability comparisons and measurements 2

SDEWES2022.0038

"low Cost" Tourism Versus Conventional Tourism: Which Will be the New Key to Achieve the Desired Sustainable Tourism?

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Abstract

The tourism sector after COVID-19 has raised different concerns towards a more sustainable model of tourism. After the health crisis, the increase in environmental awareness of tourists have become evident. In this context, it is framed the great paradigm of 'low-cost' as opposed to conventional tourism.

This work seeks to contribute to sustainable development in the Spanish tourism sector, comparing a hostel in Cantabria considered as alternative/religious tourism and a hotel in Lloret de Mar deemed as a conventional one using the Life Cycle Assessment (LCA) methodology to verify advantages and disadvantages of both of them. The functional unit (FU) used was 'per guest night with breakfast included'.

Results lead to similar results for both establishments in all the impact categories, except for the Eutrophication marine (MEP) where the hostel is worst environmental performance than the hotel. The electricity consumption and the breakfast in the hostel were identified as the main contributors to environmental burdens; hence, improvement opportunities were focused on these critical points.

SDEWES2022.0039

Learnings and Knowledge Sharing from the LCA Applied to the Cantabrian Purse Seine Fleet. What's Next?

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Abstract

The economy and cultural heritage of Cantabria, a northern Spanish coastal autonomous community, has been traditionally based on the primary sector, highlighting fish and seafood products. Nowadays, fisheries face important challenges, such as global competition, undervalued prices, fishing quotas, but also the adaptation of the activity to climate change and environmental issues.

In our work it was applied the Life Cycle Assessment methodology to the Cantabrian purse seine boats construction, maintenance and use. Purse seiners represent the 30% of the total fleet and has tuna, anchovy, sardine or mackerel as the main targeted species. The most studied indicators in the fishing sector were analysed: terrestrial (TETP) and marine aquatic (MAETP) ecotoxicity potential, abiotic depletion potential (ADP), photochemical ozone creation potential (POCP), global warming potential (GWP), acidification potential (AP) and eutrophication potential (EP).

The high dependence on fuel made it the most relevant resource in most indicators (POCP, GWP, AP, EP), while nets highly influenced on ADP. Now knowing the environmental profile, what is the diagnosis and lessons learned to improve the sector? Which actions and tools can be implemented to complete the path? Public bodies, fishermen and citizens must be part of the coordinated pathway and solutions. Thus, our work seeks to aggregate added value to the sector and some guidelines for the incoming years.

SDEWES2022.0477

How Green Can be the Smart Agriculture?

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Abstract

As agriculture worldwide is one of the most spread-out activities, which is crucial for the humankind population and the environment, it deserves appropriate attention. Recently the fast development of smart and also precise agriculture has been accelerated. Smart agriculture's total addressable market has grown from USD 13.7 billion (10⁹) in 2015 to 26.8 billion by 2020, with a compound annual growth rate (CAGR) of 14.3% and robust escalating growth being expected to come. However, it is not only increasing investment. Behind the need for smart agriculture are (i) Emphasis on Enhancing Efficiency, (ii) Need for Water Conservation, (iii) Preventing Climate Change (e.g. climate-smart agriculture, greenhouse gas (GHG) emission reduction), and (iv) Fundamentally reducing the waste and optimising the waste treatment chains toward the Circular Economy. Smart agriculture mitigates the challenges of food security by increasing productivity and enhancing resilience (e.g. drought, pests, disease). In some cases, it has been idealised as a very green and environmentally friendly solution possible to salvage the planet from deterioration of the living conditions and the environment. This contribution is raising some potential positive and negative issues, including the burdening footprint of Internet of Things (IoT) solutions, and attempting to make some forecasts for future development, pointing out issues which should be considered as well.

SDEWES2022.0508

Comparison of Different Types of Sustainable Wall with Focus on CO₂ Emissions

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Abstract

The environmental impact of the building is determined by decisions made in the early phases of the design. These phases are crucial and there is a large number of decisions to be taken. Designers, nevertheless, must be focused on decisions that are of the utmost importance to the building's impact. The buildings and construction sector is responsible for 37% of energy and process-related CO₂ emissions. Even though this number dropped due to the pandemic crisis compared to the year 2019, it is expected, that the carbon emissions will be pushed higher as the construction demand rises. To achieve significant savings, the building sector must focus on the efficiency of construction and usage of buildings. Therefore, it is essential to specify and describe building materials used in projects on their environmental level, in order to choose the most appropriate variant and by that create an eco-system instead of focusing only on aesthetics and price. Emphasis must be placed on a holistic approach, as the climate change crisis has already arrived.

This research study aims to offer an insight into decision-making based on the LCA assessment with a focus on CO₂e emissions. The main objective of this research is the evaluation of environmental impact of used building materials for a summer house with One Click LCA software. The subject of the comparison are external walls; however, the research takes into account emissions from the deliberately chosen project - summer house as a whole.

SDEWES2022.0513**Aggregation Strategies for the Sustainability Assessment of Energy Technologies. Comparing Wind Energy Projects via a Single Sustainability Indicator**

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Abstract

The aim of the European energy transition is the creation of a sustainable energy system. Sustainability in this context means that the system is aligned with climate targets and allows the continued use of high-quality energy services without compromising society's well-being. But the quantification of sustainability (impacts) still poses a challenge. While a number of sustainability studies individually assessed impacts such as environmental deterioration, life cycle cost or local job creation, there is no aggregated measure of sustainability that combines all these aspects. Therefore, this study proposes a quantification and aggregation method that delivers a single sustainability indicator for the evaluation and comparison of energy technologies.

The sustainability quantification and aggregation strategy was applied to a wind energy case study. The full sustainability assessment of this case study resulted in 12 endpoint indicators, which provided an overview of sustainability impacts. But the endpoints did not provide a clear indication of the overall sustainability of the alternatives. The NR-TOPSIS method was used for the aggregation of the 12 endpoints into a single sustainability indicator. NR-TOPSIS provided an aggregated score that illustrates the distance of an alternative to a defined reference point of sustainability. The robustness of the sustainability score and the resulting ranking of alternatives was investigated under different weighting scenarios. This analysis showed that the distribution of weighting factors did impact the ranking of the alternatives and would thereby affect the decision on the most sustainable project. At the same time, it is not recommended to use no weighting factors at all. The weighting provided an important balance between environmental, economic and social indicators and reduced the influence of single endpoints on the final results. Weighting should therefore be used with care but not disregarded.

In 63% of the investigated weighting scenarios the onshore wind energy project using a permanent magnet synchronous generator was found to be the most sustainable solution. The offshore wind energy project was ranked mostly at the last place due to high material demand for the offshore foundations which was reflected in high environmental and resource-related life cycle impacts.

SDEWES2022.0519

Environmental Assessment of Propanol Production from Unconventional Methane Sources

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Abstract

Currently, propanol production relies on conventional fossil resources. Microbial alternatives are still under development and present several disadvantages, among others low yields. Therefore, an alternative production process, called 'C123', is proposed and evaluated in which underutilised and methane rich feedstocks such as biogas (scenario BG), marginal gas (scenario MG) and associated gas (scenario AG) are converted into propanol. Nowadays, biogas is mostly used as a fuel in combined heat and power installations for the production of heat and electricity. In addition, this feedstock is regularly purified to bio-methane, which can be injected into the gas grid. Marginal gas is natural gas which is present in unexploited underground reservoirs. Associated gas is a by-product of oil production, which is often flared for economic and technical reasons. However, the conversion of these feedstocks into chemicals, such as propanol, has not yet been studied.

A first modular scale process concept was constructed in Aspen Plus, based on experimental data and knowhow of the C123 consortium partners. Mass and energy balances were compiled with the obtained simulation data. Three chemical reactions were included for this conversion into propanol, namely oxidative conversion of methane, hydroformylation and hydrogenation. Next, the environmental performance of the scenarios was compared at the life cycle level by calculating key performance indicators, such as the energy requirement, global warming burden, water use and human health damage.

The results showed that despite the energy need being the largest when biogas is used as feedstock, it is also the alternative which least depends on fossil fuels for energy use. The largest global warming burden occurs in scenario MG. Overall, scenario AG seems the most promising one as all indicators are lower compared to both scenarios BG and MG, when the avoided gas flaring emissions are taken into account. Future research could also consider the pretreatment of the feedstocks. The performance of the C123 process concept could be improved by including renewable electricity production and applying heat integration in the process concept.

SDEWES2022.0520

Food and the Environment: Analysis of Agriculture-Based Proteins in Function of Their Resource Efficiency

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Abstract

The demand for livestock products such as meat, milk and others, has been rising and is projected to increase by 14% by 2030 compared to 2018-2020. With this, concerns are also growing, given the environmental impacts associated with their production and consumption worldwide. For instance, meat production was responsible for about 54% of the greenhouse gas (GHG) emissions associated to agriculture during the 2018-2020 period (in a CO₂-eq. basis). In this context, several meat alternatives, including novel foods such as cultured meat, have been presented as environmentally friendlier options than conventional meat products. However, due the limited data available, for instance, of cultured meat, studies related to its environmental performance are scarce and, for the most part, hypothetical. On this basis, a recent analysis of what the gaps are and how to fill them has already been published, in which a key question has emerged: what is the actual resource efficiency of these systems? To answer this, a well-structured resource efficiency framework is needed. In this sense, the objective of this work was to develop an integrated framework approach for calculating the efficiency of most agro-food systems. Different indicators can be included, such as energy efficiency, exergy efficiency, nutrient efficiency, water efficiency and others, depending on the user and the system under analysis. Standard equations for the calculation of these impacts were also proposed, including product efficiency, product and by-product efficiency, single product dedicated inputs efficiency and several others that take a complete picture of both life cycle level and process level perspectives. Furthermore, the novelty of this framework is its broad applicability to most protein production systems that are generally agriculture based. The framework is being applied to two different case studies, both producing high-protein foods. In summary, it is expected that the development of this framework serves as basis for comparative environmental impacts assessments, from a resource use perspective, for novel foods' production processes, such as cultured meat, and other well-established protein production systems, as fish or milk production.

SDEWES2022.0532

Comparing the Environmental Sustainability of Plastic Food Packaging: Life Cycle Assessment Extended with Marine Littering Assessment and Circularity

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Abstract

Packaging plays a substantial role in environmentally sustainable food consumption by reducing food losses and waste (FLW) along the supply chain. However, there are several concerns related to food packaging, especially to plastic food packaging that are mostly made of fossil-based non-biodegradable materials and not fully recycled. When improperly managed, the long environmental persistence of these plastics leads to accumulation in marine ecosystems. On the other hand, biobased biodegradable packaging is still an emerging technology which might be known for its high environmental cost.

Standard life cycle assessment (LCA) is used to monitor the environmental performance of the packaging, packed food and the effects of FLW prevention. However, additional indicators are needed to enable a comprehensive comparison between biobased, biodegradable and fossil non-biodegradable packaging in function of various environmental sustainability aspects. First, a new indicator is developed related to the accumulation of plastic packaging in marine ecosystems: the lifetime costs of marine ecosystems services (ES), depending on their environmental persistence. Second, also circularity indicators to account for the origin of the packaging materials and the recoverability degree are considered in the evaluation.

The evaluation is performed for a case study testing two types of materials for the packaging (tray and film) of 1 kg of falafel, i.e. polypropylene (PP) and poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV), a biodegradable material obtained from agro-food waste, which was developed in the context of the H2020 European project (2018-2021) GLOPACK (Granting Society for low environmental packaging, grant agreement No 773375). The PHBV packaging performs less well for LCA-related indicators because of the novelty of the technology for its production and its higher mass to ensure the same functionality as PP. The indicators for accumulation in marine ecosystems and circularity are more balanced: PHBV is favorable in terms of lifetime costs on marine ES and circularity thanks to its biodegradability and sourcing, respectively. The results highlight that innovative packaging materials such as PHBV still require improvements in their production process and end-of-life valorization to outperform the current PP packaging on all environmental aspects.

SDEWES2022.0534

Cross-Sector Sustainability Benchmarking: Illustrating a New Comparison Framework

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Abstract

Benchmarking is a process known to encourage efficiency, offering many positives like assessing performance objectively, exposing areas where improvement is needed, and identifying best-performing companies, ultimately highlighting potential adoption strategies for poorer performers and a roadmap to improved efficiency. The concept of cross-sector company benchmarking, and performance comparison has many promising elements. Companies could gain value from being able to identify leaders in other sectors to then begin the process of learning from them, ultimately instigating improvements in their company, dependent on what they were measuring and analysing. Whilst such benefits may of course be gained from within-sector benchmarking, by transcending sector boundaries and possibly common practice dogma, companies have the possibility to learn something that could not have been garnered from peers, which can push the efficiency or productivity of their operations a step further. Despite these positives, the challenge remains of how to compare the performance of different organisations from different sectors. The purpose of this research was to develop a methodology to enable effective comparison of companies across sectors. A methodology was constructed based on service, environmental, and economic metrics, and cross-sector benchmarking was undertaken which generated performance scores based on company metrics relative to sector peers. This avoided issues of indicators often being mismatched across sectors and the lack of relevance and context when sectors use similar indicators. This approach allows top performers to assess top performers in other sectors and identify how they might continue improving, rather than be potentially limited within their own sectors. Conversely, lower performing companies can look within and across sectors to begin identifying best practices to improve their performance. The benchmarking framework developed can contribute to the international academic literature on benchmarking and performance analysis by illustrating a unique solution to comparing diverse sectors.

SDEWES2022.0642

Assessment of the Environmental Impact of Protein Source Used in Fish Feed Production Using Life Cycle Assessment (LCA)

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Abstract

As the consumption of fish in the human diet increases, a larger amount of production is needed. The growing demand for fish also has an impact on fish feed, its production efficiency and the sustainability of using raw materials. To evaluate the sustainability of raw materials and the impact on the environment, three protein alternatives are compared - Black Soldier Fly, Yellow Mealworm and soybean. Using Life Cycle Assessment (LCA), an environmental impact assessment is performed to define which of the protein alternatives is more sustainable. Results from LCA show that the largest impact is Yellow Mealworm protein, then soybean protein and Black Soldier Fly protein. In Yellow Mealworm protein production, the largest impact (83%) came from larval rearing and the rest from electricity. Soybean protein also has a greater impact on soybean cultivation processes. However, the biggest impact of the Black Soldier Fly protein comes from the electricity consumption, probably from the fact that all the necessary processes take place in different electrical installations. The results show the general picture of the impact of protein alternatives that can be used in fish feed production. The study can be further developed by comparing other fish feed ingredients and their environmental impacts. Also the overall impact of fish feed can also be assessed when protein alternatives are used. Existing alternatives can certainly be improved to reduce the environmental impacts and use RES in production processes and choose more sustainable alternatives to raw materials and efficient waste management.

Sustainability comparisons and measurements 3

SDEWES2022.0370

Development of Values for Sustainable Future

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Abstract

Since the introduction of the sustainability concept in 1987, there have been many challenges in its implementation. It is increasingly clear that technological solutions alone are not enough, and that the development of human values is crucial for a successful transition to a sustainable civilisation. In this contribution, we present opportunities for the development of sustainability-friendly values along with the expected significant scientific and technological breakthroughs. While the incredible technological progress in recent decades has by far surpassed even the expectations of the most optimistic futurists, it has still not solved the most pressing sustainability issues. We present the role of values in this transition to a sustainable future and some of the opportunities to take advantage of the expected new technologies for transforming the human mindset. We also explore opportunities to improve sustainability via expanded life expectancy, which can be achieved due to the technological advances in medical science, due to some relatively simple measures for improvement of health, and also with the reduction of violence. We estimate the potential of each of these pathways for an increased life expectancy and related increases in wealth and in sustainability. In this way, it is possible to achieve a more sustainable future for human civilization with a series of simple steps focused on the transformation of the human mindset.

SDEWES2022.0504

Life Cycle Assessment of Nutraceuticals: a Focus on Vitamin B12 Supplements in Different Packaging Options

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Abstract

The well-being of our lives has drastically enhanced owing to the increasing production of pharmaceuticals and nutraceuticals. This research aims to analyze the environmental profile of methylcobalamin and four different packaging options: blister packs or bottles made of glass, PET, or HDPE. The impact of methylcobalamin manufacturing in the prominent producing locations (China as baseline, and France) is assessed.

A cradle-to-grave life cycle assessment is conducted, including the following steps: methylcobalamin and excipients production, packaging material production, formulation and packaging, distribution to pharmacies, consumer, and End-of-Life. The methylcobalamin production is in detail modeled and consists of fermentation, cobalamin extraction, chemical conversion into cyanocobalamin, and chemical conversion into methylcobalamin. The functional unit (FU) is the supply to Belgian consumers of the recommended daily dose of methylcobalamin supplementation (1.2 mg). The carbon footprint results of the Environmental Footprint 3.0 method are reported.

The carbon footprint of the full supply chain is 8.6, 6.8, 6.4, and 6.3 g CO₂ eq per FU of supplements packed in blister packs, glass bottles, PET bottles, and HDPE bottles, respectively. This total footprint is mainly assigned to the production of ingredients (37-51%), the consumer (39-44%), and the packaging material production (8-16%). The impact of the production of ingredients is dominated by methylcobalamin powder production in China (85%), although the mass percentage in the tablets is only 1%. This footprint is chiefly driven by the conversion into cyanocobalamin (43%), fermentation (28%), and cobalamin extraction (26%). The consumer footprint is due to the car trip to the pharmacist and back home. Methylcobalamin powder production in France has a 22% lower footprint than in China (2.68 g CO₂ eq). This finding is due to a difference in energy sources and some inputs (e.g., solvent production).

This research provides valuable insights into the environmental profile of packaged methylcobalamin supplements. More transparency is advised for other complex components used in small quantities in the food sector.

SDEWES2022.0506

Integration Methodology for Sustainability Assessment Under Life Cycle Assessment, Emergy and Exergy Approach

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Abstract

The first attempts to quantify sustainability arose from the use of thermodynamic principles in an ecological field to measure the sustainability of ecological systems. Emergy Analysis (EmA) was one of the first, followed by other analysis tools such as Exergy Analysis (ExA) and Life Cycle Assessment (LCA). EmA is an analytical methodology that quantifies the direct and indirect services to generate a product or services and connects economic and ecological systems, which allows the contribution of social factors to be evaluated when estimating the value of an unbiased integrated sustainability index. ExA on the other hand is a thermodynamic method that allows the assessment of environmental load by the exergy destroyed for the use of renewable and non-renewable resources. LCA is a well-established and ISO-guided method that quantifies the environmental impacts of the resources used and the emissions /waste released to the environment

EmA, ExA and LCA have a similar objective, though: to provide decision-makers with indicators of environmental, economic, and/or social sustainability for the formulation and implementation of public policies. These indicators can be understood as single or composite parameters; i.e. synthetic aggregations of independent parameters that reflect stakeholder values and expert considerations. However, EmA, ExA and LCA alone cannot assess the three sustainability dimensions of process/product in a holistic way. The ground on which calculations are done or indicators are chosen is different for each of them: use of resources, generated environmental burdens, or process efficiency; while focuses on environmental, social, and/or economic sustainability. Differences and similarities between these valuable analysis tools make them compatible but not interchangeable, so that the behaviour of different production systems can be approached in a more extensive and complete way. Therefore, this research evaluated the complementarity or redundancy of the results obtained by the three methodologies from a case study in the mining sector.

To do this, a literature review was performed to address the implementation of the EmA, ExA and LCA in the mining sector, which is then complemented and confirmed with the results obtained in this case study. It is noteworthy that the aim is not to evaluate or question the theoretical and scientific basis of each methodology. The aim is to analyse the indicators used by each methodology applied to this specific case study and to assess the extent to which they are complementary or redundant, leading to a proposal for an integrated sustainability analysis methodology for future work. Through the complementarity and integration of the three analysis methodologies in a common framework, an adequate evaluation of the sustainability of the mining case study was achieved.

SDEWES2022.0536

Perspectives for Assessing Sustainability in the Transition to a Circular Economy

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Abstract

Mesmo que os problemas ambientais, sociais e econômicos sejam conhecidos e existam muitos métodos disponíveis que tentam medir a sustentabilidade, avaliar a transição para a economia circular continua sendo um importante desafio para toda a comunidade científica (Paes et al., 2020; 2021; Sala et al., 2021; Santillán-Saldivar, 2021). Alguns estudos se concentram na avaliação de setores de produção específicos, mas poucos examinam a Avaliação de Sustentabilidade do Ciclo de Vida (LCSA) em toda a cadeia de suprimentos do produto (Moraga et al, 2019; 2020; Valdivia, 2021).

Assim, este trabalho tem como objetivo apresentar e debater aspectos para a análise da sustentabilidade da transição para a economia circular, com base no pensamento do ciclo de vida e na avaliação da cadeia de suprimentos global.

Assim, foi realizada uma revisão de literatura (ou seja, artigos revisados por pares e literatura cinzenta, por exemplo, relatórios e documentos oficiais) sobre a abordagem de métodos ambientais, econômicos e sociais a serem usados no método LCSA, no contexto da economia circular e criticidade dos materiais. Além disso, foram realizadas consultas com especialistas que estiveram envolvidos no desenvolvimento de métodos para o LCSA no campo da economia circular.

Através deste modelo apresentado, pretende-se compreender 1) a quantidade de matéria-prima que pode ser substituída por resíduos e materiais secundários, 2) medir a eficiência desta circularidade através do LCSA, e; 3) a quantidade de perdas e desperdícios entre os processos de extração de recursos naturais e sua transformação em matéria-prima.

For this, it is proposed that raw material transformation activities be compared with some waste and material management activities (repair, reuse, remanufacturing, treatment via recycling and composting and landfills), through the following aspects 1) environmental: consumption of water, carbon emissions, and material flows; 2) social: fair salary, qualification, and occupational health and 3) economic: GDP per capita and GDP from activities.

Além dos cálculos desses efeitos, sugere-se que os custos das externalidades ambientais relacionadas às mudanças climáticas sejam considerados nos estudos, contabilizando os valores potenciais de créditos de carbono. Também é importante destacar que as atividades de transporte na cadeia de suprimentos e gestão de resíduos e materiais devem ser consideradas devido ao seu alto impacto relativo. Também deve ser examinado se a demanda por transporte pode ser aumentada pela inclusão de atividades de reparo de produtos.

SDEWES2022.0539**Substitutability of Recycled Materials, How Is it Approached by the Scientific Community?**

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Abstract

In life cycle assessment (LCA), recycling activities are usually credited for avoiding impacts from virgin material manufacture by producing secondary materials. Therefore, the results of the LCA can be highly influenced by assumptions relating to material substitutability. Nevertheless, several LCA practitioners assume a full substitution of primary materials by recycled ones, in many cases, without clear motivation or transparency. Additionally, there is not a clear consensus on how substitutability should be calculated. The aim of this study is therefore to critically review how substitutability is approached by the scientific community. Accordingly, 70 peer-reviewed papers, published between 2010 and 2022 were analyzed, and from this, 48 papers underwent an in-depth analysis. Some of the aspects considered during the in-depth analysis are, substitutability type (technical, price/market, and a combination of technical and price/market), level of implementation, consideration of the future application of recycled material, recycling type (open or semi-closed-loop), recycled and substituted materials, and life cycle stage in which substitutability is evaluated. The results show that most of the papers (23) considered technical and price/market substitutability, followed by technical substitutability (19) and lastly price/market substitutability (6). The most studied material is polymers (evaluated in 38 of 48 papers) followed by paper (13), metals (6), wood (3) and others (6). 31 papers analyzed substitutability in open-loop recycling, 7 in semi-closed loop recycling, and 9, in both, open and semi-closed-loop recycling. In the case of open-loop recycling, several papers are based on price/market data, while in semi-closed-loop recycling, most of the papers are based on technical data. In 25 papers, the requirements for the replacement of virgin materials in specific applications are not being considered. The implementation level shows that substitutability is a concept in development that, in some cases, is used without considering whether it is representative of a specific case or not. Hence, it is concluded that aspects such as harmonization, transparency and the consideration of the future application of recycled materials require further attention in the substitutability calculation, in order to facilitate a meaningful interpretation of the LCA results.

SDEWES2022.0540**Assessing Socio-Environmental Impacts of Offshore Wind Farms: Monetized Footprint and Handprint of an Offshore Wind Farm in the Belgian Continental Shelf**L.V. De Luca Pena^{*1}, S.E. Taelman², B. Bas², N. Pr  at², J. Dewulf²¹Universiteit Gent, Belgium; ²Ghent University, Belgium (*vittoriadeluca5@gmail.com)**Abstract**

Today, the demand for sustainable energy is increasing worldwide (IEA, 2022). To meet this demand and also climate-neutrality targets, the contribution of renewable energy is crucial in the provisioning of global energy by 2050 (Carrara et al., 2020). Among the sectors that will scale up, we can find the offshore wind energy industry. Only in the EU, the total installed capacity of offshore wind farms (OWFs) is expected to increase to 300 GW by 2050, contributing in achieving climate neutrality by 2050 (European Commission, 2020). Apart from the obvious advantages of renewable energy, the expansion of OWFs can also lead to various local to global negative and positive effects on ecosystems. To have a better understanding of the burdens and benefits of OWFs, a comprehensive sustainability assessment, which is able to capture these multiscale positive and negative effects, is needed. To provide a full assessment, methodologies such as life cycle assessment (LCA) and ecosystem services assessment (ESA) can be combined or integrated, which has been already done in the context of terrestrial ecosystems and to a lesser extent to aquatic ecosystems (De Luca Pe  a et al., 2022). In this study, a conceptually integrated LCA-ESA framework (De Luca et al., in preparation) is applied to a case study in the Belgian Continental Shelf (BCS) to study the socio-environmental footprint (burdens) and handprint (benefits), expressed in monetary terms. Prior to aggregation between the methods, an environmental LCA of the OWF is conducted to obtain the global negative (e.g. climate change) and positive (e.g. avoided burdens) effects, whereas ESA is combined other impact assessment methods to quantify the changes on the delivery of relevant local marine ES in the BCS (e.g. aesthetic value, nursery and habitat maintenance, renewable energy). Next, the integrated LCA-ESA framework of De Luca et al. (in preparation) is applied to obtain the footprint and handprint of an OWF and used to quantify a net sustainability score (benefits minus burdens) per area of protection (i.e. human health & well-being, natural resources and ecosystem quality). Moreover, to our knowledge, this is the first study that accounts quantitatively for the effects on local marine ES and global LCA categories through monetization. This study has a valuable contribution on the application of a LCA-ESA integration framework to support a comprehensive sustainability assessment of offshore wind energy.

SDEWES2022.0543**Decentralized Potable Water Supply: a Sustainable Alternative to Centralized Production?**

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Abstract

Potable water in urban areas is traditionally supplied through centralized supply systems (CSS). Freshwater scarcity due to the climate change effects, population growth and reduced infiltration challenges the CSS and raises the interest in decentralised supply systems (DSS). DSS can produce potable water on a small scale and use alternative water sources such as rainwater or wastewater. As DSS are increasingly perceived as a (more) sustainable alternative, this case study evaluated through life cycle assessment the environmental sustainability of a rainwater-based DSS and compared it with a traditional CSS. The latter comparison excluded the end-of-life phases as no information was available on the end-of-life phase of the CSS. The assessment was executed for one m³ potable water delivered to an average household in Flanders (Belgium) and was mainly focused on the global warming impact and the resource footprint, calculated with the ReCiPe 2016 midpoint (H) and CEENE methods, respectively. The hotspot analysis for the DSS showed that the energy consumed by the UV lamp stood out in most impact categories, especially for the global warming impact and the resource footprint, to which it contributed 36 and 71%, respectively. The other hotspots were the transport for maintenance visits and the active carbon filter. The comparison of the DSS with a CSS based on groundwater extraction showed that, across all impact categories, the DSS performed at least ten times worse. This could largely be explained by the much lower amount of potable water produced by the DSS for an average household as compared to the throughput of the CSS. The DSS had a global warming impact of 2.47 kg CO₂ eq./m³ compared to 0.17 kg CO₂ eq./m³ for the CSS. Their resource footprint amounted to 126.34 and 7.01 MJ_{ex}/m³, respectively. Furthermore, to assess the improvement potential of the less mature DSS, the most sensitive parameters were identified. The most considerable improvements could be achieved through an increase in the throughput of the system, the use of a LED UV lamp and a green energy mix. Implementing the most optimal scenario for the DSS, an improvement of 92% for the global warming impact and 52% for the resource footprint is possible. In conclusion, the environmental performance of the rainwater-based DSS is worse than the traditional CSS in Flanders, but the DSS has improvement potential and at some locations it is the only feasible system.

SDEWES2022.0545**Sustainability Indicators for Circular Food and Non-Food Flexible Plastic Packaging Involving Stakeholder Participation**

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Abstract

Flexible plastic packaging solutions for food and non-food products are essential for the consumer market due to their various inherent characteristics. As the protection of the product is the main function, the high requirements for food preservation and safety lead to highly engineered multi-material multilayer plastic packaging (MMPP) consisting of diverse polyolefins, their chemical variants or polyesters. MMPP packaging cannot be recycled according to the state of the art, but is incinerated and/or landfilled. Therefore, this waste stream does not contribute to the EU's 2030 plastics recycling target. Several European consortia are working to improve the recyclability of flexible packaging through infrastructural changes and improved performance. Circular FoodPack as an example aims to enable the circular use of polyethylene post-consumer recyclates through improved technology and circular design evaluated by lifecycle sustainability assessment (LCSA). Therefore, the selection of appropriate sustainability indicators through (i) the clear definition of the product system(s), (ii) the application of multi-criteria decision analysis (MCDA) to preselect a variety of indicators in an orderly manner, (iii) the use of participatory methods in the selection of the final impact indicators and (iv) the focus on the feasibility, relevance, ease of interpretation and achievability of the indicators is essential. The first step is to conduct a literature review on existing LCSA frameworks, LCAs, LCCs and S-LCAs of systems similar to the innovative product and/or processes and the reference system under investigation (e.g. waste management systems, recycling systems, food packaging). The literature is screened for the following information: (i) impact categories/subcategories (ii) indicators (iii) description of cause-effect chains and (iv) expressed units. The outcome is an extensive list of indicators, which shall be reduced through MCDA. Based on the restricted list, a workshop is held with stakeholders from all stages of the value chain, e.g. waste managers, recyclers, packaging producers and consumers, participating in the selection of the final indicators by ranking the feasibility, relevance, interpretability and viability of the indicator through their expertise. In a further study the indicators are applied to a case study in the Circular FoodPack project to comprehensively assess the holistic sustainability of circular flexible plastic packaging.

SDEWES2022.0547**Aiming for Sustainable Pharmaceutical Production: Evolution of Waste Treatment Processes**

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Abstract

Although being of great importance for human well-being, the pharmaceutical industry is the most carbon intensive business worldwide. Despite the many efforts put in the development of innovative chemical syntheses and better performing equipment, this industry has to deal with a huge amount of waste flows such as wastewater, waste solvent streams, waste gas streams and solid waste. These waste streams have to be treated before leaving the plant or for recycling. To reduce the impacts of these waste streams in the environment, different treatment processes were developed. Over the years, these processes underwent some significant changes due to changes in legal restrictions or to improve the overall environmental performance of the company. This study focuses on the treatment of wastewater and waste solvent streams, as large quantities of these streams are obtained from pharmaceutical synthesis processes. Life cycle assessment (LCA) is used to evaluate the environmental impact of the two above mentioned waste treatment processes in terms of both resource consumption and of a single-issue impact indicator, i.e., climate change. First, the total environmental impact per liter wastewater of the wastewater treatment processes was calculated and electricity was identified as the main contributor. Additionally, the scenario of using green electricity was studied, which appeared to have a big influence on the environmental performance per liter wastewater. In case that, due to legal restrictions, the wastewater installation has to become more extensive to obtain a higher purity of the wastewater, the impact of the higher electricity consumption can be lowered by using green electricity instead of grid electricity. Second, the treatment of waste solvent streams was studied. There are different processes available to treat waste solvents. In this study, incineration and distillation were investigated. Depending on the obtained purity of the distillate, the solvent can either be reused internally or it can be sold on the market. These different destinations of solvent flows influence their respective environmental impact per liter solvent waste, with distillation for internal reuse having the lowest impact. As with wastewater treatment, electricity is again the highest contributor to the overall environmental impact. This means that switching to green electricity would result in a significant decrease of the environmental impact of the solvent treatment processes.

Transport management and systems

SDEWES2022.0152

Integration of Passenger and Cargo Flows as an Opportunity for an Energy-Efficient Last-Mile Transport

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Abstract

The integrated passenger and freight First-Last Mile (FLM) is a relevant transport problem, representing a considerable share of total transport costs, pollution, and energy expenditure. According to recent literature and the inputs of the European authorities, the combination of passengers and cargo flows could be an effective approach to promote a sustainable and energy-efficient FLM transport.

This paper discusses the energetic performances of an integrated passenger and freight transport system, based on the transit network of the case study city of Koper (Slovenia). An appropriate setting is designed thanks to the proactive dialogue with relevant stakeholders. Subsequently, the energy performances of the system are evaluated and compared with those of current public transport and freight deliveries operations in the area. More specifically, the paper initially presents operational aspects of the integrated systems and then focuses on the energetic performance, including vehicle fuel and technology, total mileage, idle time, and other relevant endogenous (i.e., consolidation operations and final leg to consumers) and exogenous (i.e., climate conditions) factors.

Preliminary results seem to call for relevant operational benefits and substantial energy savings, mainly due to the reduced overall mileage and to the possible shift towards zero-impact transport means (i.e., active modes) for the final leg of both passengers and goods' trips. The opportunity for freight consolidation and efficient use of spare capacity onboard transit vehicles, in particular, highlight both significant energy efficiency improvements and transport-related targets (performance improvement and externality reduction), especially if flanked to more structural (and long-term) policy interventions.

SDEWES2022.0182

E-Mobility for Carbon Neutral Strategy: Airplane Replacement by Electrified High Speed Train

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Abstract

Growing concern about sustainable development motivates the transportation sector to decarbonize deeply. Among various modes of transportation, the aviation industry has attracted much attention because of its large emission and difficulty to be replaced. Due to the convenience of high-speed rail (HSR) and reasonable site setting, HSR has formed a competition with the aviation industry. However, few studies have explored the impact of this competitive process on the process of carbon emission reduction. Through large-scale infrastructure construction, China has built the world's largest HSR network. By analysis of relevant data, we find that compared with the base scenario, China has achieved more than 120 Mt of CO₂ emission reduction through HSR construction from 2013 to 2018. Based on the actual operation data of Guangzhou Baiyun Airport, we have developed different alternative scenarios. Combined with the greening process of the power system, under the ideal scenario, 80 Mt of CO₂ can be reduced every year. This study explores the impact of HSR development on aviation substitution and carbon emission reduction in the transportation industry, which can provide a decision-making basis for carbon neutralization strategies in various countries.

SDEWES2022.0212

Maximising Distribution Grid Utilisation by Optimising E-Car Charging Using Smart Meter Gateway Data

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Abstract

The transition towards climate neutrality will lead to more electrically driven cars (as well as other electrically operated loads) and thus to higher loads within electrical distribution grids.

This paper will present and discuss optimisation algorithms developed within the European research project PROGRESSUS that will allow to integrate significantly more loads in existing distribution grid infrastructure using smart meter and/or smart meter gateway information. The algorithms determine the state of the grid to which it is connected. This is done by analysing electrical measurement data as voltage, current, voltage angle, and power factor. The algorithms allow grid operation at its limits both considering maximum transformer and line charge as well as maximum allowed voltage drop.

For this purpose, mathematical programming was formulated in the form of linear programming. The optimisation algorithm was implemented in the Python programming language and the Pyomo optimisation framework with GNU Linear Programming Kit (glpk) as a solver. Based on the grid topology, household loads, estimated driving performance, battery state-of-charge and charging time, the algorithm determines the optimal charging schedule for all loads connected to the distribution grid. On the one hand, the non-discriminatory charging of all e-vehicles in the grid is aimed at by considering various impacting factors and, on the other hand, an optimal grid operation is ensured. In addition, attention was focused on the expandability of the infrastructure and fail-safety through decentralisation of all components.

Different scenarios are modelled and evaluated in the simulation environment. The results show that by using the control algorithms, the maximum possible charging power can be achieved at all charging stations while avoiding all relevant grid overload criteria.

SDEWES2022.0264

Hybrid Electric Trains with Fuel Cells and Batteries: Study of the Functional Characteristics of the Fuel Cell System and Assessment of Energy Needs in an Italian Scenario

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Abstract

Electricity produced from renewable sources is undoubtedly a way to substantially reduce emissions, but many applications in the transport sector require a deep transformation of the current way of generating energy, which is based mainly on the combustion of fossil fuels. A valid alternative is represented by battery-powered electric vehicles, which require external charging, or by hybrid systems powered by "PEM" hydrogen fuel cells, which have the advantage of transforming the Hydrogen into electricity, water and heat.. The problems of the weight and volume of the battery and its autonomy in terms of km driven per kW installed constitute the most significant constraints for an ever-increasing diffusion of this technology.

In the specific sector of railway transport, and in particular in regional trains and/or shunting locomotives where the installed powers are of the order of some MW, the criticalities of the aforementioned batteries are more evident. To overcome this criticality, the use of hybrid systems using batteries and hydrogen fuel cells for energy generation represents an interesting solution from a technological point of view; the interest of various manufacturers in this solution confirms that it is interesting and applicable. Furthermore, the panorama of European and Italian railway lines shows that many lines still not electrified, Europe (30%) and Italy (about 28%), are served by diesel trains.

In this paper we will analyze the operation of an electric train, powered by a hybrid system consisting of fuel cells and batteries (FCH-B) used to supply electricity to perform a specific railway service, of which the energy needs and powers are known. The study will provide the quantity of hydrogen to be stored on board the train for a given energy or autonomy. The study analyzes the advantages and disadvantages of using the fuel cell and battery system. The functional limits of fuel cells will be assessed, according to the electrical load fluctuations, representing one of the major criticalities of this technology. However also batteries have some issues: for example, excessive level of discharge or rapid recharging must be avoided. The simulation carried out with a model implemented on TRNSys is able to check the correct coupling between fuel cells and batteries, to prevent the above mentioned criticalities. Moreover, the simulation computes the consumption of hydrogen and the energy delivered by the fuel cell and batteries to meet the required needs. The study is performed on a 180 km Italian railway line, between Catanzaro Lido and Reggio Calabria.

In the simulation assuming the use of the fuel cell alone as a source of electricity production, an overall consumption of hydrogen equal to about 80 kg was estimated; on the other hand, the coupling of fuel cells with batteries and energy recovery during braking reduces hydrogen consumption to about 60 kg.

SDEWES2022.0412

Exploring the Freight Transportation Transitions for Mitigation and Development Pathways of India

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Abstract

Greenhouse gas emissions and PM_{2.5} pollution from vehicular exhaust, and the consequent negative externalities underline the urgency to investigate the low-carbon pathways for freight sector. In this paper, we undertake a comprehensive analysis to determine the implications of modal shift in freight sector on environment, energy systems and economy. We integrate the stakeholder consultations with the qualitative narratives that are further used to set the parameters in energy-economy optimization models for deriving quantitative pathways. Our analysis includes four scenarios: Current Policy (CPS), Road Focused (FROAD), Rail Technology (TRAIL) and Harmonized Multimodal (HMML). HMML scenario follows a balanced approach harmonizing the twin goals of reduction in imported fuels and carbon emissions that can assist in achieving development and decarbonisation targets simultaneously. Our results show that harmonized multimodal scenario, that is based on multimodal approach of creating a level playing field for all modes rather than prioritizing road or rail mode, is able to achieve 87.6% and 96% reduction in fossil fuel imports and CO₂ emissions respectively relative to CPS in 2050, that further leads to cumulative foreign exchange savings of 3.8 trillion USD from 2016-2050. Electrification is the main technology for decarbonising respective modes and will need policies that enhance research and innovation on batteries and investments into infrastructures for charging along national and state highways. Main policy insight from our analysis is that multimodal logistics policy needs to be designed in alignment with clean energy based electrification policy, and national rail plan so that all modes are governed by uniform rules from the origin to the destination of goods transport.

SDEWES2022.0606

A Cohort Analysis of Car Use and Fuel Expenditure

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Abstract

This study uses the cohort analysis to analyze the effects of socio-demographic changes on travel mobility in Taiwan over the period of 2008-2018. Travel mobility can be captured by driving days per week, daily trip time, and monthly fuel expenditure. The Blinder-Oaxaca decomposition is employed to explore the relative importance of possible factors for the changes of travel mobility. The age effects show that the drivers aged 30-39 years have more driving days than other age groups. The older people would have lower travel mobility relative to younger people. The cohort effects show that the drivers born before 1958 have less trip time and fuel expenditure than other cohorts, while the new cohorts have more driving days and trip time. In addition, the drivers who also use motorcycles and public transit frequently would have less car use than those drivers who do not depend on motorcycles and public transit, reflecting car use and other modes are substitute. The Oaxaca-Blinder decomposition indicates that the increases in travel mobility are mainly attributed to the changes in the marginal effects of the determinants. Among these determinants, the coefficients effect of trip purpose for commuting plays the most important role for driving days and daily trip time, indicating that car use for commuting is more intensive or frequent than before. Besides, the age and cohort effects are also important for the changes of car use behavior. The young generation has more car driving days and fuel expenditure. The population aging would result in the reduction of car use, but nowadays new generation has a stronger effect on the increase of car use than before. Thus, it is important to provide multiple transport alternatives for different groups and encourage the commuters to use public transport. These results can help us to identify the groups with a higher level of car use and fuel demand. Transportation planning should consider travel behavior of different groups and understand the changes in travel mobility based on the demographic structure in the future.

SDEWES2022.0625

The Effect of Speed Reduction on the Environmental Performance of a Containership

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Abstract

Since ships are more fuel efficient when sailing at reduced speed, slow steaming has become a valuable practice to decrease fuel costs in times when market is sluggish. Lately, this practice has become very popular due to environmental concerns as it allows the reduction of carbon dioxide emissions without additional infrastructure. However, slow steaming leads to a longer transportation time, which then raises the need for the engagement of additional ships if the yearly transport work is kept constant. The ship encounters different sea states along its sailing route, which significantly affect fuel consumption and carbon dioxide emissions and consequently impact on the benefits that come from slow steaming. Therefore, it is of utmost importance to determine the benefits of slow steaming in realistic sailing conditions. The benefits of slow steaming are estimated for a Post Panamax Containership sailing along one of the most common containership trading routes. It has been demonstrated that month significantly affects the benefits of slow steaming. The reduction in fuel consumption significantly differs along the sailing route, highlighting the importance of accurate assessment of sea states along the sailing route.

Urbanism and Buildings

SDEWES2022.0158

On the Thermo-Optical Performance of Novel Photoluminescent Components Towards an Efficient Application Within Urban Environments

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Abstract

The application of cool materials (CMs) into the built environment is a widespread solution for mitigating urban overheating. Different types of CMs, e.g. reflective, evaporative, or energy harvesting, have been found to maintain lower superficial temperatures than conventional materials typically used within cities, such as asphalt and concrete. Recently, photoluminescent materials, have been proposed for advanced cooling applications due to their twofold mechanism of rejecting the incident shortwave radiation, also known as Effective Solar Reflectance. In fact, unlike classic reflective CMs, photoluminescent CMs, apart from highly reflecting the incident shortwave radiation, simultaneously emit the absorbed energy at longer wavelengths, contributing to a higher reduction of their surface temperature against bulk colored material. Under this framework, photoluminescent CMs can function at the same time as an energy storage component for lightning applications. This article reports on the in-lab investigation of different photoluminescent components focused on their thermal behavior upon exposure to different realistic boundary conditions. Their thermal performances were evaluated within a climatic chamber configuration with respect to ambient temperature, relative humidity, atmospheric pressure, and incident shortwave radiation. Their profiles are analyzed considering different wave ranges of the spectrum and evaluated accordingly for optimizing their application in the built environment.

SDEWES2022.0250

Evaluation of the Heat Island Effect in a Mediterranean City and its Impact on the Thermal Demand of the Residential Sector

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Abstract

The heat island effect has been evaluated with ground temperature measurements obtained with satellite data from the Landsat-8 mission. This information has been compared with measurements collected at weather stations. With the adapted weather files, it has been evaluated how temperature variations affect the thermal demand of buildings. The simulation has been carried out with European standards in combination with census information obtained with GIS-based technologies. For each building, the heat island effect of its surroundings has been calculated and applied to the modelling of the building's thermal demand. Besides, the relation between land surface temperature and vegetation for different months is also presented. Results show a difference of thermal energy demand of more than 6% for the study carried out in València, a Spanish city with a Mediterranean climate.

SDEWES2022.0288

The Impact of Urban Morphology and Construction Standards on Urban Scale Energy Efficiency (A Case Study in Montreal, Canada)

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Abstract

With urban population growth, energy consumption and the "CO₂" emission of cities are constantly rising & thus, it becomes important to address the cities' energy use. This study tries to understand the impact of urban morphology and construction standards on urban scale heating and cooling demand for a case study district in Montreal, Canada. Previous studies have shown that morphological parameters significantly affect radiation received on external surfaces and energy consumption. On the other side, building compactness, construction, and insulation standards are important factors in reducing energy consumption. A software workflow was developed where the geometry of the building's model was modified using Rhino. The energy simulation for the buildings was completed using a combination of plugins of Ladybug tools which uses EnergyPlus and Radiance as backend engines. Based on previous studies, three main morphological parameters are analyzed for a real medium-density neighborhood. We investigated the influence of orientation, density, and surface-area-to-volume ratio for the district for an as-build and multiple defined scenarios. The results show that the morphological parameters change the heating and cooling demand maximum by 40 %. The results showed that when the insulation properties are modified to meet the statutory requirements of energy codes and even beyond the energy codes, a reduction of almost 80% in heating demand can be achieved. Thus, the results show that although morphological parameters are important in energy consumption and radiation received on surfaces, construction standards' effects are far more relevant for urban scale heating and cooling loads.

SDEWES2022.0306

Assessment of Buildings' Energy Efficiency over the Years at a City-Wide Level: the Case of Valencia

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Abstract

Buildings are hugely involved in reaching climate goals due to their significant potential for decreases in energy consumption and CO₂ emission. This research aims to identify buildings and districts with the most significant potential to decrease the city's final energy consumption and CO₂ emission. The influence of physical building characteristics on energy consumption was analysed to review the relevance of building retrofitting measures. We extracted energy data from energy performance certificates of residential dwellings in the City of Valencia in Spain. A sample of 7,761 energy certificates distributed over all 19 districts of the city was analysed atomically. The studied dwellings mostly have an energy rating of 'E' (72.2%) and were constructed from 1960 to 1969 (35.69%). The correlations reveal that the cadastral area and construction year influence the energy consumption in the dwellings in Valencia. The CO₂ emissions correlate strongly to the city and district energy consumption. The energy performance analysis by district reveals clusters of poorly energy-rated districts. We identify Poblats Maritims as the district with the highest average energy consumption and CO₂ emission compared to the city average. This study's results will help policymakers identify buildings and districts with the potential for energy conservation.

SDEWES2022.0323**Evaluating the Influence of Climate and Neighbouring Structures on the Energy Performance of a High-Rise Residential Block**

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Abstract

Urbanisation has increased rapidly in recent years, and more high-rise buildings are built to accommodate the increasing urban population. The energy usage of high-rise buildings is twice as high as that of low-rise buildings. High-rise buildings affect the solar conditions and wind environment of the surrounding areas which can have positive and negative effects depending upon the site-specific circumstances. The use of a multi-parameter optimisation approach for the building design can achieve considerable energy savings and cost reduction while improving thermal comfort. Factors or parameters that influence building energy consumption includes type of energy used, altitude, location, fabric, building design, shape orientation, operation and technology usage and have been explored in the literature. Most previous studies focused on how the Urban Heat Island (UHI) phenomenon affects the heating and cooling performance of buildings. There is little study on the association between neighbouring high-rise structures and energy consumption. This work aims to analyse the impact of building locations and neighbouring buildings on their energy performance by undertaking parametric modelling. A 12-storey residential building was investigated using a validated Building Energy Simulation (BES) model. The cities selected for this research are Copenhagen – Denmark, Beijing – China and Singapore, which represents three different climatic conditions: oceanic, humid continental and tropical climate, respectively. The effect of parameters such as the surroundings' number and positions of buildings were analysed and discussed. In total, over 180 scenarios were modelled to understand the influence of the variation of different parameters. Surrounding buildings could positively and negatively influence the central building's performance, depending on the location and shading conditions. For a single building, the annual solar gain difference between Denmark and China was 46.2MWh, and the total energy load difference was 47MWh. Multiple high-rise buildings with narrow spacing were observed to have the largest impact on the central building's energy performance. Overall, the results indicate that the design and layout are important issues to consider for high-rise buildings as they can influence the energy use up to 14.35% when the central building was surrounded by eight double-height buildings with 15m spacing. The present work has shown the importance of considering the influence of neighbouring structures when performing energy simulations of high-rise buildings.

SDEWES2022.0348

Impacts of Solar-Reflective Façades on Clustered Urban Heat Island Effect

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Abstract

UHI (Urban Heat Island) refers to the phenomenon that the temperatures in cities are higher than those of their surroundings, because of the changing of the albedo of the terrestrial surface and the evapotranspiration rate of the natural soil, disturbing the energy balance on the surface and the air temperature close to it. Many researchers have studied the roles of building envelope materials on UHI, but few of them have explored the impacts of the emergence of the solar-reflective coatings, films, and panels that are increasingly applied on building façades, especially in hot climates, for building energy-saving purposes. This research is to quantify the potential UHI effects of the solar-reflective façades relative to the non-reflective ones in a dense urban context. As such, a simulation method in terms of a series of tools including Radiance, Optics, SPCTRL-BIRD, and ClimateStudio in Rhino was adopted in this work to analyze the solar radiation interactions between the façade surface and the surrounding urban structures, and potential temperature rise under solar-reflective and non-reflective façades. Although emerging solar-reflective building façades exhibit strong energy-saving potential in summer, the result in this preliminary work unveils the potential adverse effects of using such materials at the urban microclimate scale, which leading nearly 2 times greater solar irradiation and UHI effects than the ones by the solar-non-reflective building surfaces in an urban area. Future optimization studies on the trade-off between the building cooling energy savings and UHI effects by the solar-reflective façades need to be conducted.

SDEWES2022.0406**Urban System Integration for Rapid, Deep and Sustained Emissions Reductions with Renewables: Clustering Pathways Towards Net-Zero Targets**

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Abstract

Ensuring rapid, deep and sustained emissions reductions requires targeted efforts for increasing the penetration of renewable energy sources. The recent report of the Intergovernmental Panel on Climate Change with a focus on mitigation identified three broad strategy areas for urban areas that were responsible for about 67-72% of emissions in 2020. These are better urban planning for reducing and changing energy use, electrification in combination with renewable energy sources, and enhancing carbon sinks in the urban environment. These three areas are applicable for all cities around the world, whether established, rapidly growing or emerging cities, in the path towards net-zero emissions. Mitigation options for urban systems are also compared based on multi-dimensional feasibility and linkages with the Sustainable Development Goals. As a running theme, these underline the importance of cross-sectoral coordination for integrating sectors, strategies and innovations for obtaining synergies for shifting development pathways towards sustainability, especially in urban areas. The present scientific contribution compares urban level scenarios for 100 urban areas under the context of green growth paradigms with different global warming outcomes, namely SSP1-1.9 and SSP1-2.6, as well as a SSP1 variant of a 100% renewable energy scenario, namely SSP1-RE. A synthetic comparison is then conducted for clustering these 100 urban areas that have been benchmarked with the Sustainable Development of Energy, Water and Environment Systems (SDEWES) City Index based on similar strengths and challenges. The clustering algorithm is used to pair cities to strengthen the collective effort towards reaching this common target. Illustrative urban mitigation pathways are described based on the clusters with urban system integration holding an important role across the urban mitigation strategies. These cluster-based descriptions are compared with the illustrative mitigation pathways of the IPCC. The research work has implications for guiding ambitious urban mitigation effort across the world. Urban areas that may have different starting points based on the benchmarking results all have opportunities to take pathways towards reaching net-zero emissions and attaining related co-benefits.

SDEWES2022.0446

Reduction of Air Conditioning Energy Consumption by Redundant Energy Gains Modification

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Abstract

For a selected building in a specific location and conditions encountered, heat gains from insolation, people, equipment, lighting, and window partitions were calculated depending on the time of day (hourly for a year), the number of people, and the activity of people in the building. The heat and humidity balance was performed. This allowed the cooling and heating demand to be determined. The air conditioning system was adjusted to the demand. The operation of the system was simulated by showing the loads (hourly for a year). The load flexibility of the air conditioners was presented. Heat gains have been determined and ranked according to which has the greatest influence on the air conditioning load. Solutions were proposed to reduce the heat load in rooms. As a result of the research, methods were presented for reducing the energy consumption of air conditioning by modifying the factors causing redundant energy gains.

SDEWES2022.0565

Investigation on Future District Heating Systems for German Cities with Existing District Heating Network

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Abstract

In the context of the energy transition, governments must increasingly look at the energy consumption of cities. The heating sector of residential buildings play a particularly important role, as the end energy demand for space heating takes 26,6 % of the German end energy use. One approach to solving this problem can be the supply through district heating networks with a high share of sustainable heat. This puts pressure on local energy suppliers to lower carbon emissions of their district heating production units and being economical.

This paper aims to present a methodology for the planning of carbon low heat supply in a future district heating system based on open data for German cities with existing district heating networks. One focus is on the integration of industrial waste heat and the uncertainty of future waste heat sources as well as restrictions on the use of biomass. For that purpose, knowledge about the energy demand is necessary. In a first step it is shown how the demand around a heating network is estimated with spatial data and a load profile is generated. Local available heat sources are examined according to their suitability and their kind of integration in the heating network. As heat production from different units is calculated, the development of a simulation model will be presented. The simulation is based on the optimisation of the operational costs of the used technologies for heating supply. Different scenarios will be developed and examined, which cover various technologies and economic assumptions. The results will show the levelized costs of heating as well as the ecological performance. A sensitivity analysis will show the importance of uncertainties for the economic assumptions.

Waste and wastewater treatment and reuse 1

SDEWES2022.0032

Removal of Congo Red Dye by Using Treated and Untreated Wood Chips

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Abstract

In the present study, the biosorption efficiency and capacity of Wood chips (Wc) were investigated for the removal of Congo red dye (CR) in aqueous solutions. The Effect of various parameters such as initial dye concentration, pH solution, contact time, and the temperature was studied and optimal experimental conditions were determined. The sorption capacity was found to be 15 mg/g and 25mg/g for Wood chips (Wc) and Wood chips treated with Cetyltrimethylammonium bromide CTAB (Wc + CTAB) respectively. Consequently, a marked improvement in the adsorbed amount of Congo red onto Wc + CTAB is to be noted.

The biosorption behavior of Wc towards Congo red dye removal based on the coefficients determination values R^2 was well fitted by Langmuir and Temkin isotherm models.

The biosorption process was inspected using the kinetic models of pseudo-first-order, pseudo-second-order. Biosorption kinetic analysis showed that pseudo-first-order model fitted very well the biosorption of Congo red dye onto Wc.

The thermodynamic study indicated that the biosorption process of Congo red onto Wc was endothermic and spontaneous. The study revealed that Wood chips have a great potential for Congo red dye removal.

The research results indicate that Wood chips could serve as an inexpensive source for Congo red removal from contaminated water due to their low cost. Therefore, the practical and economical use of biosorbents for the treatment of dilute colored wastewater is quite clear, which gives more importance to this study.

SDEWES2022.0065**Biomass Gasification to Synthesis Gas in Thermal ARC Air Plasma Environment**

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Abstract

The rapid expansion of population worldwide increases energy demand and waste generation. Wastes and biomass are potential energy resources. Concerning sustainable development, appropriate methods for waste and biomass conversion are necessary. Lately, plasma technologies have drawn attention as a possible way for biomass and waste conversion into valuable intermediate products, such as synthesis gas, which could partially satisfy the growing energy demands. Nevertheless, plasma technologies are not yet fully developed and commercialized and therefore further research at the laboratory scale level is needed.

Thus, this experimental research aimed to determine the ability to gasify biomass (wood pellets) to synthesis gas in the thermal air plasma environment. The influence of different material conversion parameters, including the power of the plasma torch and the plasma-forming gas flow rate on the biomass gasification process, were analyzed. Also, the evaluation of the plasma system performance was carried out.

The experimental biomass gasification system was designed at the Plasma Processing Laboratory of the Lithuanian Energy Institute. The experimentations were performed using the 6 mm diameter wood pellets as the reference biomass feedstock. Air was used as a plasma-forming gas and the main gasifying agent.

The gasification of the wood pellets was carried out at the plasma torch power of 40.5–54.9 kW, air flow rate of 10.18–18.18 kg/h and the feedstock flow rate of 20.73 kg/h (equivalence ration of 0.11–0.16). The quantification of the biomass gasification system in terms of the producer gas composition, the H_2/CO ratio, the lower heating value (LHV), the carbon conversion efficiency (CCE), the energy conversion efficiency (ECE), and the specific energy requirement (SER) were performed. The highest H_2 and CO concentrations in the producer gas were 26.6% and 33.35%, respectively, giving the H_2/CO ratio of 0.8. The LHV of the produced synthesis gas varied from 7.62 MJ/Nm³ to 8.82 MJ/Nm³, respectively. The CCE ranged from 85.3% to 97.2%, while the ECE was equal to 29.23–30.57%. The SER producing 1 mole of syngas from wood pellets varied from 165.47 kJ/mol to 195.61 kJ/mol, respectively.

Summarily, the thermal arc air plasma was applied to convert biomass to syngas. The comparison of different flow rates of the gasifying agent at a constant feedstock ratio showed that the air flow rate did not make a significant difference in the biomass conversion process. The synthesis gas generation varied from 59.95% to 62.51%, while the H_2/CO ratio ranged from 0.68 to 0.8. Moreover, this primarily experimental research shows promising results for successful application of the newly designed plasma gasifier. Further research is needed to optimize the conditions of biomass/wastes conversion process in air plasma and other plasma environments.

SDEWES2022.0089

The Effect of Acid Catalyst on Hydrothermal Carbonization of Sewage Sludge

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Abstract

Common access of households to high-efficiency wastewater treatment plants induces greater generation of wastewater and thus sewage sludge. Therefore, an appropriate treatment of sewage sludge is urgently required in order to improve sewage sludge properties, its hygienization, and further sewage sludge management. The hydrothermal process complies with those conditions, furthermore, it enhances dewaterability of sewage sludge and generates hydrochar with adequate properties necessary for to energy production. Although, it is a very promising technology, the heavy metals in sludge do not degrades during the hydrothermal carbonization process. Hence, there is a great need to fill this gap and discover some additives which could solve this problem. Accordingly, the research is focused on the effect of the addition of a catalyst, which was sulphuric acid (VI), as an addition to sewage sludge, on both solid and liquid hydrothermal carbonization process products, mainly on heavy metals migration from solid to liquid phase. Consequently, the proximate and ultimate analyses, and the higher heating value of hydrochars, solid product, were determined. The FTIR spectrophotometric analysis, as well as thermogravimetric analysis were conducted. The heavy metal contents in the ash composition of hydrochars were analyzed. It was confirmed that the catalyst addition had changed the structure as well as the physical and chemical properties of hydrocarbons and their ashes. Moreover, the ICP-MS and ICP-OES analyses of the liquid phase were also studied. It was found that the addition of the catalyst had a positive effect by decreasing the heavy metals content and increasing of phosphorus compounds in filtrates.

SDEWES2022.0242**Pyrolysis of Waste Materials of Retired Wind Blade by TG-Ftir-Ms**W. Ma¹, N. Deng¹, X. Wang^{*1}, H. Mikulčić², D. Ma¹, A. Zhou¹¹Xi'an Jiaotong University, China; ²University of Zagreb, Croatia
(*wxb005@mail.xjtu.edu.cn)**Abstract**

With the rapid development of wind power, the amount of waste of composite blades for wind power generation has increased greatly. Although wind power generation is regarded as clean energy, considering a large amount of waste of thermosetting composite materials from retired wind blades after the service life, how to manage the solid waste from wind power in a clean technic route is attracting more and more focus. Pyrolysis of wind turbines is a common method to achieve material recycling and energy recovery. It is a process of thermal degradation of waste in an inert atmosphere resulting in valuable products including char, oil, and combustible gases. In this paper, typical two typical materials of wind turbines (glass fiber reinforced resin and balsa wood) were studied by using TG-FTIR-MS. The research results show that the weight loss process of glass fiber reinforced resin is divided into two stages, the temperature range of the first stage is 270-370 °C, and the temperature range of the second stage is 370-612 °C. The weight loss process of balsa is divided into three stages. The first stage is 90-244 °C, the second stage is 244-433 °C, and the last stage is 433-608 °C. Both of glass fiber reinforced resin and balsa wood are pyrolyzed at around 600 °C; The functional groups of the gas products released by resin and balsa wood during the process are basically the same. By comparing the mass spectrometry information, the main products released by the resin during the pyrolysis process include CO₂, CO, aldehydes, alcohols, carboxyl groups and hydrocarbons. In addition to the above hydrocarbons, some nitrogen-containing substances, including pyrrole, pyridine, vinylpyridine, etc., are released by balsa wood. The mass loss characteristics and the chemical composition of gas phase products of balsa wood and resin during pyrolysis provide a theoretical basis for pyrolysis recovery of retired wind turbine blades.

SDEWES2022.0243

Energy Balance Assessment on a Treatment System of Municipal Sewage Sludge by Pyrolysis and Partial-Combustion: Aspen Plus Model

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Abstract

As a new type of sludge disposal technology, sludge pyrolysis technology can realize the reduction and resource utilization of municipal sludge. In this paper, Aspen Plus software is used to simulate the drying and pyrolysis process of sludge, and the combustion process of pyrolysis oil and gas during pyrolysis and carbonization. By changing the initial moisture content of MSS, moisture content after drying, pyrolysis temperature and air supply in the incinerator, the possibility of achieving energy self-balance in the system is analyzed. The simulation results show that under the same process conditions, whether the system can achieve energy self-balance is related to the quality of MSS. The higher the dry basis calorific value of MSS, the easier it is for the system to achieve energy self-balance. Considering the system's energy loss, the dry basis calorific value of MSS should not be less than 10MJ/kg. The higher the initial moisture content of sludge, the more external energy input the system needs. It is recommended to dehydrate MSS mechanically to about 60% before entering the system. When the pyrolysis temperature is increased, the amount of oil and gas produced by MSS pyrolysis increases, and it is easier to achieve self-balance of system energy. But the higher the pyrolysis temperature, the greater the energy consumption required. In practice, it is suggested that the pyrolysis temperature is about 400°C. The moisture content of dried sludge has little effect on the energy self-balance of the system, and it is recommended to be about 30%. The air supply volume of the incinerator mainly affects the flue gas outlet temperature and flue gas volume, but has little effect on the energy balance of the system. The excess air coefficient can be kept between 2.6 and 2.8.

SDEWES2022.0245**Pyrolysis Characteristics and Kinetic Analysis of Coal Gangue with Ultra-Low Calorific Value: Thermogravimetric Study**H. Zhang¹, Z. Shi¹, X. Wang^{*1}, G. Wang², Y. Chen², H. Mikulčić³¹Xi'an Jiaotong University, China; ²Huichao New Energy Technology Co., Ltd, China;³University of Zagreb, Croatia (*wx005@mail.xjtu.edu.cn)**Abstract**

In the process of coal mining, washing and utilization, a huge amount of coal gangue is produced, which has become the largest solid waste in China. Large accumulation of coal gangue is not only occupying the land area, but also is leading to severe environment pollution because of the leaching solution with toxic elements can be dissolved into the land after rainfall. Therefore, the resource-utilization of coal gangue is extremely urgent. At present, coal gangue with comparatively-high calorific value has been burned in circulating fluidized bed (CFB) power plants. However, the coal gangue of a certain calorific value burned in CFB only accounts for 10-15% of the total coal gangue generated from coal mining and washing in China. Most coal gangue is discarded because of its ultra-low calorific value and ultra-high ash content. Since there is still a certain content of volatile, spontaneous combustion usually happens to these discarded coal gangue and resulting in severe air pollution by emitting a large amount of sulphur and nitrogen species. How to use these coal gangue of ultra-low calorific value is attracting attentions in recent years. In this paper, the pyrolysis characteristics of four kinds of coal gangue with ultra-low calorific value were studied by thermogravimetric analysis. At the same time, the kinetic analysis of pyrolysis process of four kinds of coal gangue was carried out. The results show that the pyrolysis processes of the four ultra-low calorific value coal gangues have similar laws, which can be divided into several main stages: dehydration and degassing, softening melting and activation decomposition, and secondary degassing, and the coal gangue with high volatile content has a larger weight loss rate and a faster weight loss rate. The results of the pyrolysis kinetic analysis show that the three-dimensional spherical symmetric diffusion mechanism model can well describe the first stage of ultra-low calorific value coal gangue pyrolysis, and the reaction series model with series 2 can accurately describe the second stage, while the optimal reaction model of the third stage is different according to the different combustible components of coal gangue. The research in this paper can provide theoretical guidance for the pyrolysis and subsequent stable combustion utilization of ultra-low calorific value coal gangue, and improve the comprehensive utilization capacity of coal gangue.

SDEWES2022.0246**Pollutant Emission Characteristics of Coal Gasification Fine Slag Combustion and Co-Firing with Coal**Z. Shi¹, X. Wang^{*1}, J. Zhang², D. Ma¹, A. Zhou¹¹Xi'an Jiaotong University, China; ²Xi'an Jiaotong University, China
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In this paper, the pollutant emission and particulate matter generation characteristics of the CGFS under different combustion temperatures (900°C, 1100°C, 1300°C) and different combustion atmospheres (5%, 10%, 21%) are studied. Furthermore, the characteristics of pollutant emission and particulate matter formation are studied by mixing the CGFS with raw coal in different proportions. Furthermore, the characteristics of pollutant emission and particulate matter generation are studied by co-combusting different proportions of fine gasification slags (10%, 20%, 30%) with raw coal. Finally, qualitative and semi-quantitative analysis of point, line and plane elements in the micro-area of sample surface is carried out to analyze the formation reasons of particles from the microscopic level. Studies on pollutant emission characteristics show that the increase of furnace temperature and oxygen concentration can effectively promote combustion and improve burnout, but will lead to an increase in pollutant emissions. Adding a certain proportion of fine gasification slag into raw coal can reduce the total emission of air pollutants to a certain extent and optimize the emission of pollutants of coal burning. Studies on the characteristics of particulate matter generation show that the reduction of furnace temperature and oxygen concentration can effectively reduce the amount of particulate matter generation in the sub-micron particle size range. With the increase of the mixing proportion of YL, the sub-micron particle size range becomes smaller and the peak value is lower. The co-combustion of raw coal with fine gasification slag can reduce the concentration of particles in the sub-micron particle size range and reduce the emission of particles in the sub-micron particle size range. Studies on the element composition of the particles show that with the increase of furnace temperature and oxygen concentration, the contents of Fe, S and Si in the particles with sub-micron particle size range generated by YL increase significantly, which is the main influencing factor for the increase of the particles with sub-micron particle size range. With the increase of YL mixing ratio, the contents of Fe, K, Mg and other major components of particles in the sub-micron particle size range decrease significantly, which is an important factor influencing the reduction of particles in the sub-micron particle size range with the increase of YL mixing ratio.

SDEWES2022.0521**Valorization of Liquid Seafood Side-Streams. Life Cycle Assessment of a Membrane Concentration Technology to Recover Savory Compound from Mussel Cooking Water**

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Abstract

According to recent studies, world fish production has increased to about 200 MT, with a per capita consumption of 20 kg/year. These figures are also reflected in the increase in solid and liquid side streams (between 20 – 80% of landed fish weight can turn into by-products, depending on the processing and fish species). Currently, liquid side streams, such as process waters, are treated as waste with a significant potential environmental impact due to the high presence of organic load, as well as salinity content. This makes it difficult for some fishing industries to comply with the discharge limit values established by the water management entities. This fact is particularly relevant if it is considered that organic matter is a potential source of many healthy and biologically active compounds, which have an important potential for use in food, feed, or other valuable purposes. In this sense, groundbreaking technologies for the valorization of these sources and the identification of the potential environmental impacts compared to current practices are needed. The present work has focused on the environmental performance evaluation of an innovative technology for the valorization of mussel cooking water by concentrating it to obtain a savory component. The life cycle assessment (LCA) methodology was used to identify the burdens of this technology on the freshwater eutrophication indicator; this impact category was selected because of its strong relationship with aquatic pollution. Life cycle inventories were obtained from a real pilot plant installed in northern Spain. The proposed technology, which includes nanofiltration and diafiltration with nanofiltration membranes, showed a high concentration of the main savory ingredient, such as glutamic acid, and produces a low organic content brine. Likewise, this technology presented a ~90% reduction of the freshwater eutrophication potential, which allows the water to be discharged into the sea or used as initial cleaning water for mussels, due to the sterilizing capacity of nanofiltration. In summary, the analyzed technology minimizes, on the one hand, the environmental impacts related to freshwater pollution and, on the other hand, extracts valuable compounds that can be potentially applied in food/feed products.

SDEWES2022.0634**Application of Membrane Aerated Biofilm Reactor Mabr for Sustainable Wastewater Treatment**

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Abstract

Wastewater treatment plants face a future challenge with growing population, where higher treatment capacity is needed, and new expected requirements for total nitrogen <10 mg N/L in the discharge. Membrane aerated biofilm reactor (MABR), a newly developed technology with simultaneous nitrification and denitrification, is a promising technique to cope with the challenge. It is a fixed film process where the biofilm is fed with oxygen via the membrane on which the biofilm sits. The pilot scale study was performed at Ekeby wastewater treatment plant in Eskilstuna, Sweden. The experiments were conducted for a 230 days period from July to February at varying wastewater temperatures from 10 °C to 20 °C.

The pilot plant was designed as an activated sludge process with pre-denitrification with first an anaerobic tank where ZeeLung membrane modules were placed, followed by an aerobic tank and finally a sedimentation unit where the return sludge was recirculated back to the inlet. The feed water for the pilot plant comes from the treatment plant's pre-sedimentation. Several analyzes were made on the inflow to the MABR reactor, in the volume with the ZeeLung module, in the aerated volume and in outflow from the sedimentation tank. DO, pH, temperature and conductivity were monitored by online sensors.

The results from pilot plant showed that ammonium nitrogen removal efficiency was as an average 92 %. Nitrification rate was 2.37 g/(m²·d) as an average value. Total nitrogen removal efficiency increased from 32 % at the start of the study to an average of 53 % at the end of the study. The reduction of organic material (as BOD₇), decreased from 90% at the start to 60% at the end of the experiments. Oxygen transfer efficiency (OTE) varied between 6.3 and 13.2 g O₂/(m²·d). When the availability of organic carbon for denitrification was insufficient to cope with operation at low water temperature, and in combination with low levels of dissolved COD in wastewater, acetate was added from day 121. Prior to the addition of carbon source, the denitrification removal efficiency was on average 40%, after the addition of carbon source increased to 60% at the end of the experimental period.

MABR technology, with higher oxygen transfer rates and efficiencies leading to reduced aeration costs, is a promising and sustainable technology for future wastewater treatment. A pre-denitrification process can be easily converted into MABR for simultaneous nitrification/denitrification.

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SDEWES2022.0371

Reuse of Treated Wastewater in Agricultural Irrigation

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Abstract

The growing water scarcity has necessitated the need for alternate water sources aside from conventional sources. Treated wastewater or recycled water has emerged as a promising alternate source for agricultural irrigation. Many studies have been conducted on the use of recycled water for irrigation; however, these studies usually augment the irrigation scheme with fertilizer application or soil amendments. Can the use of treated wastewater only, promotes plant growth? Will the use of recycled water negatively impact the soil's chemical properties?

The study, therefore, sought to find answers to these questions by irrigating cherry tomato and carrot plants with secondary effluent from an activated sludge treatment system (T1), and effluent from an ultrafiltration membrane treatment system (T2). Tap water was used as a control (T3). Each treatment of tomato consisted of triplicates and carrot consisted of duplicates. Plants were grown on loam soil in a greenhouse under climatic conditions similar to tropical climate. The pH, conductivity, nitrate and phosphate of T1, T2 and T3 were 7.90, 0.74 mS/cm, 0.90 mg/L and 0.72 mg/L; 8.01, 0.72 mS/cm, 8.96 mg/L and 0.73 mg/L; 7.86, 0.33 mS/cm, 3.38 mg/L and 0.05 mg/L respectively.

Preliminary results after five months of irrigation showed T1 and T2 had higher growth rates for both carrots and tomatoes and higher leaf counts for tomatoes. Percentage dry weights of T1 and T2 for carrot and tomato were 18.3%, 16.6% against 15.9% of control, and 10.5%, 10.1% against 9.0% of control, respectively. The mean fresh weights of carrots were 4g, 3g, and 2g for T1, T2 and T3, respectively. The obtained results reveal better growth of T1 and T2 relative to T3. Therefore, the use of recycled water for irrigation could promote plant growth; however, to boost crop production, fertilizer application or soil amendment may be required. The next phase of the study will focus on the impact of the treated wastewater on the soil's chemical properties.

SDEWES2022.0374

Effect of Moisture Content of Sewage Sludge to the Pyrolysis Reactions

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Abstract

The amount of annually generated sewage sludge is continuously increasing. Owing to the more restrictive legislation and the environmental or health effects, the most widely used incineration and agricultural utilisation are hardly acceptable as long term sustainable sewage sludge treatment. To eliminate the aforementioned harmful effects, thermochemical conversion technologies (e.g. pyrolysis, gasification) seem to be the most promising options.

Pyrolysis of sewage sludge results the formation of solid (biochar), liquid (bio-oil) and volatile gaseous products, which can be used in various applications. As a result of it, the effects of temperature, heating rate, reaction time and particle size on the yields and characteristics of pyrolysis products is widely investigated, especially in case of dried sewage sludge. However, the moisture content is a key factor for both the energy consumption of the process and hydrogen rich gas production. Nonetheless limited information is available about the use of wet sewage sludge as pyrolysis feedstock.

Therefore, in this study sewage sludge with different moisture contents was pyrolysed in a tubular reactor, and the pyrolysis products yields and composition were investigated.

Based on the results, it was found that moisture content had significant effects both on the product yields and the compositions. The steam generated by the moisture content reduced the amount of the biochar and in general facilitated the reforming reactions. However, finding the optimum of moisture content is essential.

SDEWES2022.0433

Toxic Effects of Microplastics on Freshwater Microalgae *Pseudokirchneriella subcapitata* and Crustacean *Daphnia magna*

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Abstract

Microplastic pollution has become a growing problem worldwide. Microplastic (MP) in the aquatic environment enter the food chain and cause negative impacts on human health and the ecosystem. MP serve as a vector for various substances present in water, including emerging and priority pollutants such as pharmaceuticals and pesticides. The adverse effect of MP in water is therefore influenced by factors affecting adsorption capacity; particle size, specific surface area, aging degree, crystallinity, and polarity of MP, and the properties of organic pollutants. In this study, we investigated the interactions of polyethylene terephthalate (PET) MP with pharmaceuticals and pesticides in water. The aim was to establish the correlation between the properties of MP and the adsorption capacity for the studied pollutants, and to elucidate the resulting toxic effect. For that purpose, we tested the adsorption of pharmaceutical diclofenac and pesticide atrazine on PET MP of different particle sizes and aging degree. PET was inspected for morphological changes, induced by accelerated aging under UV irradiation, using Fourier Transformation Infrared Spectroscopy and Differential Scanning Spectroscopy techniques. In adsorption tests, using pristine and aged PET MP, the concentration of pollutants in aqueous phase was monitored by HPLC analysis. Aquatic toxicity of MP was assessed by exposing freshwater organisms to the aqueous dispersion of pristine and aged MP, without and with adsorbed pollutants. Acute toxicity bioassays were performed with the microalgae *Pseudokirchneriella subcapitata* (*Selenastrum capricornutum*) and the crustacean *Daphnia magna* according to standard procedures (ISO). It was shown that the toxicity of MP increases with the aging degree which is correlated with enhanced adsorption capacity owing to morphological changes and the formation of surface functional groups during accelerated aging, as confirmed by the observed changes in carbonyl index. Complex samples indicated additive toxicity effects in the case of both organisms, in comparison with the individual components, indicating the complexity of the emerging problem of MPs in the aquatic environment.

SDEWES2022.0437**The Nitrogen, Phosphorous Controlled Recycling Within Poultry Manure Mixed with Opoka Rock Used for Soil Improving**M. Kacprzak^{*1}, J. Sobik-Szolytysek²¹Warsaw University of Technology, Poland; ²Czestochowa University of Technology, Poland (*malgorzata.kacprzak@pw.edu.pl)**Abstract**

Poultry manure is traditional organic fertilizer containing considerable amounts easy available nitrogen (in the form of NH_4^+ , NO_3^-) and phosphorous (orthophosphates and organic) compounds. Most environmental threats of uncontrolled management of poultry manure result from exceed of ammonia (NH_3) and nitrous oxide (N_2O) emissions to environment, being higher compared to cattle and cow manure. Hence the use of inorganic additives may modify the physical and chemical sorption/desorption character of poultry manure. Pervious work shown that poultry manure mixing with opoka rock may positively inhibit so quick desorption of N and P ions to soil solution. Hence, poultry manure-opoka rock mixtures were used for improving two types of soil – agricultural and peat. The opoka and poultry manure were mixed with soil in following ratio: 4%, 2%, 1% weight/weight. Chosen doses are comparable with these used for standard fertilization. The rape, wheat, red fescue and ryegrass were cultivated during 3 months. Next, the plants were harvested and following analysis of soils and plant were done: pH (H_2O), pH (KCl), P- P_2O_5 (mg/kg), $\text{N}_{\text{Kjeldahl}}$ (mg/kg), N- NH_4 (mg/kg), humidity of soils (%), biomass weight (g), the number of germinated seeds. Generally all additives (independently on dose, type of soil) increased initially the content of P- P_2O_5 and N- NH_4 and pH value and total plant biomass. However, it was found that both plant species and type of soil influenced the efficiency of poultry manure-opoka rock mixtures as fertilizer. Moreover opoka alone negatively affected and availability of phosphorous in soil solution. It confirm that the high content of CaCO_3 in the opoka determined sorption/desorption capacity in relation of P ions. In turn, addition of poultry manure-opoka mixture stabilized the presence of N- NH_4 ions in both types of soils, independently of cultivated plants. Presented results gave promising input in research concerning on use of modified substrates based on poultry manure and inorganic additives such opoka rock for controlled release of nitrogen and phosphorous compounds to soil solution and matter recovery.

SDEWES2022.0440**Pyrolysis of Marine Wastes and an Analysis of the Formed Products**

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Abstract

During the last few decades, environmental problems, such as eutrophication and water pollutants, have attracted more and more attention. Moreover, the CO₂ reduction of fossil fuels leads scientists and fuel industries to explore alternative sources and methods for energy production and recovery. The best solution for both of these problems could be waste utilization, gathering higher added value energy products, and contributing to creating a circular economy. This investigation is focused on the fishing nets (FN) and the seaweed (SWD) thermal utilization over different catalyst types of catalyst. The feedstock thermal decomposition was analyzed using a thermogravimetry (TG) analyzer combined with Fourier-transform infrared spectroscopy (TG-FTIR) and gas chromatography-mass spectrometry (TG-GC/MS). The results showed that the SWD sample has two decomposition peaks around 300 °C and 700 °C, which could be assigned to cellulose/hemicellulose and lignin thermal stability. The cellulose and hemicellulose are mainly composed of β-1,4-glycosidic bonds, which need less energy to break the bonds between the atoms, while the lignin has a strong aromatic walls matrix, giving cells strength and resistance. The results of FN thermal decomposition showed that the regions are divided into two parts: around 200 °C and 450 °C. These results confirm that the feedstock is mainly composed of nylon-6 whose boiling point is around 452 °C, and polyproline (PP) – Polyethylene (PE), which boiling points range from 140 to 210 °C. Chemical analysis by FTIR and GC/MS of the SWD sample showed that the major compounds are variously substituted aromatic, phenolic, and furans compounds, having alkyl C-H, C=O and O-H stretching, while the FN most significant compounds are caprolactam and phenolic derivatives. The catalyst increased the amount of the most significant derivatives with both feedstocks leading to a conclusion, that further investigation for energy and higher added value product recovery must be performed.

SDEWES2022.0481

Sustainability Analysis of Alternatives to Manage Waste Generated in Greenhouses

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Abstract

Intensive agriculture is expanding due to its high productivity. Nevertheless, some of its practices generate significant amounts of waste. For example, horticulture in greenhouses, common in several Mediterranean countries, generates waste that is difficult to manage, for instance plastic waste. This waste is often managed in non-sustainable ways, like incineration or dumping. However, alternative potential solutions for sustainable waste management exist. This paper presents five alternative systems to manage waste generated in horticultural cooperatives in Almeria, southern Spain. These alternatives are analysed in terms of their economic, social and environmental performance. Expert knowledge is used and processed with the Analytic Hierarchy Process (AHP) method. Results show that there are alternative solutions to manage waste more sustainably in the horticultural cooperative studied, such as the alternatives 'Cooperative manages inorganic waste', where the cooperative becomes a waste manager, and 'Collaboration between cooperative and managers', where the cooperative coordinates a system that is executed by managers. These two alternatives are not currently implemented by any cooperative in the region.

SDEWES2022.0514**Characterization of Degradation Products at Different Temperatures in Fast Pyrolysis of Plastics Using TG-Ftir**

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Abstract

Thermogravimetric analyzer coupled with Fourier transform infrared spectroscopy (TG-FTIR) allows identification of evolved gases during the thermal degradation of organic matters. However, it is hard to compare products at different pyrolysis temperatures with conventional methods. Because the purge gas is constantly introduced to the TGA in conventional methods, evolved gases are instantly ejected from the TGA to the IR cell without further cracking or secondary pyrolysis reactions. For that reason, regardless of the TGA temperature programming (such as heating rate or holding temperature), identical FT-IR spectrum is obtained for a sample at different temperatures.

In this study, a simple approach to stop the purge gas to hold evolved gases from TGA was conducted to characterize vapor products at different degradation temperatures. The purge gas was stopped until sufficient vapor phase reactions occurred at the desired temperature. After the reactions were completed, the purge gas was turned on to carry vapor products to the IR cell.

TG-FTIR was performed with different five types of plastics (PE, PP, PS, PET, and real waste plastic) at reaction temperatures of 500, 600, 700, and 800 °C. PE and PP showed similar degradation patterns, producing wax as the major product at 500 °C. Wax almost vanished from 600 °C, and a strong formation of aromatics was observed at 800 °C. Major pyrolysis product of PS in the temperature range of 500–800 °C was styrene monomer. With increasing temperature, benzene and toluene formation were observed at the expense of styrene monomer. In the temperature range of 600–800 °C, FT-IR spectra of PET were similar at all the temperatures, which indicates that degradation products of PET above 600 °C were stable and unlikely to react. Finally, FT-IR results of real waste plastic revealed that the degradation products were chiefly wax at 500 °C, light alkenes and small amount of methane at 600 °C. The methane formation was accelerated when aromatization above 700 °C was accompanied. In summary, degradation products at different temperatures could be predicted by controlling the purge gas of the TG-FTIR system. The results will be helpful for researchers to determine reaction temperature in a process when they are trying to recover particular products in high yields in pyrolysis.

SDEWES2022.0580

Effect of Free Ammonia and Free Nitrous Acid Inhibition on Nob Activity in the SBR Under Elevated Temperatures

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Abstract

Successful start-up of a partial nitrification (PN)-anammox system for sidestream can be achieved by regulation of free ammonium (FA) and free nitrous acid (FNA) concentrations to outcompete NOB at elevated temperatures specified for reject water from the anaerobic digestion. In this study, stand-alone FA inhibition and combined influence of FA and FNA on NOB suppression and AOB activity in a lab-scale environment, during synthetic reject water treatment at an elevated temperature (up to 30 °C) was investigated. At pH=8.3 and FA=17.2 mg/L, the most favourable NO₂-N accumulation/AUR ratio (0.49) occurred, indicating a nearly 50% decrease in nitrate accumulation and the strongest inhibitory effect on NOB activity. The results showed that pH control to adjust FA and FNA concentration, directly and indirectly, triggers the activity of AOB and NOB accordingly. Although the combined impact of FA and FNA enhances NOB suppression, the FA technique alone performed better in overall process efficiency and nitrite accumulation, due to maintaining higher AOB activity.

SDEWES2022.0638

Production of Sustainable Concrete Using Rice Husk Ash as Partial Replacement of Cement

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Abstract

To reduce the environmental impacts associated with the manufacturing of concrete in the form of carbon dioxide released during cement production, which is an important ingredient of concrete, various agricultural wastes and/or industrial byproducts are used as partial replacement of cement for the production of concrete. In this research rice husk after incineration to ash was investigated as a partial replacement of cement for the production of sustainable concrete also called green concrete. Rice husk ash (RHA) which is rich in silica (> 90 wt. %) has favorable chemistry as supplementary cementitious material for use in concrete. The use of RHA in concrete results in its chemical reaction with the hydrates of cement, chiefly Calcium Hydroxide, and forms secondary products that impart strength and stability to the resulting concrete mixture.

The effects of RHA as a partial replacement of cement in concrete were investigated in a laboratory experimental program. Cement was replaced at 5%, 10%, and 15% (by weight) with RHA for the production of concrete. Important strength and durability characteristics of the resulting concrete mixtures were evaluated in fresh and hardened states at various concrete ages. Test results showed that the use of RHA as a partial replacement of cement in concrete enhances the later-age compressive strength, abrasion resistance, and moisture barrier characteristics of concrete. On the other hand, an important durability indicator of concrete named low drying shrinkage is significantly improved with the incorporation of RHA as a partial replacement for cement. The outcomes of the test results point to the viability of using RHA in concrete for the production of economical, durable, and environmentally-friendly concrete mixtures which is an important step in the direction of sustainable construction practices.

Waste and wastewater treatment and reuse 3

SDEWES2022.0285

Analysis of Embodied Energy and GHG Emissions from Wastewater Reuse Strategies: a Case Study of Urban Water System in the Indian Himalayan Region

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Abstract

Water-Energy-GHG (WEG) nexus is extensively used for investigating sustainable solutions for urban water systems (UWSs). Limited WEG nexus studies are available for the UWS in the hilly terrains. The water system in the hills is characterized by intermittent water supply, high elevation head, and limited surface water sources that make it imperative to seek solutions for sustainable water management. The objective of this study is to investigate the energy use and GHG emissions from different wastewater reuse strategies in a UWS located in the Indian Himalayan region. The population of the region is ~25,000 and 4.8 MLD of treated water is delivered through taps in every household. The 70% of total wastewater generated is collected and treated in a 5 MLD capacity treatment plant. Hypothetical scenarios for the direct potable reuse and non-potable reuse in the region were analyzed. The functional unit for the analysis was 1 m³ of water delivered to the study area. The system boundary included energy and emissions from civil works, piping infrastructure, operational energy, and chemical usage. The data for the present operation of water and wastewater systems (baseline scenario) was collected from detailed project reports and official databases of the region. The data inventories for different reuse scenarios were developed using literature and other site-specific information. The total embodied energy and total GHG emissions were estimated using the existing models based on the mass balance approach. The energy and GHG emission factors were based on Indian-specific literature, reports, and standard databases such as ecoinvent. The embodied energy represents the primary energy use in the system. The UWS uses 17.7 kWh/m³ of energy and emits 5.88 kgCO₂eq/m³ GHG emissions in the baseline scenario. Over 90% of energy and GHG emissions were associated with pumping energy which is required to cover over 1000 m of elevation head for treated water conveyance. The combined scenario comprising both non-potable and direct potable reuse had the lowest embodied energy use with a magnitude of 15.37 kWh/m³, while non-potable reuse of wastewater had the lowest GHG emissions of 5.59 kgCO₂eq/m³. The direct potable reuse scenario was 16% more GHG intensive than the baseline scenario. The robustness of the results was enhanced using uncertainty analysis through Monte-Carlo simulations. The energy use and GHG emissions can be further reduced by planning wastewater treatment facilities in close proximity to the township. The study shows that reducing the freshwater supply and reusing wastewater from the source located at relatively low elevation difference is a sustainable water management solution for UWSs in hilly terrains.

SDEWES2022.0482

Metals Recovery from Hydrodesulphurization Catalysts: a Profitability Analysis

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Abstract

The paper aims to present a techno-economic analysis to recover nickel, molybdenum, and vanadium from spent hydrodesulfurization (HDS) catalysts. Some of these catalysts are wet because of residual naphtha or other hydrocarbon fractions, in a 5-13% concentration range. Others, instead, are dried and dusty, mainly containing coke and sulfur. Some are based on active metals like Ni-Mo, others on Co-Mo. The plant, with a 6000 tons/year capacity, is based on a industrial process with pre-treatment thermal stages tested on a pilot scale. In contrast, the hydrometallurgical section was studied at the University of L'Aquila. The simulations were carried out using lab- and pilot-scale experimental data. Only wet Ni-Mo catalyst was used as the plant's feedstock, producing 1272 tons/year of V₂O₅ 98%wt, 239 tons/year of MoO₃ 57%wt, and 227 tons/year of Ni-V-Mo alloy with an approximate composition of 72-25-3%wt, respectively. The investment is highly profitable, with a net profit of around 14.1 MEUR/year, gross margin of 37.2%, return on investment equal to 23.9%, and a payback time slightly greater than 4 years.

SDEWES2022.0494

Solid Waste Management in Emerging Economies: Opportunities and Challenges for Reuse and Recycling

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Abstract

The challenges and prospects for long-term garbage reuse and recycling are highlighted and outlined. Many developing and rising countries have attempted to solve solid waste management issues as well as severe limits on material reuse and recycling. However, due to poor economic and political institutions, it is not well developed, and reuse and recycling activities have yet to be fully implemented. The findings demonstrate that important indicators are grouped into five categories, with circular resource management, societal demands, and municipal sustainability as causal factors for improving sustainable solid waste management in terms of trash reuse and recycling. The circular economy, the informal sector, material flow analyses, policy limits, and waste treatment technology are the most significant indications that can help to improve the prospect of reuse and recycling. The current review identifies the absence of national policies, improper local regulations, insufficient funding, lack of proper education, lack of infrastructures, co-operation with other organizations, source separation, culture, and corruption as the challenges of solid waste reuse and recycling. There lies opportunities of composting, fertilizer for soil, land development, business prospective, development of organizations, energy recovery, and animal feed.

SDEWES2022.0529

Thermo-Catalytic Pyrolysis of Sewage Sludge: Towards the Sustainable Waste Management

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Abstract

The environmental and sustainability challenges posed by sewage sludge are one of the unsolved issues of waste management. Sewage sludge can be utilized by different methods; e.g. landfilling, composting, agricultural utilization or even high temperature processes (combustion, pyrolysis, gasification, etc.). Pyrolysis looks attractive way to transform the lipids, carbohydrate, protein and other constituents in sewage sludge into valuable and less harmful compounds. The product yields, their composition and further utilization can be significantly influenced by the reaction parameters and catalysts to be used.

This work focusses to the thermo-catalytic conversion of sewage sludge by pyrolysis into valuable products. To affect the decomposition reactions commercial zeolite catalysts, different natural sourced minerals and by-products were used in concentrations of 10%, 30% and 50%. The pyrolysis of raw material had different decomposition steps (below 370°C, 370-600°C and 600-900°C). Catalysts can significantly affect the activation energies of each decomposition step, however in different degree. It was also concluded, that the zeolite type catalysts can reduce especially the activation energy of the pyrolysis reactions below 400°C, while catalysts with metal carbonate/oxides reduced the activation energy of decomposition reactions between 400 and 600°C. Regarding the catalytic effect, more significant reduction in activation energy was found by increasing the catalyst concentration from 30% to 50%, than that of from 10% to 30%.

SDEWES2022.0538**Devolatilization of Polypropylene Particles in Fluidized Bed**

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Abstract

Pyrolysis is the first step of the gasification process, and it influences the final product gas composition, i.e., the hydrogen and the hydrocarbons content. In this work thermal decomposition of polypropylene (PP) at high temperature has been studied in a bubbling fluidized bed using N₂ as fluidization media. The influence of particle size (8-12 mm), and bed temperature (650-850 °C), on gas composition and gas, tar, and char yields, has been evaluated experimentally.

The fluidized bed reactor (50 mm i.d.) is inserted into an electric furnace to maintain it at the desired temperature. The bed consists of 240 µm quartz sand. A batch of PP particles (3D printed spheres) are dropped instantaneously onto the hot sand bed. The gas passes through a tar sampling unit to collect tar for the subsequent GC-MS analysis. The instantaneous flowrate of the clean gas is then measured by a Mass Flow Meter. Finally, the gas composition, in terms of H₂, and CH₄, is analyzed by on-line analyzer. Gas bags are also collected to evaluate the light hydrocarbons concentration by means of GC analysis.

At the end of the devolatilization tests, air is fed to the reactor to quantify the residual char by measuring the CO and CO₂ released.

The weight fraction distribution of gas, char, tar and residue obtained at different temperature and particle size have been determined as the gas composition at different temperatures.

As observed char and gas yield increase with temperature. Furthermore, there is an increase in hydrogen content. This is probably due to the cracking reactions, favoured at higher temperature. The results also show that tar (aromatics) concentration increases with temperature. This result can be explained by the Diels–Alder reaction, followed by dehydrogenation. The residue is mainly composed of aliphatic hydrocarbons (condensable oils higher than C₄).

The model developed by Jand and Foscolo has been finally implemented for the devolatilization step. The polypropylene conversion has been described as an apparent activation energy and a preexponential factor that varies with particle size.

SDEWES2022.0614**Applicability of Multi-Layered Plastic Waste for Plastic-to-Fuel Transformation via Pyrolysis**

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Abstract

Since 1869, when the first synthetic polymer began replacing natural materials, industrial polymer use has grown dramatically. This increased the number of polymer materials that became waste after reaching the end of their products' lifespans. The overall composition of discarded waste is different, thus, suitability for recovery needs to be analysed individually. Material recovery is the preferred waste management solution. However, it is applicable only for sorted and clean mono-fractions. Here pyrolysis stands out as one of the most environmentally sustainable energy recovery options for multi-material plastic waste. Through a technological assessment of 30 pyrolysis plants, the applicability of pyrolysis for the recovery of multi-layered plastics (MLP) is reviewed. Acceptable feedstock composition and additional feedstock requirements are identified. According to Resin Identification Code (RIC) system, MLP is classified as other (7). Only 40% of existing plants accept other (7) waste stream, and acceptance of polymer materials that are not classified by the RIC system is even lower. This represents a problem as MLP are commonly used in the food industry and account for over 14% of packaging waste. Currently, the recovery is challenging because the available technologies cannot identify and separate the individual layers of MLP. The feedstock composition is important parameter in setting the operating conditions (temperature, residence time, catalyst) of pyrolysis process. Since the composition of MLP waste stream is not sufficiently investigated, it was decided to conduct the identification of its average composition from the discarded plastic waste by Fourier transform infrared (FTIR) microscopy. The obtained average MLP mixture was examined using thermogravimetric and kinetic analysis and pyrolyzed in fixed bed reactor. Pyrolysis products (oil and gas) were analysed using FTIR spectroscopy, Gas chromatography–mass spectrometry, Nuclear Magnetic Resonance and Bomb Calorimetry.

SDEWES2022.0637

Sustainable Wastewater Management and Energy Production for Sludge Incineration Process in Industrial Wastewater Treatment Plants

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Abstract

One major issue in industrial wastewater treatment plants is sludge handling and management with associated significant costs. Furthermore, the accumulated sludge handling such as the American Petroleum Institute (API) process can lead to environmental issues and health challenges such as cancer for workers in the site. This study applies combustion methods to analyse nexus of sludge incineration process and energy production potentials for this solid waste as a by-product of wastewater purification process. The methodology is demonstrated by its application to a real-world case study of petroleum refinery wastewater treatment in Iran. For this purpose, sludge samples were taken from the accumulation site and tested by calorimetry bomb, PARR 1266, Preiser Scientific, USA. In this study, 15 samples were evaluated from different points of the sludge in the case study. Measurements show that the average heat value is equal to 3,100 kcal/kg. The experimental results show that increasing water content in the sludge can lead to decreasing the net heat value. On the other hand, increasing Chemical Oxygen Demand (COD) in wastewater can result in increasing the harvested energy. In total, the sludge accumulation in the plant over the eight past years is around 4,000 tonnes which is equivalent to the thermal value of 12,400 GCal of potential energy that will be otherwise leads to environmental and health problems if not released through incineration process. This can highlight the significance of wastewater-energy-pollution nexus in sludge management of petroleum refineries by converting a threat to an opportunity.

SDEWES2022.0643

Performance Assessment of Ceramic Water Filters by Using SWOT Matrix

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Abstract

Filtration is one of the units in water treatment process that usually comes before disinfection in water and wastewater treatment plants. Filters would reduce the amount of microorganisms and volatile suspended solids by trapping them. Ceramic filters are one of the latest technologies in filtration technologies that would considerably reduce the water contaminants and solids. This study conducts performance assessment for a new generation of silicon carbide ceramic filters (SIC) by using SWOT (Strengths, weaknesses, opportunities and threats) framework. Filters analysed in this study were installed in three different sections of a water treatment plant including entrance storage, raw water and backwash water. In this study, the treatment rates between water influent and effluent were measured for twenty parameters of physical and chemical water treatment factors and used for SWOT matrix analysis. Results showed that the efficiency in turbidity removal is high whereas removal efficiency for volatile suspended solids (VSS) and fixed suspended solids (FSS) are quite lower and hence can be used as pre-treatment process in the plant. The efficiency of turbidity removal in entrance storage and raw water are 99% and 65%, respectively. The use of SWOT matrix shows it can be efficient managerial tool to analyse the possibility of using various treatment technologies in the plant by comparing strengths, weaknesses, opportunities and threats of these technologies.

Water-energy nexus/ Water treatment

SDEWES2022.0105

The Effects of Microplastic Leaching on Water Quality and the Stability of the Water Distribution System

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Abstract

Water distribution system is a key infrastructure providing good quality water resources to the individual consumers. However, water interacts with the plastic materials within the water distribution system. It can eventually leach the microplastics and nanoplastic particles–pollutants that have been linked to potential chronic health problems in human beings. In addition, leaching of microplastics from pipes may cause pipes to be degraded, leading to reduced long-term serviceability. The objective of this study is to evaluate the effects of pH, chlorine dosage, and pipe materials on the leaching of microplastics and nanoplastics. The objective is achieved through a set of laboratory-based experiments conducted on three standard pipe loop systems comprising of polyvinylchloride (PVC), polyethylene (PE), and polypropylene (PPR). Experiments were conducted at three different pH levels, three different chlorine dosage using setups with all three different pipe materials. Characterization of the plastic particles were analysed with Fourier transform infrared spectroscopy (FTIR) and microscopic analysis was used for quantification. Visual and spectroscopic analysis indicated abundant micro and nanoplastic particles being present in all the samples. Basic pH conditions aggravated leaching whereas free chlorine variation revealed no particular trend. Overall, water samples in PE pipes exhibited the highest number of plastic particles, followed by PPR and PVC, respectively.

SDEWES2022.0234

The Water-Hydrogen-NEXUS Beyond H2: Opportunities for Expanded Value Creation Through New Technologies for Countries with Water Stress Using the Example of Jordan

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Abstract

Hydrogen and, in particular, green hydrogen belong to recently debated topics in the field of energy. Discussions, amongst others, focus on i) the “colours” or types of hydrogen, ii) hydrogen applications in sectors such as industry or mobility, iii) electrolysis technologies, which allow hydrogen to be produced from water and electricity, iv) synthesis processes to form hydrogen-based liquids (e.g. synthetic kerosene, methanol etc.), v) hydrogen partnerships and trade opportunities, and vi) framework conditions for a hydrogen market ramp-up.

Research, which can be classified as addressing the water-hydrogen-nexus, mostly investigates upon the water used in so-called Power-to-X (PtX) technologies, likewise factoring in water needs of electricity production to run electrolyzers. Apart from that realm, where water is seen as a feedstock for hydrogen, there are other highly interesting relations between these sectors. For instance, electrolyzers produce hydrogen and oxygen as by-products. While hydrogen has the potential to reduce remarkably GHG emissions, oxygen is likely to serve specific purposes in the wastewater treatment sector.

This research paper seeks to unveil and map the broader relations between (waste-)water and hydrogen by carrying out desk research concentrating on green PtX and sustainable biogas. It aims to derive challenges attached with realizing the synergies. Furthermore, it discusses findings for a specific country context. As Jordan is water stressed, while having excellent potentials for renewable energies, the country may serve as an illustrative example for a reflection of the findings. Based on a stakeholder dialogue project between Germany and Jordan, funded by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection, first ideas for the field will be presented.

SDEWES2022.0255

Chitosan/xylan-Coated Magnetite for the Removal of Emerging Contaminants

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Abstract

Emerging contaminants are a class of pollutants that were recently discovered to pose health risks to humans and living organisms over prolonged exposure times with no satisfactory regulatory framework to control their levels in water bodies. Our work investigates the removal of such contaminants from aqueous solutions by a biopolymer-based adsorbent constituting a chitosan/xylan composite coating magnetite nanoparticles to ease the separation from water by a magnetic field after the adsorption process. Characterization of the prepared nanocomposite using Fourier Transform Infra-Red Spectroscopy (FTIR), X-Ray Diffraction (XRD), Thermogravimetric analysis (TGA), Brunauer-Emmett-Teller (BET), Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM) and Dynamic Light Scattering (DLS) showed successful binding of chitosan to xylan via Schiff-base mechanism, and their coating over magnetite to yield thermally-stable mesoporous nanoparticles with a slightly negative to neutral charge. The nanoparticles were tested on the heavy metal, Pb (II) and the pharmaceutical contaminant, salicylic acid (SA), and they successfully removed above 60% when 6 g/L adsorbent dose was applied on 50 ppm of Pb²⁺ and the negatively-charged SA. Adsorption followed Freundlich isotherm for both contaminants, and it took place mainly via chemical interactions in case of Pb (II) and physical interactions in case of SA. This demonstrates the promising potential of these nanoparticles to capture a variety of species regardless of their charge, due to their multiple adsorption mechanisms.

SDEWES2022.0261

Technoeconomic Analysis of Utilising Wastewater Excess Heat for Sludge-Drying in Municipal Wastewater Treatment Plants

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Abstract

Heat reclamation plays a substantial role in converting a wastewater treatment plant into a resource recovery plant. Besides the energy content of the influent organic matter and the produced excess sludge, the wastewater stream itself carries low-grade heat that can be recovered employing heat pumps. In winter, the thermal energy can be utilised either in district heating or locally to heat offices and auxiliary buildings and for domestic hot water production. On the other hand, in summer only the latter is needed.

Another issue in a wastewater treatment plant of any size is the treatment of the excess sludge produced in the biological processes. Micropollutants and microplastics tend to accumulate in the sludge; thus, using wastewater sludge as fertiliser is not without risks. In addition, due to the high water content, the sludge has to be dried before using in incineration or pyrolysis, requiring substantial energy, hence reducing the probability of both processes.

In this paper, the option of using the excess heat of the treated wastewater for sludge-drying is considered. The necessary heat-pump capacity and layout are designed for wastewater treatment plants of different sizes with or without primary settler and anaerobic digester. Options to provide the necessary electricity for the operation and management of resulting dry biomass are also evaluated. The feasibility of the methods is evaluated by performing a net present value and payback time calculation. In addition, the cost-benefit ratios are determined to show whether and how many times the discounted amount of the initial investment and operating expenses are recovered from the discounted amount of revenues and residual value over the entire life of the investment.

SDEWES2022.0268**Integrated Water, Energy, Food Analysis: the Times Land-WeF Model for Modeling the Agricultural System in the Basilicata Region (Southern Italy)**

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Abstract

Agriculture plays a crucial role in achieving many of the sustainable development goals thanks to its multifunctional role (e.g. food and energy security, preservation of biodiversity, resilience of territories). It is also one of the sectors most affected by the impacts of climate change. The occurrence of extreme weather events, thermal stress, water scarcity and soil degradation can cause irreversible damage to the entire agri-food system and affect its productivity. As also underlined by the Farm to Fork strategy of the EU Green Deal, a substantial transformation of agriculture over the next decade is required to support climate neutrality and to make the agri-food system fair, healthy and environmentally friendly. An integrated modelling approach is therefore required to exploit synergies and trade-offs among variables and design effective policy strategies. This paper aims to propose a methodological framework based on the integration of the Nexus approach, which focuses on the interactions between energy, water, food and climate and addresses them as a comprehensive system ruled by complex interrelationships. These are represented by the IEA-TIMES modelling framework based on scenario analysis.

The TIMES Land-WEF model is a land use-driven model based on the IEA-TIMES paradigm where land availability, the main driving parameter, is linked to input/output commodities through agricultural activities. This modelling approach allows evaluating directly the effects of climate change and energy-environmental policies in terms of energy, water, land use and agricultural productivity, emphasising the synergies among these different components.

The TIMES Land-WEF model analyses the agricultural system of the Basilicata Region (Southern Italy) in a 50-year time horizon, from 2010 to 2060. The scenario analysis focuses on the comparison of the BAU scenario (evolution of the agricultural system over the time horizon based on the statistics projections) and two scenarios, PEST_50 and FERT_20, modelling the Farm to Fork strategy objectives, i.e., 50% reduction in the use of chemical pesticides, 20% reduction in the use of fertilizers, achievement of at least 25% of organic agricultural land by 2030.

The results of the scenario analysis show the effects of the policy constraints in terms of the breakdown of land use between conventional and organic productions, suitable crops, energy and water consumption environmental impacts.

SDEWES2022.0272

Thermal Desalination from Rejected Heat of a Transcritical Cycle Working with a CO₂-Based Mixture for CSP Application: a Focus on the Med Technology

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Abstract

Concentrated Solar Power (CSP) technology typically finds application in hot and arid regions, where the electric energy demand often meets water scarcity. For this reason, this work deals with the integration of an innovative transcritical CO₂-based power cycle in a CSP plant with a thermal desalination system (CSP+D) for drinking water production.

Transcritical cycles adopting CO₂-mixtures have been studied in the literature as valid alternatives to sCO₂ power cycles to reduce the cost of electricity of CSP plants, with a potential benefit where the cycle minimum temperature is set above 50°C due to climate conditions. The heat that in standard operating conditions would be released from the power cycle to the ambient with an air-cooled condenser (where the mixture is typically condensed from up to 90°C down to the minimum cycle temperature) can be exploited in a thermal desalination process, as in a multi-effect distillation system (MED), avoiding the consumption of the condenser fans and providing fresh water as an additional output of the system.

This solution is applied to a 100 MW_{el} solar tower CSP plant located in Sevilla: both the power cycle and the desalination system are modelled in Aspen Plus. Various cycle layouts working with the CO₂+C₆F₆ mixture and the state-of-the-art recompressed sCO₂ cycle are investigated considering 550°C and 51°C as maximum and minimum cycle temperatures. The MED layout is parallel-feed, with sensible pre-heaters and intermediate evaporation stages, exploiting a variable number of effects from 3 to 8. An intermediate closed loop of demineralized water decouples the systems by absorbing all the thermal power available by the heat rejection unit and releasing it to the MED unit. Annual performances are calculated in terms of levelized cost of electricity (LCOE) and levelized cost of water (LCOW) of the combined CSP+D plant.

The proposed integration between high minimum-temperature power cycles and the MED technology presents promising results: the entire heat released from the cycle can be recovered by the desalination plant, while the thermal consumption varies from 250 to 120 kWh/m³ of fresh water, depending on the number of effects, with LCOW in the range from 3 to 1.5 \$/m³. Finally, the LCOE of the configurations working with the mixture is around 5 \$/MWh lower than the pure sCO₂ plant.

SDEWES2022.0420**Energy, Economic and Sensitive Analysis of Mechanical Vapor Recompression (Mvr) Desalination System in Various Climates and Conditions**H. Kariman¹, S. Hoseinzadeh^{*2}, A. Shirkhani³, B. Nastasi², D. Astiaso Garcia²¹School of Engineering, Edith Cowan University, Australia; ²Sapienza University of Rome, Italy; ³University of Tehran, Iran (*siamak.hosseinzadeh@uniroma1.it)**Abstract**

Many countries and regions are currently facing water shortages, which is restricting their survival and further development. Desalination systems play a crucial role in supplying fresh water in many regions. The costs of different seawater desalination technologies are various and important. Large-scale desalination systems have problems, such as high investment and maintenance costs and water transfer costs to target areas, for these reasons small-scale desalination plants play an important role. In this study, the possibility of using mechanical vapour recompression (MVR) and easy multi effect desalination (MED) systems in different cities (Perth in Australia, Las Palmas in Spain, Pantelleria in Italy, Abu Dhabi in UAE, and Hormozgan in Iran) in various regions of the world have been examined and the economic analysis of these systems has been investigated. Both of these systems are small-scale domestic desalination systems with high efficiency, suitable energy consumption, scattered freshwater production, and less pollution that have not been done much research related to them; especially economic analysis and feasibility of using these systems in various areas have not been done so far. The results showed that the MVR system in all cities has a higher annual total cost than the easy MED system, while the easy MED system in all cities has a higher fresh water cost than the MVR system. Also, the total annual cost of the MVR system in Pantelleria is 18,911 €/yr, which is the highest in all cities. And the most economical city for both systems is Perth, which has fresh water cost of 6.86 €/m³ and 12.95 €/m³ for MVR and easy MED systems, respectively.

SDEWES2022.0465

Experimental Evaluation of Degradation Impact on the Performance of a Solar Still

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Abstract

The need for fresh water is increasing every day, whereas the sources that is getting limited more and more. This point, in addition to the economic and environmental issues of the conventional water desalination system highlight the importance of more economical and environmentally friendly desalination technologies, such as solar stills. Like all other energy systems, the performance of a solar still declines by passing the time, which the word “degradation” refers to. However, to the best of the authors’ knowledge, solar stills have been investigated in the literature by neglecting the degradation impact. Considering this point, the current study is done. Here, by taking advantage of the experiments that were being done for two years, the impact of passing the time on the performance degradation of a single slope solar still is studied. For the cumulative yield and efficiency, as the two main performance indicators of the system, the ratio of experimental to the simulated value is calculated and the monthly variation profiles are plotted and discussed in details, while a comparative study between the level of the performance decrement between the first and second years is also carried out.

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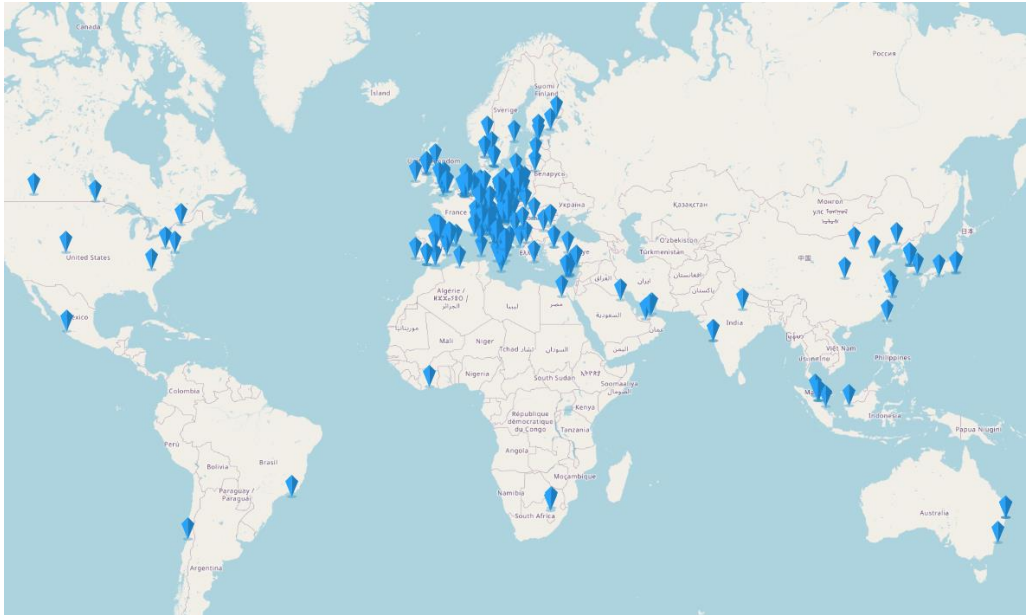
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