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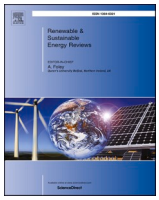

District heating system as the infrastructure for competition among producers in the heat market

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ABSTRACT

Heating and electricity account for one-quarter of annual global greenhouse gas emissions. Many countries still use natural gas and oil for central heating, but interest in district heating as a possible low-carbon alternative is growing. District heating is well-developed in some countries, such as Sweden, Denmark, Poland, and Lithuania. However, there are considerable differences in the organisation of district heating markets in different countries. As these differences may have apparent implications for district heat pricing, competitiveness against other heat supply options, and clean energy uptake, this research explores existing approaches toward competition in the district heating market. We describe the differences in the conceptual frameworks and quantitative outcomes of district heat markets in selected countries and discuss the consequences of the different approaches. This study also considers the possible impacts on consumer prices relative to market opening to competition among heat producers. An important conclusion is that introducing third-party access on the supply side and a one-sided auction may positively affect consumer price downhill development. Finally, we provide insights that could interest other countries and contribute to the future development of the district heating market.

1. Introduction

District heating is a centralised heat supply system that serves many heat consumers. District heating systems have been in operation for more than a century. These systems typically meet the heating needs of people and industries in densely occupied areas. In addition, district heating systems are more developed when the heat demand is high and consistent, for example, in large urban networks in Beijing, Seoul, Milan, and Stockholm [1]. District heating is rapidly becoming more popular as heat production has increased by more than 30% worldwide compared with the 2000 level [1]. Europe is among the leading users of district heating systems. The share of heat demand supplied by district heating ranges between a few per cent in Italy, more than 50% in Lithuania, and more than 60% in Denmark [2].

In recent years, almost a quarter of the total European Union (EU) household expenditure has been devoted to housing, water, electricity, gas, and other fuels [3]. More than 7% of EU households cannot keep their homes adequately warm [4]. Products and services such as electricity, gas, water, and space heating cannot be avoided. In other words, these products meet basic needs; therefore, competition matters [5]. Competition improves overall performance [6] and becomes the price impact factor for making energy products more affordable [7]. In this regard, the introduction of competition might contribute to achieving the UN's sustainable development goals, in particular, SDG 7 (affordable and clean energy).

Owing to its physical characteristics, namely heat loss, heat cannot be transmitted over long distances. This is one of the reasons why common rules for district heating are not subject to EU directives on market liberalisation [8]. This results in a local, fragmented, and single-country dependent situation in heat markets. Compared with electricity and gas, heating remains a *terra incognita* for policymakers, industry, and academic research [9]. Therefore, it is a challenge to find a similar understanding between countries, develop common solutions, and foster breakthroughs in decision-making.

The district heating sectors in Central, Eastern, and Northern Europe, particularly in the Baltic States, account for more than 40% of the domestic heat market. This demonstrates the importance of district heating [10] for reducing greenhouse gas emissions and improving energy efficiency and security [11] in these countries. In addition, these countries and the status of their district heating networks can provide technical guidance and market case studies for other countries heavily dependent on imported fossil fuels such as gas and oil.

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Apart from Sandberg et al. [12], who compared district heating framework conditions for Nordic countries, most studies have looked at specific conditions and their impact, focusing primarily on one specific country and technology. Soderholm and Warell [13] analysed the possible effects of introducing third-party access in district heating, indicating small positive effects on competition, and warned about the risks of running district heating cost-effectively. However, Bürger et al. [14] emphasised that introducing a certain third-party access approach depends on the specific policy targets and it is not enough to ensure the transformation toward fast decarbonisation of district heating. Kirppu et al. [15] presented the future applicability of carbon-neutral, heat-only production technologies. Schach and Wollstein-Lehmkuhl [16] revealed that seasonal heat storage systems in Germany are compatible with conventional heat supplies. Wissner [17] analysed price regulations applicable in the district heating sector, partly focusing on the German case. Sandberg et al. [12] reviewed the literature concerning district heating in Nordic countries and emphasised that minimal studies have analysed the applicability of decisions that would lead to competition in district heating. Nevertheless, Linden and Peltola-Ojala's [18] study results highlight the prospects of such an approach, which encourages market deregulation and industry restructuring because they play a role in lowering prices [18].

The district heating sector currently faces many challenges, including significant investments needed to ensure emission reduction and to increase the economic efficiency of this heat supply option. The introduction of competition into the electricity sector has positively impacted its development. Therefore, competition driven by the same or a similar approach applied to the electricity and gas sectors might be an option for district heating. Hence, there is still a lack of evidence proving that the introduction of competition in district heating works like that in the electricity and gas sectors. However, only real-life case studies can provide firm evidence for such claims, as competition in district heating would always have some important peculiarities that prevent it from reaching a perfect competition level. Consequently, the introduction of competition does not necessarily follow the results of the theoretical analysis of pure competition markets.

This work aims to analyse existing approaches toward competition in the district heating market and reveal their short- and long-term implications for district heating development and customer prices. Furthermore, we provide insights into the initial steps in the future development of district heating. This study uses Lithuania as a case study because of the prevalence of this heating mode and the relatively advanced level of competition in district heating. More than half of all the dwellings in Lithuania are connected to district heating networks. The penetration of district heating into cities is much higher, accounting for 70–80% of all dwellings and other buildings [19]. Moreover, Lithuania has implemented certain decisions that make it possible to analyse the implications of competition on customer prices. A review of experience and implications can serve as a basis for future decisions in other countries.

This study comprises five sections. Section 1 introduces and contextualises the aim of this study. Section 2 presents a possible approach toward introducing competition in district heating. Section 3 presents the materials and methods used in this study. Section 4 presents the results of a comparative study of district heating in Lithuania and other countries and discusses the findings. Section 5 concludes the study and discusses policy implications for district heating development.

2. Literature review on the introduction of competition in the energy sector

District heating infrastructure shares the same natural monopoly characteristics as electricity and gas. The construction of parallel transmission grids is economically ineffective. Therefore, newcomers entering the market must use a network of natural monopolists [13]. This threatens a monopolist with the loss of part of their revenue because of the amount of heat sold by the competitor and the effect of competition on price [8]. Such changes in the market are essential for market participants' performance and need to be adequately prepared for by creating clear and transparent rules.

Despite the monopolistic nature of transmission activity, lessons learned from electricity and gas market liberalisation show that two activities are considered potentially attractive for competition: energy production and supply, which is not a transmission, to consumers [20]. The measures, methods, and speed to reach liberalisation can vary [21]. At the beginning of liberalisation, the EU established two main ways to open markets for competition among generators: regulated third-party access or negotiated third-party access, and two ways to perform purchasing activities: through direct supply activity or a single buyer. The latter means a person 'who, within the system where he is established, is responsible for the unified management of the transmission system and for centralised electricity purchasing and selling' [22]. This approach allows for contractual arrangements of volume and price between eligible parties [13], generators, and suppliers, but purchasing must be performed through a single buyer, adding distribution or system costs [23]. The latter requirements were introduced considering the ability of large-energy consumers to operate independently in the market. The single-buyer approach did not gain much popularity and became inapplicable because of the unbundling requirements [24]. By contrast, district heating primarily meets the needs of small consumers. Therefore, the suitability of the single-buyer approach cannot be eliminated and requires further exploration.

The application of regulated third-party access refers to access to an energy transmission and distribution network under known conditions and tariffs [13]. However, negotiated third-party access allows network owners to negotiate with applicants under unknown conditions [25]. The latter principle raises many questions about transparency and non-discrimination [26]. Therefore, the subsequent directive enforced only possible third-party access based on published tariffs [27]. EU Directive 2003/54/EC also required that vertically bundled transmission and distribution activities be performed and accounted for in legally separate business units [26]. The EU introduced negotiated third-party access and a single-buyer model to reduce the anxiety of reluctant countries [26]. Many generators have also become energy suppliers (in countries where a separate licence is required) and have eventually used the third-party access model. Over time, efforts have been made to find ways to further stimulate competition by creating power exchanges [28]. It took several years to complete this process. Many authors have found that a lack of a clear vision, a clear path to meet the vision, common understanding, and acceptance of the path and vision [20] harmed and prolonged the entire process. The lessons learned in the electricity sector reveal that solutions must be complex, holistically facilitating district heating development instead of solving single problems. District heating and power markets are interconnected through combined heat and power plants. This results in one product of the same power market participant being sold based on competition and the other being sold based on regulation (if any). This only increases the risk of achieving the desired efficiency in a regulated environment, as regulation makes it more challenging to ensure a fair allocation of costs. In addition, products created in different environments (electricity and heating) compete, which is not beneficial for district heating.

The question of whether and how to open a market for supply-side participants is particularly relevant when the generation, transmission, and supply of energy are conducted in a single company, potentially undermining the scope of its business by granting access. The latter situation applies to district heating and is mainly vertically integrated [29]. Only a few authors indicate that opening networks to competition through an increased number of supply-side participants is not necessarily accompanied by a price reduction [18]. However, much evidence strengthens the statement that a competitive market leads to lower generator operating costs, improved availability [26], and price reductions. This statement primarily applies to electricity market

development, as research on market development in district heating is scarce [9]. District heating is also influenced by price changes caused by developments in the liberalised electricity market [30]. District heating markets are more fragmented and consist of many isolated markets, whereas power markets are more integrated. A larger number of producers and consumers in the power market indicates a more efficient functioning of the market. In contrast, the structure of each relatively small district heat market may be different, ranging from single producers to multiple producers, and similar situations as in some power markets.

Grohnheit et al. [17] indicated that the possibility of liberalising district heating in the same way as the electricity sector is scale-dependent, and a competitive wholesale market for district heating is not applicable due to technological limitations and isolation. The results of several recent studies reveal the importance of an adequate balance [20] between the overall aim and measures to be introduced when considering the implementation of a competition-level playing field. Full third-party access may be considered if a country aims to introduce free customer choice. If a country aims to reduce consumer prices, third-party access, applicable only to the supply side, may be introduced [31]. The authors mentioned that third-party access should be coupled with additional decisions to tackle future challenges while supporting the expansion of renewables [31]. Therefore, like any decision in the energy sector, price (de)regulation [32] or the introduction of third-party access when it is not obligatory [33] must have a strong political will. Gunnarsdottir et al. [34] noted that transformation is not possible unless it is economically viable for the market participants. Therefore, price reduction [35] through the introduction of competition is an important factor in making district heating more attractive [36] to customers. Moreover, competition leads to cost efficiency, which is the key driver of the global energy transition toward sustainability [37]. In addition, examining the potential impact of the introduction of competition on district heating prices becomes particularly important in the context of dependence on fossil fuels [38] as it provides an opportunity to overcome many barriers to clean energy through integration. However, the incentives for transformation toward sustainability may differ depending on the market structure. Evidence from other markets shows that monopolies [20] and oligopolies are more rigid, whereas competition provides more motivation for dynamic changes. Revealing the acceptability of theoretical statements concerning transformation toward decarbonisation through a research study would not only expand knowledge but also provide a valuable background for evidence-based decision-making.

Some authors distinguish several options, including zoning and collective decisions, which may add to competition [8]. Zoning is an approach where the use of a particular heating technology or fuel in a particular district heating zone is required. Consumers make collective decisions through public planning [8]. Another study revealed that consumers lack understanding of district heating *per se*. This raises doubts as to whether consumers, even if they have a choice between different heating methods, can do so rationally [39]. Some authors have focused on centralised decision-making regarding the possibilities and obstacles to the introduction of different fuel sources, such as renewables [40] and solar [41], waste heat [42], and carbon-neutral heat production technologies [15] into the existing district heating system and even nuclear cogeneration [43]. Therefore, this study also focused on decarbonisation and other future district heating development directions. Introducing new solutions and technologies should not worsen the situation of end-users or increase energy poverty [44]. Additionally, it is crucial to ensure the application of non-discriminatory, transparent [20] ex-ante rules followed by ex-post enforcement to ensure fair competition [8]. Establishing and implementing proper market rules would also increase access to energy products, in this case, space heating, and make it more affordable for any type of end-user [45].

3. Materials and methods

In reviewing previous studies in this field, we found no existing workable examples in which third-party access would be implemented, at least on the supply side. Polish legislation provides such an opportunity, but its implementation, according to Korhonen [46], is complicated. The same applies to the introduction of the competition. Therefore, this study applies comparative analysis, which helps expand the limited knowledge of the framework of third-party access introduction on the supply side [12] and the situation with the introduction of competition at large. This study considers the situation and level of preparedness in certain countries, where discussions about district heating development are the most active. In addition, the application of the comparative analysis method can better reveal the differences and similarities that can be detected exceptionally. The comparative analysis was followed by a case study approach [47], which was applied mainly using a single country [48]. A suitable practice of studies in this field shows that an even smaller research unit, a city [49], is appropriate [11] to gain valuable insights. In this regard, the study focuses on Lithuanian district heating systems where third-party access is implemented in the three largest cities and on several district heating systems where third-party access is absent. The study is based on a qualitative review of reasons and the process of framework application and a quantitative data collection of economic parameters, such as fuel and heat prices. The qualitative approach is utilised to explore, structure, and explain the reasons and processes of the framework application. The quantitative approach aims to quantify the outcomes of district heating systems to reveal both the differences [50] among the results of the framework application in the chosen systems and between the framework application and the systems where such implementation has not taken place. The data were collected through an extensive review of national regulations, public reports, and statistics [12] and analysed through external desk research. Data credibility was ensured while taking all data from official sites, such as the National Energy Regulatory Council, International Biomass Exchange Baltpool, Lithuanian District Heating Association, and district heating network operators.

4. Results and discussion

4.1. Comparative analysis of district heating market developments among different countries

To understand the current situation and possible future district heating market development, the first step was to perform a comparative analysis of the chosen European countries. The choice of countries depends on the advancement of their electricity and natural gas markets and the scope and importance of district heating in their heating markets.

Sweden is an EU country where district heating plays an important role [51], catering to a net heat demand of approximately 100 TWh per year [52]. District heating is a climate-smart energy system that heats over half of all commercial and residential buildings [53]. Given that reforms in the electricity sector have progressed well, dedicated authorities have decided to deregulate district heating prices [32] for efficient competition [54] between electricity and district heating in the space-heating market [13]. In addition, companies generating considerable amounts of industrial waste heat promoted the introduction of third-party access [13] and an increase in district heating prices after deregulation [51]. The evidence identifies positive attitudes toward the introduction of competition in district heating. However, there is no designated market for district heating in Sweden, and competition exists between district heating and whatever alternatives are available in local markets for heating [52]. A similar approach was introduced in Finland, whereas most other countries use some sort of price regulation [54].

District heating plays a significant role in Finland as almost half of the population is connected to this source of space heating [39]. District

heating regulations indicate that the price must be sufficiently comparable to production costs and other available heating options [39], but no specific legislation concerning the selection or pricing is in force [55]. Competition is also applied through customers' freedom to choose the heating method [55], such as heat pumps [56]. Finland and Sweden can be considered countries with some sort of competition. However, none of these countries is characterised by a complex, long-term approach.

Norway is also a northern country, but district heating accounts for only approximately 5% of the energy consumption [57]. The main customers are the commercial and public service sectors. The regulation of the sector foresees a licencing procedure for district heating plants with heat outputs greater than 10 megawatts [57]. A special program is dedicated to supporting investments in renewables, waste incineration, waste-to-energy, and the transformation from fossil fuels to renewables [58]. Price regulations were established in the Energy Act. The regulation provides a price structure (connection fee, fixed yearly charge, and charge dependent on heat consumption) [59]. The same legal act implies a price cap regulation when the price for district heating does not exceed that for electric heating in the same supply area [60]. Hence, there is no significant development toward competition utilisation for price formation in the Norwegian district heating market.

Denmark is where district heating is essential in supplying space to customers [12]. Using district heating, Denmark reduced its fossil fuel dependency and solved waste management problems, urban planning and pollution [61]. District heating faces competition from other heating technologies [30], mainly gas-fired boilers, when consumers consider the choice of space heating for individual buildings [38]. Danish district heating is regarded as a natural monopoly because there are often only a single or few heat producers in the local district heating network. The ownership structure is diverse: consumer-owned cooperatives, municipality-owned companies, and joint-stock companies [60]. However, most companies are monopolistic [62]. The market is regulated on a cost-reflection basis, coupled with the non-profit principle [61]. A similar approach applies to Iceland, where prices must reflect the costs of heat production (based mainly on geothermal energy [63], distribution, and sales). The rate of return is also under regulation [60]. It is noteworthy that the Danish case shows the applicability of heat exchange to some extent comparable to the original Electricity Pool of England and Wales [8].

District heating accounts for approximately half of the total heat supply in the Czech Republic [64]. As district heating supply is considered efficient and has a low negative impact on local air pollution, the regulation foresees the development of heat and electricity cogeneration from renewables. Hence, no strategy has focused specifically on district heating in the Czech Republic [65]. The regulation is a simple setting for the yearly district heating price. Although certain obstacles exist to switching to individual heating, consumers tend to disconnect from the district heating system [64]. It is worth emphasising that the Czech Republic faces a problem similar to that of Lithuania. The efficiency and affordability of district heating technology have lost their attractiveness owing to the lack of proper market mechanisms and rules that would foster modernisation and price reduction.

Estonia also has an extensive district heating sector that accounts for 60% of its total heat supply [66]. Private ownership prevails in the ownership structure, and all companies can be granted monopoly status [67]. From a regulatory perspective, monopoly status might be attractive. However, the monopolistic nature reduces efforts to act optimally and invest in renewables [66]. Moreover, there are concerns regarding the long-term sustainability of this sector [66]. Estonia uses cost-plus price regulations, and one of its side effects is higher prices in smaller networks [66]. Estonia falls among many other countries that do not consider the introduction of competition as a way toward improved efficiency, decarbonisation, and the attractiveness of district heating among consumers.

Poland has the second-largest combined district heating network in Europe, and its district heat production is mainly from fossil fuels [68]. Prices for district heating are set by district heating companies of a monopolistic nature and must be approved by the regulatory authority [68]. Poland's Energy Policy until 2040 aims to bring all the heating supplied to households under district heating and significantly lower emissions [69]. To achieve this, Poland needs to work in two directions: to make district heating more attractive and to transform production toward zero-/low-emissions. Therefore, preparing a new market model, coupled with increasing renewables and waste in cogeneration, is foreseen [68]. Thus, Poland perceives district heating as an opportunity to achieve its important strategic goals. The Slovak Republic has a political will to create a long-term regulatory framework as well.

District heating accounts for more than half of all the heating markets in the Slovak Republic, and fossil fuels, particularly natural gas, are dominant [70]. A large number of heat producers characterise the heat market, and some produce and supply heat to the district heating system. Heat production and supply by other producers, usually smaller ones, are referred to as centralised rather than district heating [71]. The price setting satisfies the cost-plus principle [72]. Access to district heating is regulated for both sides; producers are licenced, and customers can switch to another heat source only under certain conditions (i.e. if the customer and supplier agree to the switch) [73]. Although switching to another heat source is rather complicated, the heat consumption from district heating is decreasing [70] because of the poor focus on customers and inefficiency, which is reflected in the final price. Therefore, the country aims to develop efficient district heating [71] and create a long-term, stable, and predictable regulatory framework.

The Netherlands has also experienced a decline in district heating consumption [74]. However, the Environmental Assessment Agency expects growth in newly-connected households by 20–30% by 2050 [75]. Therefore, the district heating sector should increase the number of renewables instead of remaining heavily reliant on natural gas [74]. The district heating price is set by the authority of consumers and markets, following the price cap principle [75]. The benchmark for price cap setting was determined by comparing the district heating price and the price of heating produced using a gas boiler [76]. The regulator aims to develop new pricing to facilitate the departure from fossil fuels. The main district heating market actors are vertically integrated energy companies [74]. Evidence from the Netherlands, the Slovak Republic, and Poland identifies that district heating is gradually gaining importance and can be a path to foster decarbonisation, efficiency improvement, and become more attractive to end users.

The case of district heating in Hungary is exceptional compared with that in other countries. Heat production and supply are treated as separate activities, and both are licenced [77]. District heating prices were regulated at two levels. The Ministry of National Development sets production prices following the cost-plus principle, separates prices for households, and provides compensations [78]. Compensation is required if the end customer's price does not ensure allowed profitability on the production side [78]. Natural gas is the predominant fuel used for district heating. The existing regulatory regime with the compensation system might explain why district heating has not become more efficient.

Austria is an example where the popularity of district heating has been growing [79] for decades. Biofuels and renewable waste are mainly used for heat production, whereas natural gas accounts for a slightly smaller proportion [79]. It is worth mentioning that a price cap principle is used for pricing. District heating companies set prices, and competition authorities only monitor and regulate excessive profits if needed [80]. Therefore, price ceilings may be imposed on district heating companies which overcharge their customers.

In 2019, district heating covered only 1% of Belgium's energy demand [81]. Heat pricing is considered a tool for tackling poverty by setting social prices [81]. Belgium joins countries that try to solve certain problems in the district heating market instead of having a vision and acting accordingly.

France is distinguished by the fact that until 2020, it had support

schemes for combined heat and power units using natural gas [82]. Recent efforts have been made to develop more renewable resources (57% of district heating was supplied by renewables and waste in 2019), particularly heat pumps [83]. Hence, competition in the district heating market is not considered among other reforms.

District heating has emerged in many towns in northern Italy [84]. The expansion of the existing district heating sector is foreseen to be a regulation that obliges all new buildings within a kilometre and closer to the district heating network to be connected [85]. District heating generation mainly comes from fossil fuel-fired cogeneration, whereas renewables contribute one-fifth of the total heat [84]. Therefore, regulations require the integration of renewables [85]. The vast majority of district heating companies are vertically integrated. For example, in Mantua, heat is generated by several independent producers [84]. Moreover, corporate unbundling has already been completed by the Iren group in the Turin area [84]. This has encouraged the establishment of a wholesale market. Price regulation follows a cost-plus approach coupled with a price cap usually based on the natural gas price benchmark and sometimes on oil prices [84]. Although prices are relatively heavily regulated, this does not lead to a price decrease in consumer demand [84]. Evidence from Italy and other countries (the Czech Republic, Slovak Republic, Poland, and Estonia) indicate that price regulation, even a heavy one, does not guarantee a level of efficiency that would have the desired effect on heating prices.

The review shows that district heating is essential in northern and central European countries. In other countries, however, district heating is either not considered an important question (i.e. Canada [86]) or is at the very beginning of its transformations (Turkey has just recently started discussing the promotion of the use of waste heat and building a market for the trading of that heat [87]). Table 1 provides a summary of the countries reviewed.

As shown in Table 1, the situation in the district heating market among the countries reviewed is very similar to that in the electricity and gas markets before the liberalisation process began. The latter situation is characterised by vertically integrated monopolies, heavily regulated prices, the use of fossil fuels, a lack of efficient modern solutions, and end-user dissatisfaction. Countries with deregulated prices switched to a more significant share of renewables in heat production more quickly and with less state intervention.

Notably, a slightly greater shift toward competition is observed in several northern countries. However, vertical integration can be observed in most of the countries analysed. An interesting example is Lithuania, where competition for district heating has already been implemented.

As Fig. 1 shows, the two most popular price regulation regimes are the cost-plus and price-cap regimes. Only three countries (Finland, Lithuania, and Sweden) out of the 18 analysed have deregulated district heating prices.

A summary of the countries' developments toward competition is provided in Table 2. This table also reflects the status of competition in Lithuanian district heating, which is discussed in more detail in a subsequent subsection.

Competition issues are closely related to the overall development of district heating as such and its role in future energy systems. In agreement with the new trends in district heating singled out by the authors (introduction of smart systems [53], low-temperature district heating [40], distributed generation [41], demand-side response, the inclusion of multiple [40] and diverse [15] heat sources, various storages, and reduced dependence on fossil fuels [38], it is important to emphasise that these trends put new requirements on the organisation of the entire system with, possibly, multiple actors and conflicting interests.

4.2. District heating developments toward the competitive market in Lithuania

Although district heating has been widespread in Lithuania for many years, especially in cities, consumers have been dissatisfied with its high prices [88], which are also typical for large cities. The end users' price for district heating was highest in Kaunas, the second-largest city in Lithuania, compared with other large cities. In February 2012, district heating prices were 9.36 €ct/kWh in Kaunas, 8.69 €ct/kWh in Šiauliai, 8.58 €ct/kWh in Vilnius, 8.1 €ct/kWh in Klaipėda, and 7.73 €ct/kWh in Panevėžys [89]. Meanwhile, the lowest district heating price in Lithuania was in Elektrėnai – 5.44 €ct/kWh. This price was 1.72 to 1.42 times lower than in the aforementioned cities.

In particular, high prices were typical for a few years in Kaunas, accounting for 20% of the country's district heating market [90]. One of the main reasons for this is an unfavourable contract with one of the dominant heat producers. The contract obliged the city to purchase at least 80% of the heat consumed by the district heating network. However, in other cities, the price of heat is unattractive. Kaunas has taken the lead in looking for possible solutions to reduce prices for consumers and, at the same time, maintain the attractiveness of district heating [91]. After almost a year of discussions with scientists, heat market

Table 1
District heating sector regulation and main features of a sector in different countries.

Country	Regulative regime	Essential features of the sector
Sweden	No price regulation	Dominated by vertically integrated companies
Finland	No specific legislation on price regulation	Dominated by vertically integrated companies
Norway	Regulated price, licencing of big producers	Dominated by vertically integrated companies. Support for the transition from fossil fuels
Denmark	Regulated price	Dominated by vertically integrated companies. District heating facilitates the transition from fossil fuels
Iceland	Regulated price	Dominated by vertically integrated companies
the Czech Republic	Regulated price	Dominated by vertically integrated companies. Need for modernisation. Declining number of users
Estonia	Regulated price	Dominated by vertically integrated companies. Lack of effectiveness. Need for the transition from fossil fuels
Poland	Price set by a company and approved by the regulative authority	Dominated by vertically integrated companies. Need for the transition from fossil fuels
the Slovak Republic	Regulated price, licencing of producers	Mix of vertically integrated companies and independent producers. Lack of effectiveness. Declining number of users
the Netherlands	Regulated price	Dominated by vertically integrated companies. Need for the transition from fossil fuels
Hungary	Regulated price, licencing of producers and suppliers	Unbundling of production and supply activities. Compensation mechanism for producers. Lack of effectiveness. Need for the transition from fossil fuels
Austria	Price set by a company, ex-post regulation	Dominated by vertically integrated companies. District heating facilitates the transition from fossil fuels
Belgium	Price is a measure to tackle poverty	The sector is particularly small
Italy	Regulated price	Dominated by vertically integrated companies. Lack of effectiveness. Need for the transition from fossil fuels
Lithuania	Price regulation is applicable for dominant heat producers (if it accounts for more than 1/3 of the market need)	Unbundling of activities. Competition on the supply side. Existing model has attracted new investments and facilitated the transition from fossil fuels

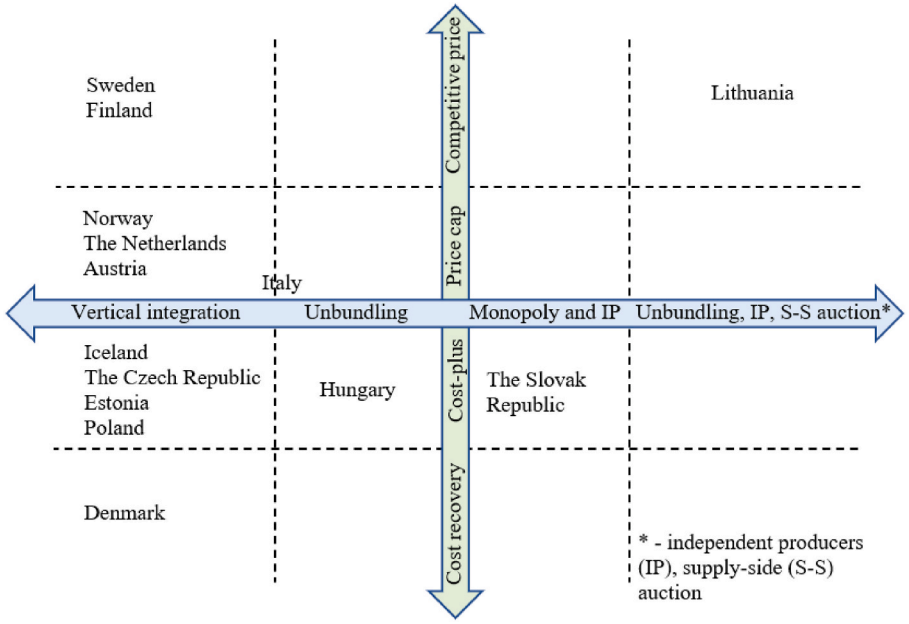

Fig. 1. Price regulation regimes and integration level.

Table 2
A summary of the Northern countries' developments toward competition.

Country	Approach toward competition	Third-party access	Heat trade
Sweden	among heating methods	not applied but positive toward third-party access	Mainly vertically integrated heat supply
Denmark	among heating methods	not applied	Vertically integrated heat supply (with an indication of heat exchange applicability)
Finland	among heating methods	not applied	Mainly vertically integrated heat supply
Lithuania	among heat producers	regulated third-party access	From a supply-side auction through heat supplier to end-user

participants, and high-level decision-makers, it was decided to implement regulated third-party access on the supply side. This approach does not limit any technology, such as geothermal heat, heat pumps, heat storage facilities, electricity, or solar heat [92], to enter the Lithuanian district heating market. It is worth mentioning that solar heat may enter the district heating market by 2025 [93]. In addition, there are no limitations on business models or capital structure, some of which are purely privately owned, some owned by municipalities, and some have a mixed capital structure (a partnership between private and state companies). In most cases, new entrants operate as independent producers, regardless of the chosen heat-production technology and business model.

Third-party access on the supply side approach is in line with the authors' emphasis on the interrelations between price reduction for customers and the introduction of third-party access on the supply side [31]. When discussing the approach choice, scientists consider the already proven path of regulated third-party access [26] instead of a negotiated one. A one-sided auction not only provides incentives to reduce the price for all customers but also acts as a reference price for both possible newcomers (new district heating customers and new heat producers) and supports regulation developments for district heating systems where third-party access and one-side auctions are not applicable.

Following the chosen approach, the heat supplier announces the quantity needed to meet the heat demand, and producers provide offers identifying the quantity and price. The first pilot auction was conducted in Kaunas in November 2012. As shown in Fig. 2, district heating prices have steadily declined since introducing third-party access and auction in Kaunas.

It took a lot of political will, but downward price trends led to regulatory change. The Law on Heat of the Republic of Lithuania aims to ensure a reliable and high-quality heat supply to heat consumers at the lowest cost and legitimise reasonable competition in the heating industry. For this purpose, the heat auction operates as a system to determine the amount of heat supplied by the heat supplier in existing heat production facilities and/or purchased from independent heat producers according to the price offered by the auction participants and the technical possibilities of the heat supply system [94]. In the heat sector, the National Energy Regulatory Council regulates district heating suppliers that sell at least 10 GWh of heat per year (it sets heat price components, checks annually recalculated heat price components, and, if necessary, indicates price violations). The Heat Law entitles the National Energy Regulatory Council to unilaterally determine the heat price components if municipalities do not eliminate the specified violations or set the heat price components in time [95]. The National Energy Regulatory Council also regulates independent heat producers who 1) have received financial, municipal, or other support from the EU; 2) receive a subsidised electricity tariff, for example, using public service obligations or flat-rate measures to promote the use of renewable energy sources; and 3) produce more than 1/3 of the need for a district heating system.

The changed regulation raised the hopes that similar price trends would be observed in other cities, despite the remaining disturbances. The first is the method of purchasing fuel. Some heat suppliers purchase biomass through long-term high-price contracts. Therefore, the regulator gradually transitioned to a more transparent fuel-procurement process. In 2016, it was mandatory to purchase 100% of the biomass required for heat production in exchange (in 2015, this amount should have been at least 50% in 2014 – at least 10%). This requirement does not apply if, for objective reasons, it is not possible to obtain the required quantity or part of the required fuel on the exchange, or it is more cost-effective to acquire energy resources by other means (biomass purchased by other means is at least 5% cheaper than that in biomass exchange) [96].

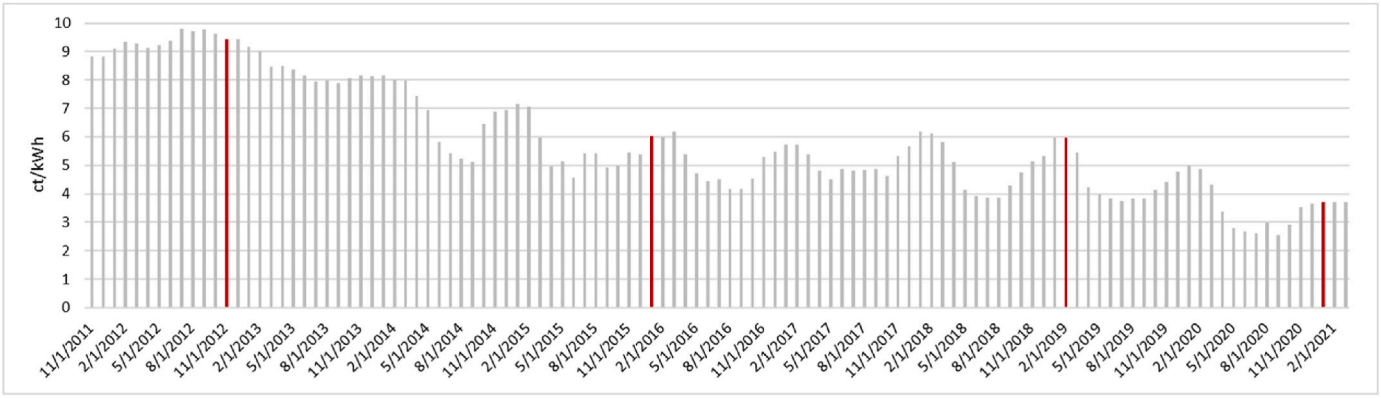

Fig. 2. District heating prices in Kaunas, January 1, 2012–March 1, 2021, €ct/kWh. Source [89].

Notably, competitive conditions for heat producers owned by heat suppliers and independent producers differed for some time. Therefore, the National Energy Regulatory Council 2018 on 28 February approved a new regulation. The essence of these changes is the introduction of equal competitive positions between heat suppliers and independent heat producers, which must consider the full cost of heat production (instead of just variable) when participating in the heat purchase auction, a more transparent and clear procedure for organising the heat auction, and the planned two-month forward auction period allow for efficient planning of fuel purchases at the best price. The heat auctions were moved to a unified electronic system on May 20, 2018. According to the new procedure, the heat purchase auction was organised on December 20, 2018, purchasing heat for January 2019 [95]. These auctions were conducted by the Baltpool. Baltpool, at its roots, is a biomass exchange operating in Lithuania, Latvia and Estonia, Poland, Denmark, and via partners in Finland and Sweden, which currently has 452 members. It is one of the most successful models of well-organised biomass trade [97]. Correspondingly, Baltpool was chosen to handle the heat auctions. Improved regulation, a clearer auction procedure, and price reductions increased the number of district heating systems that introduced competition, from one pilot case to 14 in 2021 [98]. This transformation has occurred to ensure regulatory transparency, clarity, and non-discrimination. These practical changes confirm the theoretical insights made by other authors in terms of both well-prepared general rules of conduct [20], purchasing procedures [28], and the need for strong political will [33]. The study shows that the process of change and its features are quite similar to those that occurred earlier in the EU electricity sector and later in other countries [99]. Moreover, the spread of competition and the processes that occurred in biomass purchasing scaled up the use of biomass to produce heat. The latter development responds to Münster et al.'s insights regarding reducing fossil fuel dependence [38] for future district heating.

Compared to the 2017–2018 heating season, Vilnius, the biggest city and capital of Lithuania, purchased the required amount of heat for the 2018–2019 season at a price that was 26% higher (3.19 €ct/kWh). During the 2018–2019 winter season, Kaunas purchased heat at a considerably lower price, that is, 2.68 €ct/kWh (a 29% increase from the previous heating season). During the heating season of 2018–2019, Vilnius and Kaunas each had 10 active heat producers. All the heat produced by private heat producers in Vilnius was purchased. The potential heat supply normally exceeds the demand in Kaunas; consequently, fierce competition among suppliers in Kaunas might lead to higher end users' price reductions (see Fig. 3). Downhill price development plays a role in maintaining existing customers and attracting new ones [100]. Moreover, a techno-economic assessment of the centralised approach application in district heating performed by Narula et al. [101] showed the lowest cost of decarbonisation. The latter results show that decarbonisation can be accelerated and scaled up through the introduction of competition.

Table 3 shows the change in prices over the last three years, the number of heat producers connected to the grid, the excess capacity, and the share of biomass in the heat production mix. Three of the five towns with the highest heat prices do not apply for third-party access or supply side auctions (shown in *italics*).

Analysing the data provided in Table 3, it can be seen that the situation is quite diverse. Vilnius, Kaunas, and Šiauliai have shown the largest price reductions over the last three years. Kaunas and Vilnius had the highest number of heat producers. Šiauliai has only one dominant

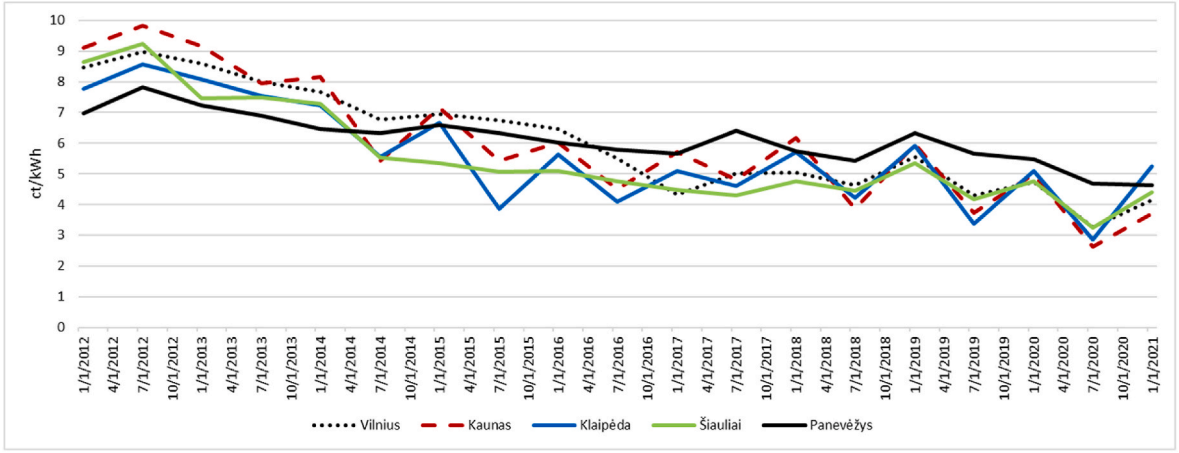

Fig. 3. End users' district heating prices in the biggest cities of Lithuania, January 1, 2012–March 1, 2021. Source [89].

Table 3
Comparison of the cheapest and the most expensive district heating systems in Lithuania (1).

	High season average price (€ct/kWh)			Low season average price (€ct/kWh)			Number of producers	Excess capacity (%)	Biomass share in heat production (%)
	2018	2019	2020	2018	2019	2020			
Vilnius	5.06	5.53	4.48	4.93	4.30	3.29	11	85.18	5.01
Kaunas	5.71	5.35	4.46	4.14	3.89	2.76	16	77.34	75.73
Klaipėda	5.64	5.64	4.90	4.32	3.52	3.21	9	69.38	14.74
Šiauliai	4.78	5.22	4.51	4.58	4.32	3.69	1	47.10	20.68
Panevėžys	5.72	6.06	5.32	5.57	5.54	4.68	2	57.11	8.69
Palanga	*6.34*	*6.51*	*5.76*	*5.81*	*5.91*	*5.18*	*2*	*79.04*	*10.08*
Pakruojis	*7.40*	*6.52*	*6.18*	*6.28*	*6.02*	*6.45*	*2*	*65.82*	*32.45*
Telšiai	7.67	7.78	6.88	6.73	6.97	5.66	2	68.78	6.58
Joniškis	7.24	7.58	7.27	6.79	6.99	6.75	4	67.90	23.92
Vilkaviškis	*8.02*	*8.38*	*7.23*	*8.15*	*7.18*	*6.64*	*1*	*69.51*	*13.40*

producer, and is among the cheapest heat suppliers. Joniškis has four possible producers, but shows on average 1.66 times higher prices compared to the cheapest options. Vilnius, Kaunas, and Palanga had the highest excess capacities. However, compared to the cheapest options, the prices in Palanga are on average 1.3 times higher. Analysing the share of biomass in total production and prices, it can be seen that only Šiauliai, one of the three cheapest options, falls between systems with the largest share of biomass. The other are Kaunas, Joniškis and Pakruojis. The latter has one of the largest shares of biomass, but its price is on average 1.18 times higher compared with the cheapest heat suppliers. Biomass prices differ among regions, with a difference between 9% and 27% [102]. It is noteworthy to mention that Klaipėda with the third biggest part of biomass falls in the highest price region for biomass and still has one of the cheapest district heating prices.

Table 4 shows the change in prices over the last decade (10 years and five years December price averages), the share of a particular district heating system from the total heat produced in Lithuania, and the correlation between fuel (natural gas and biomass) and heating prices.

Analysing the data provided in Table 4, it can be seen that prices are lower in larger systems than in smaller ones. Therefore, a sufficiently large heat market may be a precondition for price reduction. However, it is possible to discover small district heating systems in Lithuania, such as Visaginas (third-party access and supply side auctions are implemented), where prices are close to the cheapest ones. Vilnius has the largest heat market and falls among the four cheapest options according to the five-year December average price but does not show the lowest price. The three cheapest options (Kaunas, Šiauliai, Panevėžys) are characterised by a statistically significant moderate positive relationship between the prices of biomass fuel and heating. Kaunas shows the lowest district heating price according to the five-year December price average and falls between the three cheapest options according to the ten years December price average. It is noteworthy that Kaunas is characterised by the most intense competition, with the largest number of heat producers in the second largest district heating market. This competition makes the district heating sector more attractive than individual heating sectors. Although the global renewable heat supply is dominated by biomass, the comfort level is not acceptable. The shift to modern energy use is usually understood as a way forward from energy poverty, particularly in developing countries. In other countries, district heating is considered a tool for decarbonisation [103], as it enables the shift to clean energy solutions in a less complicated way than installing individual appliances.

Recent developments show greater growth of newly connected customers to district heating systems [104] in Lithuania, despite heating prices increasing because of the rise in fuel prices. Individual heat consumers particularly feel this increase in fuel prices in cities that use natural gas most often for heating and hot water. There are a few islands of interconnected multifamily houses supplied by a centralised boiler house inside the district heating system which are not connected to the city's district heating system. These islands belong to the Kaunas district heating company and have the same prices as the main district heating

Table 4
Comparison of the cheapest and the most expensive district heating systems in Lithuania (2).

	10 years Dec price average (€ct/kWh)	5 years Dec price average (€ct/kWh)	Share from total heat produced in Lithuania (%)	Correlation between natural gas and heating prices		Correlation between biomass and heating prices	
Vilnius	6.23	5.56	30.81	r	0.494	r	0.422
				p	*0.00001*	*p*	*0.000272*
Kaunas	6.01	4.95	14.43	r	0.015	r	0.600
				p	*0.901859*	*p*	*0.000000*
Klaipėda	6.05	5.62	9.70	r	0.291	r	0.527
				p	*0.013822*	*p*	*0.000000*
Šiauliai	5.51	5.07	4.67	r	0.528	r	0.631
				p	*0.000002*	*p*	*0.000000*
Panevėžys	5.95	5.55	4.32	r	0.022	r	0.554
				p	*0.857793*	*p*	*0.000000*
Palanga	–	6.36	0.39	r	0.413	r	0.501
				p	*0.000565*	*p*	*0.000016*
Pakruojis	7.74	6.95	0.20	r	0.131	r	0.001
				p	*0.27768*	*p*	*0.995142*
Telšiai	–	7.23	0.71	r	0.058	r	0.474
				p	*0.629428*	*p*	*0.00003*
Joniškis	7.95	7.47	0.29	r	0.590	r	0.464
				p	*6.31E-08*	*p*	*0.000001*
Vilkaviškis	–	7.68	0.45	r	0.120	r	0.770
				p	*0.320401*	*p*	*0.000000*

area. This implies that all customers served by the same company in the same geographical area are treated as the same. Simultaneously, it does not motivate the switch to a less expensive fuel unless it is disconnected from an existing heating system. It should also be noted that such cases are rare.

When comparing the two biggest district heating markets, the recent jump in fuel prices resulted in more than a 100% hike in heating prices in Vilnius (from 3.96 €ct/kWh December 2020 to 8.74 €ct/kWh December 2021) and only a 45% price hike in Kaunas (from 3.65 €ct/kWh December 2020 to 5.3 €ct/kWh December 2021). Several reasons for this difference in price development include the weaker dependence on fuel prices and the significantly less intense competition in Vilnius than in Kaunas. Demand-side liberalisation can add an additional stimulus to further the development of competition. Free customers can participate on both sides of the auction, buying heat in the market and selling non-consumption of heat. This can also provide more opportunities for network operators to balance the supply and demand. Fig. 4 represents a possible next step in competitive development in the Lithuanian district heating market.

This study's results support the opinion that third-party access applies to a district heating market and introduced on the supply side facilitates price reduction [31]. This approach also allows the entry of a district heating market by various producers such as industrial residual heat sellers and heat pumps. This makes it easier to lessen concerns about promoting renewables, as indicated by Malico et al. [105] when analysing the perspectives for energy production from solid biomass in the European industry. At the same time, the results presented in this work refute that transformations toward a competitive district heating market are dependent on market scale and technological peculiarities [17]. Moreover, the results suggest that competition can be introduced into district heating markets with different characteristics. The introduction of competition can positively affect the downhill price development. In addition, the introduction of competition can contribute to the achievement of other goals.

5. Conclusion

It is widely understood that introducing competition in the electricity and gas sectors is possible and necessary to initiate positive change. However, owing to the isolation and relatively small scale of the district heating sector, the success of the introduction of competition was questioned. Research carried out in the district heating sector confirms that the introduction of competition is beneficial in many ways, despite its inherent limitations. For the success of the process, it is important to have a vision reinforced by political will and to prepare a framework of transparent rules that would include the separation of production and other activities, the entry of independent producers into the market, the regulated principle of third-party access to connect to networks, and the trade mechanism. Based on the analysed case of Lithuania, it is proposed to start trade with a single-buyer approach, implementing competition on the supply side. Nonetheless, implementing the proposed solutions and fostering breakthroughs in decision-making at a multi-county level will be challenging. Comparative analysis showed that the situation varies from the rather deep introduction of competition in Lithuania to the approach that district heating is a means to solve a certain problem, that is, to tackle poverty in Belgium. Therefore, EU policies should provide the necessary boost.

The literature review, considering the experience of the electricity sector, justified the expectation that the introduction of competition would also lead to price reductions in district heating. A comparative analysis of the chosen countries reveals that most of them struggle with the efficiency of district heating and eventually high prices, which lessens district heating attractiveness among consumers. These problems are less common in countries with competitive elements. The Lithuanian case study shows that the introduction of competition through regulated third-party access on the supply side, coupled with a one-sided auction, led to a significant decrease in heat prices. The latter was observed regardless of the number of heat producers, the share of biomass, installed excess capacity, or the size of the district heating system. This has resulted in a sustainable decrease in the heating price and a growing number of new customers. The next step should be market liberalisation for large customers whose participation would result in a more efficient operation of the district heating system.

The literature has also noted the possibility of accelerating the transformation toward decarbonisation. Current decarbonisation initiatives require utilising the benefits provided by district heating: efficient use of primary energy resources, ability to use innovative technologies, and clean fuels on a large scale. The evidence gained from the comparative analysis revealed that some countries comprehend district heating reforms that facilitate the goal of zero emissions. However, district heating systems are still dominated by fossil fuels because of a lack of investment in cleaner solutions. As shown in the Lithuanian case study, competition accelerated the shift from fossil fuels to biomass. Therefore, governments should concentrate on developing supply infrastructure while leaving the generation sector to private investors. This option is in line with the ongoing EU policies in the natural gas and electricity markets. Introducing a more competitive market structure may attract private investment to generation sources and ensure that the investment is made more efficiently. For countries without well-developed district heating systems, this would reduce the burden of

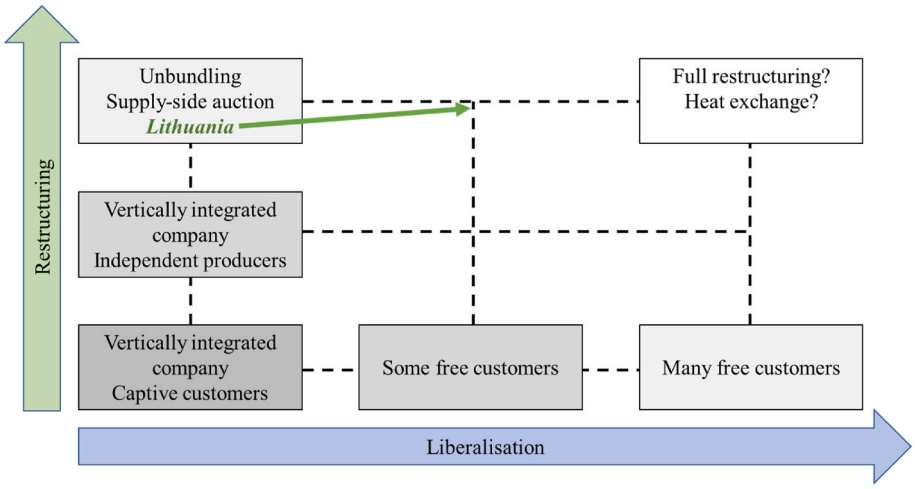

Fig. 4. Possible directions for a district heating market development.

development.

Although universal, the introduction of competition in the district heating market requires consideration of the local conditions and circumstances. Thus, it would be relevant to carry out broader research on readiness for competition in district heating, involving more countries, especially those with significant dependence on fossil fuels, and simulating the introduction of competition in anticipation of what changes might occur. Another important research direction is new products and business models related to innovative technologies and solutions in district heating and integrated markets. For instance, solutions implemented to transform well-developed vertically integrated markets may be unnecessary for countries with district heating or cooling systems in the initial stage. In addition, current vertically integrated structures may not be suitable for some innovations. Therefore, they may impose additional transformation requirements.

This study contributes to the current discussion and scientific literature by exploring the introduction of competition, application of regulated third-party access, and a one-sided auction and its implications on the sector's development and prices paid by the end users of district heating. We also believe that a better understanding of the legal, regulatory, and process preconditions can play a role in developing the district heating sector in other countries.

Credit author statement regarding

The paper "District heating system as the infrastructure for competition among producers in the heat market" prepared by A. Pažėraitė, V. Lekavičius, R. Gatautis is following: Aušra Pažėraitė: Conceptualization, Methodology, Data curation, Writing - original draft, Writing - review & editing. Vidas Lekavičius: Writing - review & editing. Ramūnas Gatautis: Conceptualization. Sincerely, A. Pažėraitė, V. Lekavičius, R. Gatautis Laboratory of Energy Systems Research Lithuanian Energy Institute, Breslaujos 3, 44,403 Kaunas, Lithuania.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rser.2022.112888.

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