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ANALYSIS OF MOROCCO'S RENEWABLE ENERGY PRODUCTION AND TRANSMISSION POTENTIAL*

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Abstract. Alongside efforts to reduce carbon emissions, energy production and use took on new urgency last year, when Europe and other countries faced harsh realities regarding electricity availability and affordability; therefore, solutions are needed to avoid the consequences of the existing gas monopoly because electricity prices are directly correlated with gas prices. One possible alternative to solving this problem is to purchase sustainable electricity from countries with high potential to produce and sell electricity from renewable sources, such as Morocco. A detailed examination of the current situation and the mentioned potential above is required to find new solutions that can have significant political consequences. Publicly available secondary information and scientific literature were investigated to reflect the current situation; statistical information was collected and analyzed to find out the cases of energy transfer from Morocco to other countries; expert investigation was carried out to identify the specifics of problems related to renewable energy production and transmission to Europe. Actual cases of electricity transmission have been or are currently happening only between neighbouring countries Spain and Algeria. The electricity transmission with Algeria is interrupted due to political disagreements. Three future electricity transmission connections are planned: a substantial long-distance project - "Xlinks" with the UK; second, with Portugal, and discussions are underway regarding Mauritania. Morocco can become an essential actor by exporting electricity to Europe, considering its proximity to Spain and huge potential for solar and wind energy that can fulfil the needs of all of Europe. However, it is essential to pay attention; not only Europe but African countries are on the list of those who want to purchase Moroccan electricity.

Keywords: electricity; renewable energy; analysis of opportunities; specifics of production and transmission; Morocco

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Additional disciplines: ecology and environment; electricity electronic engineering; environmental engineering; energetics and thermo energetics.

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1. Introduction

Electricity affordability has taken on new relevance in the past year as European countries and elsewhere have faced the harsh reality of addressing energy availability and affordability issues. There is an urgent and more efficient transition to renewable sources. One possible alternative to solving this problem is to purchase sustainable electricity from countries with high potential to produce and sell electricity from renewable sources, such as Morocco. One of the significant steps in making strategic decisions is collecting necessary, reliable information to verify the imagined potential to produce and supply electricity to European countries.

An interdisciplinary/multidisciplinary approach may lead to novel solutions with significant policy implications. In the context of the war, innovative solutions stemming from the inter-sectoral cooperation of geographically remoted partners can become resilience drivers. Many authors (Kousksou et al., 2015; Šimelytė et al., 2016; Oxford Analytica, 2021; Jerome et al., 2019; Kasri et al., 2023; Charouif & Lehnert, 2024; Hajou et al., 2024; Leonard et al, 2024) have explored Morocco's renewable energy potential from various perspectives. However, this article assesses Morocco's current energy situation through an in-depth analysis of key renewable energy projects completed and under development in Morocco. It also focuses on planned, existing and past international electricity transmission cases to predict prospects. For the same purpose, an expert study was conducted to determine the reasons limiting the development of such international projects.

To find out the current situation of renewable energy production, use and trade in Morocco:

- to investigate publicly available secondary information and scientific literature to reflect the current situation on the production of electricity from renewable sources;
- to analyze the latest statistical information provided by the Moroccan Agency for Energy Efficiency to find out the cases of energy transfer from Morocco to other countries;
- to present the results of the expert investigation conducted to identify the specifics of problems related to renewable energy production and transmission.

2. Current situation and plans for renewable electricity generation in Morocco

Morocco still faces fundamental challenges – its geographical position in a warming hotspot makes it vulnerable to the impacts of climate change. Moreover, even as it seeks to end its dependence on fossil fuels, its energy demands are rising fast. While Morocco's emissions are small compared with those of many more developed nations, burning fossil fuels for energy and cement production is still a significant source of emissions in the country. Morocco still imports most of its energy to meet its rising energy consumption, which increased at an average annual rate of 6.5% between 2002 and 2015 (Alami, 2021). According to 2015 data, Morocco generated 98% of its electricity by burning fossil fuels and importing the missing electricity from Spain (Alami, 2021). Morocco relies particularly heavily on coal power, which it is expanding along with renewables, and now, around 40% of electricity in the country comes from coal (Alami, 2021).

However, the Moroccan authorities decided to be “a destination for renewable energy”. Morocco has used its geographical position and environment to gain an edge in renewables, especially solar energy (Mensour et al., 2019). Morocco's national action on climate change dates back to the mid-2000s when the country decided to become a regional leader in clean energy and to push forward massive renewables projects. In 2009, Morocco set out an ambitious energy plan to make 42% of total installed power capacity renewable by 2020. Ultimately, Morocco missed its 2020 target, with enough renewable capacity to produce 37% of its energy 2020. By 2023, Morocco will reach the 42% target set for 2020, a delay caused by the pandemic (Fernández, 2023). It has a total installed generating capacity of about 11 000 MW and 4 030 MW of renewables. An additional 4 516 MW of renewables is under construction or planned (King, 2022; MASEN, n.d.).

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Morocco has since pledged to increase the renewables in its electricity mix to 52% by 2030, comprising 20% solar, 20% wind, and 12% hydro. The Kingdom expects that by 2030, it will more than meet its targets, exceeding 64% green production of its total energy. The Minister of Energy Transition and Sustainable Development, Leila Benali, announced the announcement during an appearance at a plenary session of the House of Representatives of the Moroccan Parliament. The minister explained that there are currently 61 projects underway with a total investment of around 550 million dollars (Fernández, 2023).

According to Professor Mohammed Bennouna, interviewed by Hespress FR, the country's development and, therefore, all energy-related projects were developed according to 2008 studies, which indicated that the Kingdom would need a capacity of 24,000 GW to reach the 52% target. However, recent studies have shown that only 16,000 GW will be required by 2030, so the target is not closer; this situation will allow Morocco to be more ambitious in its quest for less dependence on hydrocarbons such as oil and coal.

According to some sources, Morocco seeks to generate 80% of its electricity from renewable energy resources by 2050 (Anouar, 2022; King, 2022). The minister explained that there are currently 61 projects underway with a total investment of around 550 million dollars (Fernández, 2023).

The government has achieved almost complete access to electricity for its rural population and is developing the country's significant renewable energy resources. However, progress in reducing the energy intensity of Morocco's economy is more challenging to achieve. While the share of renewables in electricity is progressing fast, its share in total final consumption decreased considerably over the past decade, given the expanding energy demand. Morocco has only renewable energy targets for electricity. The government is encouraged to set targets for modern renewables in residential and transport; this will strongly promote reducing fossil fuel use across the economy. As Morocco continues to rely on coal, oil, and gas imports for most of its energy needs, opportunities abound to reduce imports by developing domestic energy resources to reduce oil and coal use (IEA, 2023a).

Initiated in 2009, the Moroccan Solar Plan is very ambitious. Many solar power plants have been planned and scheduled to be installed to implement this plan. The Moroccan Agency for Solar Energy (MASEN) was set up to execute these projects in 2010. Its mission is to implement all projects related to the National Energy Strategy and to coordinate and supervise all other activities connected with this initiative (Boulakhbar et al., 2020). This organization, the central player in this national strategy, is in charge, alongside the National Office of Electricity and Potable Water (ONEE), of implementing the Royal vision for renewable energy.

ONEE is currently the major player in Morocco's electricity market; it is the sole purchaser responsible for power imports and exports and purchasing electricity generated by independent power producers (IPPs), surplus electricity from self-generators and all renewable electricity production from MASEN projects. ONEE holds longterm power purchase agreements (PPAs) with these entities. ONEE also owns generation plants, including coal, gas and wind (which will be transferred to MASEN by 2021). ONEE's own generation market share has decreased with the growth of renewable energy projects developed by MASEN. Otherwise, under Law 38-16, ONEE has to transfer all renewable energy generation assets within five years to MASEN (except pump storage hydro plants, plants critical for the national electricity supply security and plants under Law 13-09). In terms of market shares in 2016, ONEE supplied power to the national market from its own plants (29.2%) and through independent power producers (52.9%) and imports (14.6%), with power from private industrial producers accounting for the remainder (3.3%).

Masen generates clean electricity through integrated renewable energy projects to make the best possible use of solar, wind and hydraulics relevant to the country. The distribution of solar power generation projects in Morocco can be divided into four zones: Noor Midelt, Noor Quarzazate, Noor Laayoune, and Noor Boujdour. The average

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incident solar radiation varies between 4.7 and 5.6 kWh/m2/day with a number of hours of sunshine that varies from 2700 hours/year in the North of Morocco to more than 3500 hours/year in the South. All projects known to the authors are presented in 1-3 Tables.

Table 1. Solar energy projects, including private projects and projects under study

Solar Energy Project Name/Location		**Installed Power: MW**		**Surface Area: Ha**	**Commi -ssioned**	**Technology Used**
AIN BENI MATHAR - Ain Beni Mathar		450-470		160	2010	CSP With Combined Cycle/ Integrated Solar Combined Cycle
NOOR Tafilalt	ERFOUD - Erfoud	120	40	-	2019	PV
	ZAGORA - Zagora		40	-	2019	PV
	MISSOUR – Missour		40	-	2019	PV
NOOR MIDELT I - Midelt		800		939	2022	CSP+PV
NOOR OUARZAZATE I, Ouarzazate		160		480	2016	CSP, with a thermal storage of about 3 h
NOOR OUARZAZATE II, Ouarzazate Drâa-Tafilalet		200		610	2018	Dry cooling CSP, with a thermal storage capacity of more than 7 h
NOOR OUARZAZATE III, Ouarzazate		150		582	2018	Dry cooling CSP, with a thermal storage capacity of more than 7 h
NOOR OUARZAZATE IV, Ouarzazate		72		137	2018	Polycrystallin PV with tracking system
Noor Atlas (260MW)	Ain Beni Mathar	42		-	-	PV
	BOUDNIB - Errachidia	36		-	-	PV
	NOOR BOUANANE - Bouarafa	30		-	-	PV
	NOOR ENJIL - Boulmane	42		-	-	PV
	Outat El-Haj	36		-	-	PV
	NOOR TATA - Tata	36		-	-	PV
	NOOR TANTAN – Tan-Tan	36		-	-	PV
NOOR LAAYOUNE I - Laâyoune		85		240	2018	Polycrystallin PV with tracking system
NOOR BOUJDOUR I - Boujdour		20		60	2018	Polycrystallin PV with tracking system
Noor PV II (400 MW)	NOOR BOUJDOUR II - Boujdour	-		1690	-	PV
	NOOR LAAYOUN II - Laâyoune	-		1330	-	PV
	AIN BENI MATHAR - Ain Beni Mathar	184		-	-	PV
	Sidi Bennour	48		-	2023	PV
	BEJAAD – Bajaad	48		400	-	PV
	TAROUDANT - Taroudant	36		393	-	PV
	OUTAT EL HAJ - Outat El Haj	36		-	-	PV
	GUERCIF - Guercif	-		400	-	PV
	KELÂA DES SRAGHNA - Kelâa Des Sraghna	48		473	-	PV
	NOOR EL HAJEB – EL Hajeb	36		212	2024	PV
	NOOR LAKHTATBA - Lakhtatba	-		300	-	PV
	Noor Midelt Solar PV Park 1	210		-	2024	PV

Source: (Power Technology, n.d.; MASEN, n.d.)

Two technologies are used to produce solar energy:

- CSP (Concentrated Solar Power) technology captures the sun's rays using flat and curved mirrors and then concentrates them on a receiver that contains heat transfer fluid. This technology provides a good storage capacity, which helps meet the specific needs of the Moroccan grid.

- PV (photovoltic) technology generates electricity directly from solar rays captured by semiconductor cells. This technology's maturity in a rapidly growing market makes it a very competitive solution for Morocco.

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Wind energy is currently considered one of the most critical energy sources among the other renewable sources; it's fastest growing, commercially attractive source and is commonly used to generate electrical energy because of the mature and cost-effective energy conversation system technology (El Khchine et al., 2019). The Moroccan government has a strategy for developing renewable energies and energy efficiency. According to its energy strategy, the Moroccan government supports the development of renewable energies and their energy efficiency. According to statistics, Morocco's energy demand is rapidly increasing due to economic and demographic growth and is expected to triple by 2030.

Morocco has good climatic and geographic conditions for installing wind turbines, with 17 regions selected for their use in wind power generation. Morocco has 3500 km of coastline, which means wind speeds can reach up to 10 m/s. Therefore, the estimated total theoretical potential of wind power in Morocco is 25 GW. Table 2 shows the Moroccan wind energy generation projects known to the authors.

Table 2. Wind energy projects, including private projects and projects under study

Wind energy projets	**Installed Power: MW**	**Surface area: ha**	**Commi -ssioned**	**Technology used**
HAOUMA wind farm	50.6	-	2013	22 wind turbines. This project falls within the framework of Law 13-09
TANGER I wind farm - Béni Mejmel	140	500	2011	165 wind turbines
TANGER II wind farm - Dhar Sadane Farm (PEI 850 MW)	70	563	Planned 2024	39 wind turbines
Jbel KHELLADI wind farm - Ksar Sghir	120	-	2018	40 wind turbines, this project falls within the framework of Law 13-09
AL KOUDIA AL BAIDA (Abdelkhalek Torrès Farm) I	53.9 – 120 by 2020	270 230	Phase 1: 2000 - 2001	84 ~ wind turbines
AL KOUDIA AL BAIDA (Abdelkhalek Torrès Farm) II	Repowering 120-200	-	Phase 2: 2022 – 2024, under construction	5 ~ wind turbines
LAFARGE wind farm - Tétouan	32	-	2010	This autoproduction project falls within the framework of Law 54-14
TAZA wind farm – IPE Phase I (150 MW) - Taza	150	800	2022 – 2025, under construction	45 wind turbines
MIDELT - IPE (850 MW) - Midelt	180 - 210 - 850	2230	2020	48 wind turbines
AMOGDOUL ESSAOUIRA wind farm - 15 Km South ESSAOUIRA	60	1600	2007	71 wind turbines
JBEL LAHDID wind farm- IPE (850 MW) - Essaouira	200 - 270	2404	2021 – 2023, under construction	61 wind turbines
AKHFENNIR wind farm - TARFAYA province Laayoune	101,87 MW	-	2014	61 wind turbines
AKHFENNIR II wind farm - AKHFENIR (extension)	101.87 MW	-	2016	61 wind turbines
AKHFENNIR III wind farm - Laayoune Sakia El Hamra	50 MW	-	Planned 2023, under construction	-
TARFAYA wind farm - 15 km South Tarfaya	301	8900	2014	131 wind turbines
CIMAR - Laâyoune	5	-	2012	This autoproduction project falls within the framework of Law 54-14

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Wind energy projets	**Installed Power: MW**	**Surface area: ha**	**Commi -ssioned**	**Technology used**
FOUM EL OUED - Laâyoune	50	-	2013	22 wind turbines. This project falls within the framework of Law 13-09
Wind Farm AFTISSAT I - Boujdour	200	-	2018	56 Siemens turbines, this project falls within the framework of Law 13-09
Wind Farm AFTISSAT II - Laayoune - Sakia El Hamra	200	-	2022	67 turbines GE Energy
Boujdour - IPE (850 MW) - Boujdour	300 – 850	12485	2021	30 wind turbines
The Xlinks, Guelmim-Oued Noun	3500	-	2028	It will be powered by wind and solar
DAKHLA Wind Farm – (Dakhla Wind Farm-IB	900	-	2027	-
DAKHLA Wind Farm (Dakhla Wind Farm-II)				
DAKHLA Wind Farm (Dakhla Wind Farm-III)				
BIRANZARANE wind farm - 70 km north of DAKHLA	200	-	Planed 2024, under construction	-
TISKRAD wind farm (850 MW) - Laayoune	100	2618	Under construction, expected in 2024	93 wind turbines
GHRAD JRAD wind farm – Laayoune -Sakia El Hamra	80	-	Under construction, expected in 2024	-
CAP CANTIN wind farm – MARRAKECH - SAFI	108	-	Under construction, planned 2024.	-
AM WIND wind farm - DAKHLA	100	-	Under construction, planed 2023	-
FERKAT wind farm - Region de GUELMIM	80	-	Under construction, planed 2023	-
OUALIDIA I wind farm	18	-	2021	-
FOUM EL OUED wind farm	50,6	-	2013	22 wind turbines

IPE - Integrated Wind Project

Source: (Power Technology, n.d.; MASEN, n.d.; The Wind Power, n.d.)

The Moroccan government has prioritized the growth of the renewable energy sector by enhancing the regulatory framework. The Ministry of Energy Transition and Sustainable Development has recently amended Law 13-09 on Renewable Energy, Law 82-21 on self-production of electrical energy, as well as Law 48-15 on the regulation of the electricity sector and the creation of the ANRE (National Agency of Electricity Regulation). These amendments aim to improve the legislative and regulatory framework governing renewable energy projects by the private sector while guaranteeing the security and viability of the national electricity system (International Trade Administration, 2024).

With an installed capacity of about 1770 MW, hydropower plays a key role in Morocco's energy mix, contributing 22% of its power generation. Morocco has long opted for the development of electric power dams. Indeed, King Hassan II had called for a new dam to be built every year. Today, Morocco is home to 26 hydropower stations, totalling 1360 MW in capacity, including Al Wahda, the second-largest dam in Africa. A 460-MW pumped-storage facility in Afourer near Beni-Mellal complements Morocco's hydropower system. As part of Morocco's new energy development roadmap in 2008, authorities were looking to add 580 MW in hydropower capacity by 2020 through several engineering, procurement, and construction development projects. The flagship project is

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developing a 350 MW pumped-storage power plant in Abdelmoumen, commissioned in 2020. The second major project is the development of a 170-MW dam in Mdez-El Menzel. Simultaneously, authorities have been looking to bolster private investments to develop new greenfield small to medium-scale hydropower plants under the scope of the renewable energy law. ONEE identified 200 sites that could contribute to isolated areas' energy needs. To facilitate the implementation of these hydropower projects, authorities amended Law No. 13-09 in September 2015 by lifting the legal cap on private-driven dam development from 12 MW to 30 MW. As a result, in 2015, Moroccan company Platinum Power – whose reference shareholder is US private equity fund Brookestone Partners – was awarded IPP licenses for five hydroelectric projects, totalling a projected combined capacity of 120 MW. The company launched tenders to construct the power stations, the cost of which has been estimated at $318m (€286m). Similarly, French renewable company Voltalia signed its first deal in 2015, consisting of the construction of several hydropower plants for a cumulated capacity of 40 MW. In 2015, ONEE launched a tendering procedure for the rehabilitation of 12 small and medium-sized hydropower plants (Oxford business group, 2016).

Table 3. Hydroenergy projects, including private projects and projects under study

Hydro energy projects	**Installed power: MW**	**Surface area: ha**	**Commi -ssioned**	**Technology used:**
MOHAMMED V - Nador	23	0.15	1967	1 turbine
BOUAREG - Berkane	6.4	-	1969	1 turbine
ALLAL EL FASSI - Taounate	240	2.1	1994	3 turbines
IDRISSI I - Taounate	41	0.45	1973	2 turbines
AL WAHDA - Ouezzane	240	0.32	1998	3 turbines
TAZA - Taza	0.6	-	1929	2 turbines
LAU -TALAMBOT - Chefchaouen	14.1	-	1942	4 turbines
STEP IFAHSA - Chefchaouen	300	-	2026	-
TAURART - Chefchaouen	2	-	1951	2 turbines
FEZ - Fez	3.1	-	1934	5 turbines
EL MENZEL - Séfrou	95	-	-	-
SEFROU - Séfrou	0.6	-	1994	-
STEP EL MENZEL II - Séfrou	300	-	2026	-
IMEZDILFANE/TASKDERT/TAJEMOUT - Khénifra	128	-	2025	-
TANAFNIT-EL BORJ - Khénifra	40	106	2010	4 turbines
MAACHOU - El-Jadida	20.8	-	1929	4 turbines
AHMED EL HANSALI - Kasba Tadla	92	1.2	2003	1 turbine
AIT MESSOUD - Kasba Tadla	6	0.66	2003	2 turbines
AFOURER - Béni Mellal	94	2.5	1953	2 turbines
STEP AFOURER - Béni Mellal	464	2.5	2005	4 turbines
BINE EL OUIDANE - Béni Mellal	135	12.3	1953	3 turbines
ZIDANIA - Béni Mellal	7.1	-	1936	2 turbines
HASSAN I - Azilal	67	70	1991	1 turbine
MOULEY YOUSSEF - Kelâa Des Sraghna	24	1	1974	2 turbines
AGDEZ - Ouarzazate	20	-	2023	-
MANSOUR DAHBI - Ouarzazate	10	0.35	1973	2 turbines
AL MASSIRA - Settat	128	9	1980	2 turbines
DAOURAT - Settat	17	5	1950	2 turbines
IMFOUT - Settat	31.2 MW	5	1947 - 1949	2 turbines
LALLA TAKERKOUST - Marrakech	12 MW	7.22	1934	2 turbines
STEP ABDELMOUMEN - Taroudant	350 MW	-	2022	-
BOUFEKRANE - Meknès	0.6 MW	-	1925	3 turbines
MAASSER - Meknès	0.1 MW	-	2008	-
OUED EL MAKHAZINE - Ksar El Kébir	36 MW	0.5	1979	1 turbine
EL KANSARA - Sidi Slimane	14 MW	0.2	1935	2 turbines

Source: (Power Technology, n.d.; MASEN, n.d.)

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Over the years, hydropower has remained a significant piece of Morocco's renewables equation as a major pollution-reducing tool. As authorities and local businesses have been keen to develop stock energies further, administrative procedures have also been simplified to accelerate the development of hydropower plants. This action should support further growth in this critical field.

3. The current situation and plans for electricity transmission from Morocco to other countries

The Sahara has a lot of land and sun, making it an appealing place to site massive solar generating stations, and the Kingdom of Morocco is doing just that. Add substantial wind resources inland and on the coast, and Morocco looks set to fulfil its declared intention of satisfying its own demands and becoming a regional exporter to North Africa and Europe. Morocco is positioning itself as a clean energy hub with the potential to export renewable power to Europe. It already has two electricity cables connecting it to Spain and plans for a subsea connection to the UK (Alami, 2021).

Morocco can become an essential actor in exporting renewable electricity to a large regional market by exporting green electricity to Europe, considering its proximity to Spain. In this regard, several EU countries have interestingly implemented a "Roadmap for Sustainable Electricity Trade" (SET Roadmap) and signed an official declaration during the COP22 with Morocco. In this perspective, Morocco has already achieved significant electricity interconnection capacities with Spain (1,400 MW). The interconnection with Spain is the unique link between Europe and North Africa (Figure 1). Morocco is also interconnected with Algeria, with an exchange capacity of 1,200 MW. However, in 2021, Algeria decided unilaterally to cut diplomatic ties with Morocco, which also affected the termination of electricity exchange. Table 4 presents the quantities of Morocco's international exchange of electricity.

The African market is up-and-coming since it is relatively poorly electrified and represents real investment opportunities for future years (Boulakhbar et al., 2020) in Sub-Saharan Africa, which accounts for 80% of people lacking electricity access (IEA, 2023a, 2023b).

Table 4. International electricity exchanges

Electricity indicators	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Exchanges with Spain, GWh	5 833,697	4 926,117	4 950,124	5 747,323	3 778,387	-837,984	293,378	-178,793	1 396,882
Exchanges with Algeria, GWh	176,537	47,408	203,979	149,110	-3,945	-89,645	-61,067	-15.793	-
Electricity production, GWh	33 529,614	34 413,148	35 414,527	37 216,652	37 446,116	38 852,570	38 754,532	41 259,792	41 420,371

Source: Information provided by Moroccan Agency for Energy Efficiency (ONEE, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022)

The African market is up-and-coming since it is relatively poorly electrified and represents real investment opportunities for future years (Boulakhbar et al., 2020) in Sub-Saharan Africa, which accounts for 80% of people lacking electricity access (IEA, 2023a, 2023b). Currently, Morocco continues the process of regional integration of energy markets. Firstly, the country has a project to establish an electrical interconnection line to Portugal with a capacity of 1,000 MW. Morocco is also planning to expand the interconnection with Spain by a third line with a capacity of 700 MW (Figure 1).

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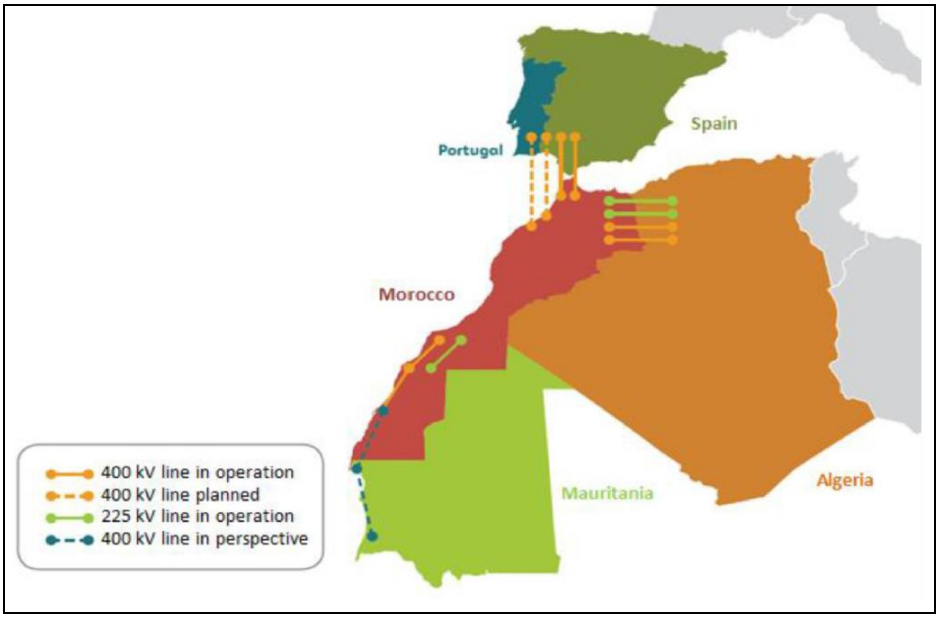

Figure 1. Morocco's regional and international electricity connections
Source: (Boulakhbar et al., 2020)

Already in 2022, Morocco's Energy Transition Minister Leila Benali told Forbes that Morocco could export more of its power from renewables to Spain, Portugal, and even the United Kingdom. Currently, there are two electricity interconnections with Europe, and a third is planned. The capacity of the interconnections is 1,400 MW, and power flows both ways, depending on generating and market conditions in Europe and Morocco (King, 2022).

Discussions are under way to establish new interconnection lines with Mauritania (Boulakhbar et al., 2020).

An ambitious project, Xlinks, is under consideration to develop a new 3 GW submarine cable linking Morocco to the UK, allowing green electricity to be sent directly to the UK without using existing infrastructure in Spain and France. The project will generate 6% of the UK's electricity demand (Boulakhbar et al., 2020).

The Xlinks project seeks to broaden Morocco’s renewables export market to the UK. The Xlinks Morocco-UK Wind Project is a 3,500MW onshore wind power project in Guelmim-Oued Noun, Morocco. It is currently in the permitting stage and is expected to enter commercial operation in 2028 (Power Technology, 2023).

The Morocco – UK Power Project will be powered by a wind and solar farm within Morocco's Guelmim Oued Noun region. The wind farm will utilize the reliable Trade Winds in the area, driven by the temperature differential between the Atlantic Ocean and the African continent. The windspeed at the generation site increases throughout the late afternoon and evening, ensuring power can be delivered to Britain during peak demand.

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Figure 2. Morocco – UK Power Project Xlinks: visualization of the cable systems that will follow the shallow water route from the Moroccan site to a grid location in Great Britain.
Source: (North Africa Post, 2024)

The solar photovoltaic (PV) farm will track the sun from east to west throughout the day. This technology will maximize the solar farm's output and increase the output early in the morning and late in the afternoon, providing Britain with the most consistent generation profile. Although the project will benefit from the most advanced solar panel designs, they will work the same way as the ones installed on people's houses throughout the UK and existing generation sites within Morocco. However, the increased solar resource means that the same PV panels generate approximately three times more power in Morocco than they would in the UK. Notably, the solar panels will generate as much as five times more energy from January to March than those in the UK, which will help to keep the lights on and homes warm in Britain throughout the coldest winter days.

Four 4000km long cables form the twin 1.8GW HVDC subsea cable systems, which will follow the shallow water route from the Moroccan site to a grid location in Great Britain, passing Spain, Portugal, and France (Xlinks, n.d.).

3. The specifics of problems related to renewable energy production and transmission

An expert investigation was conducted to understand the specifics and extent of the problems related to the production, use, and trade of electrical energy in Morocco from 2023 December 4 until 2024 February 9. The aim of the first stage of research was to create a framework of factors/problems and answer the question: What factors/problems influence the transmission of electricity from one country to another, in this case, from Morocco to Europe?

Experts with at least ten years of experience in electro-energetics were selected for the investigation. Three experts were from the academic environment - professors of Moroccan universities: the Cadi Ayyad University, Faculty of Sciences Semlalia (Marrakesh) and the Sidi Mohamed Ben Abdellah University, Higher School of

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Technology (Fez); eight experts - employees of the Ministry of Energy Transition and Sustainable Development Department of Sustainable Development, Moroccan Agency for Energy Efficiency participating in different ways in the formation of the Moroccan energy strategy and making strategic decisions. To ensure the accuracy of the data, the experts were given a questionnaire in English and French and asked to express their opinions by naming the factors/problems promoting or limiting the production and transmission of electrical energy.

Table 5. Results of expert research

No	Factor name	Expert answers											Points
		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	
1.	**Factors group: situation on the market**												
1.1.	- the amount of electrical energy demand	•	•	•	•	•	•	•	•	•	•	•	11
1.2.	- intensity of competition: how many potential electricity suppliers are there?	•	•	•	•	•	•	•	•	•	•	•	11
1.3.	- percentage of the energy produced from fossil	•								•			2
1.4	- expansion of industrialization	•								•			2
1.5.	- the presence of other sources of energy that are more economical, flexible and easily mobilized (regularity of supply)		•				•					•	3
2.	**Factors group: financial environment**												
2.1.	- costs of infrastructure creation for transfer of energy	•	•	•	•	•	•	•	•	•	•	•	11
2.2.	- price of a unit of electricity (LCOE)	•	•	•	•	•	•	•	•	•	•	•	11
2.3.	- price energy from other sources	•								•			2
2.4.	- return on investment (ROI)	•								•			2
2.5.	- period of recovery of the investment	•								•			2
2.6.	- the presence of incentive measures in favour of renewable energies		•				•					•	3
											•		1
3.	**Factors group: technological features**												
3.1.	- electricity transmission distance	•	•	•	•	•	•	•	•	•	•	•	11
3.2.	- the quality of energy				•				•				2
3.3.	- electricity transmission possibilities depending on geographical / climate conditions/intermittency of energy conversion	•	•	•	•	•	•	•	•	•	•	•	11
3.4.	- direct normal irradiance (DNI) for solar technologies	•								•			2
3.5.	- availability of infrastructure/ quality of the national power grid		•			•	•					•	4
3.6.	- technical mastery: level of mastery of technology, presence of spare parts, possibility of repair in the event of a breakdown		•				•			•		•	4
3.7.	- type of energy transport (continuous or alternating)				•				•				2
3.8.	- automatic solutions for fast defect management and long-term grid forecasting					•							1
3.9.	- electricity interconnection infrastructures at the regional and international level to mitigate the variations in electricity intermittent sources					•							1
3.10.	- energy storage technological possibilities					•				•			2
4.	**Factors group: legal environment**												
4.1.	- benevolence of national legislation for electricity transmission possibilities	•	•	•	•	•	•	•	•	•	•	•	11
4.2.	- national legislation adapted to the legislation of partner countries/- the difference between standards in the field of energy		•		•		•		•			•	5
4.3.	- legislative framework governing the marketing of electrical energy		•				•					•	3
5.	**Factors group: political environment**												
5.1.	- interstate relations	•	•	•	•	•	•	•	•	•	•	•	11
5.2.	- political stability of the host country of renewable energy	•	•				•			•		•	5
5.3.	- adherence of the country to international agreements and conventions relating to environmental issues and especially to the energy sector		•				•					•	3
5.4.	- strategic directions of the country		•				•					•	3

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No	Factor name	Expert answers											Points
		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	
6.	**Factors group: social, natural conditions and environmental protection environment**												
6.1.	- availability of labour to work in the field of energy conversion and electricity transmission, availability of qualified personnel	•	•				•			•		•	5
6.2	- carbon dioxide release rate				•				•				2
6.3.	- level of solar, wind or hydroenergy complementarity that can fulfil potential needs	•								•			2
6.4.	- management quality of the electricity sector of the supplying country					•							1

The next stage of the research, using the results of the first stage, will be aimed at excluding irrelevant factors/problems and determining their significance and meanings; however, this is a future research direction.
After summarizing the assessments of experts, it became clear that the most prevalent factors/problems influencing the production and transmission of electricity to another country are:
- the amount of electrical energy demand;
- intensity of competition;
- costs of infrastructure creation for transfer electro energy;
- price of a unit of electricity (LCOE);
- electricity transmission distance;
- electricity transmission possibilities depending on geographical / climate conditions/intermittency of energy conversion;
- benevolence of national legislation for electricity transmission possibilities;
- interstate relations.

The X1 expert's statement reflects the situation quite well: “The MENA region has huge solar energy potential that can fulfil the needs of Europe. Solar energy in the MENA region can satisfy half of the world's electricity needs and is very close to Europe.

Conclusions

Morocco has very ambitious plans. It seeks to generate 80% of its electricity from renewable energy resources by 2050; however, today, around 40% of electricity in the country comes from coal.

The Moroccan Agency for Solar Energy (MASEN) was established in 2010 to execute all renewable energy projects. This organization is the central player in this national strategy and is in charge of implementing the royal vision for renewable energy alongside the National Office of Electricity and Potable Water (ONEE).

It turned out that actual cases of electricity transmission have been or are currently happening only between neighbouring countries Spain and Algeria. The electricity transmission between Algeria and Morocco is interrupted due to political disagreements and a tense political situation. Three electricity transmission connections are planned for the future: first, the huge long-distance project “Xlinks” with the UK; second, with Portugal; and discussions are underway to establish new interconnection lines with Mauritania.

By exporting electricity to Europe, considering its proximity to Spain, Morocco has the potential to become an important actor. The African market is up-and-coming since it is relatively poorly electrified and represents real investment opportunities for future years. Sub-Saharan Africa accounts for 80% of people lacking electricity access. Therefore, according to one expert's observation regarding the huge potential of solar energy that can fulfil Europe's needs, we can confirm the huge renewable potential of solar and wind. Still, it is essential to note that a considerable demand exists, too.

An expert investigation was carried out to identify the essential factors/problems of electricity production and transmission and to understand the specifics and scale of problems related to renewable energy production, use and trade. The most prevalent factors/problems influencing the production and transmission of electricity to another country are: the amount of electrical energy demand, the intensity of competition; costs of infrastructure creation for transfer of energy; price of a unit of electricity; electricity transmission distance; electricity transmission possibilities depending on geographical / the climate conditions/intermittency of energy conversion; benevolence of national legislation for electricity transmission possibilities; interstate relations.

References

Alami, A. 2021. *How Morocco went big on solar energy*. Retrieved from https://www.bbc.com/future/article/20211115-how-morocco-led-the-world-on-clean-solar-energy

Anouar, S. 2022. *Morocco Has Invested $5.2 Billion in Solar Energy Projects*. Retrieved from https://www.moroccoworldnews.com/2022/08/350593/morocco-has-invested-5-2-billion-in-solar-energy-projects

Boulakhbar, M., Lebrouhi, B., Kousksou, T., Smouh, S., Jamil, A., Maaroufi, M., & Zazi, M. 2020. Towards a large-scale integration of renewable energies in Morocco. *Journal of Energy Storage*, *32*, 101806. https://doi.org/10.1016/j.est.2020.101806

Charouif, Y., & Lehnert, M. R. 2024. The offshore wind energy potential of Morocco: Optimal locations, cost analysis, and socioenvironmental examination. *Integrated Environmental Assessment and Management*, *20*(1), 201–210. https://doi.org/10.1002/ieam.4796

El Khchine, Y., Sriti, M., & El Kadri Elyamani, N. E. 2019. Evaluation of wind energy potential and trends in Morocco. *Heliyon*, *5*(6), e01830. https://doi.org/10.1016/j.heliyon.2019.e01830

Fernández, E. 2023. *Marruecos podría lograr su objetivo energético antes de 2030*. Retrieved from https://www.atalayar.com/en/articulo/economy-and-business/morocco-could-achieve-its-energy-target-2030/20221220125637159481.html

Hajou, A., El Mghouchi, Y., & Chaoui, M. 2024. A new solar-wind complementarity index: An application to the climate of Morocco. *Renewable Energy*, *227*, 120490. https://doi.org/10.1016/j.renene.2024.120490

IEA. 2023a. *SDG7: Data and Projections, Access to affordable, reliable, sustainable and modern energy for all*. Retrieved from https://www.iea.org/reports/sdg7-data-and-projections

IEA. 2023b. *SDG7: Data and Projections Access to electricity*. Retrieved from https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity

IEA. 2023. *Morocco*. Retrieved from https://www.iea.org/countries/morocco

International Trade Administration. 2024. *Morocco - Country Commercial Guide.* Retrieved from https://www.trade.gov/country-commercial-guides/morocco-energy

Jerome, A., Nnadozie, E., & Nabena, D. 2019. Africa's Energy Conundrum. In *African Economic Development* (pp. 395–423). Emerald Publishing Limited. https://doi.org/10.1108/978-1-78743-783-820192020

Kasri, M., El-Ansari, A., El Fissaoui, M., Cherkaoui, B., Birjali, M., & Beni-Hssane, A. 2023. Public sentiment toward renewable energy in Morocco: opinion mining using a rule-based approach. *Social Network Analysis and Mining*, *13*(1), http://doi.org/10.1007/s13278-023-01119-3

Kousksou, T., Allouhi, A., Belattar, M., Jamil, A., El Rhafiki, T., Arid, A., & Zeraouli, Y. 2015. Renewable energy potential and national policy directions for sustainable development in Morocco. *Renewable and Sustainable Energy Reviews*, *47*, 46–57. https://doi.org/10.1016/j.rser.2015.02.056

King, L. 2022. *Morocco Wants To Be A 'Destination' For Renewable Energy*. Retrieved from https://www.forbes.com/sites/llewellynking/2022/08/01/morocco-wants-to-be-a-destination-for-renewable-energy/?sh=65ebab603f06

Leonard, A., Ahsan, A., Charbonnier, F., & Hirmer, S. 2024. Renewable energy in Morocco: Assessing resource curse risks. *Renewable & Sustainable Energy Reviews*, *192*. http://doi.org/10.1016/j.rser.2023.114210

Mensour, O. N., El Ghazzani, B., Hlimi, B., & Ihlal, A. 2019. A geographical information system-based multi-criteria method for the evaluation of solar farms locations: A case study in Souss-Massa area, southern Morocco. *Energy*, *182*, 900–919. https://doi.org/10.1016/j.energy.2019.06.063

North Africa Post. 2024. *Xlinks appoints new CEO to lead Morocco – UK Power Project*. Retrieved from https://northafricapost.com/75441-xlinks-appoints-new-ceo-to-lead-morocco-uk-power-project.html

NS Energy. N.d. *Ouarzazate Solar Power Plant, Draa-Tafilalet*. Retrieved from https://www.nsenergybusiness.com/projects/ouarzazate-solar-power-plant-draa-tafilalet/

ONEE. 2019. *Chiffres Clés 2019 Energie Electrique*. Retrieved from www.one.ma

ONEE. 2014. *Electricité Chiffres clés 2014*. Retrieved from www.one.ma

ONEE. 2015. *Brochure Chiffres Clés 2015*. Retrieved from www.one.ma

ONEE. 2016. *Brochure Chiffres Clés 2016*. Retrieved from www.one.ma

ONEE. 2017. *Chiffres Clés 2017 Energie Electrique*. Retrieved from www.one.ma

ONEE. 2018. *Chiffres Clés 2018 Energie Electrique*. Retrieved from www.one.ma

ONEE. 2020. *Energie Electrique Chiffres clés 2020*. Retrieved from www.one.ma

ONEE. 2021. *Energie Electrique Chiffres clés 2021*. Retrieved from www.one.ma

ONEE. 2022. *Energie Electrique Chiffres clés 2022*. Retrieved from www.one.ma

Oxford Analytica. 2021. Morocco's renewables targets are falling behind. *Expert Briefings.* Retrieved from https://doi.org/10.1108/OXAN-DB265377

Oxford business group. 2016. *Hydropower plays a growing role in the development of renewables in Morocco.* https://oxfordbusinessgroup.com/reports/morocco/2016-report/economy/pumped-up-hydropower-plays-an-increasingly-significant-role-in-the-renewables-segment

Power Technology. 2023. *Top five onshore wind power plants in development in Morocco*. Retrieved from https://www.power-technology.com/data-insights/top-5-onshore-wind-power-plants-in-development-in-morocco/?cf-view

Power Technology. N.d. Retrieved from https://www.power-technology.com/?cf-view

Šimelytė, A., Ševčenko, G., El Amrani El Idrissi, N., & Monni, S. 2016. Promotion of renewable energy in Morocco. *Entrepreneurship and Sustainability Issues*, *3*(4), 319–327. https://doi.org/10.9770/jesi.2016.3.4(2)

The Moroccan Agency for Solar Energy (MASEN). N.d. *RE PROJECTS MAP*. Retrieved from https://www.masen.ma/en/projects

The Wind Power. N.d. *Databases and reports*. Retrieved from https://www.thewindpower.net/

Xlinks. N.d. *The Morocco - UK Power Project*. Retrieved from https://xlinks.co/morocco-uk-power-project/

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