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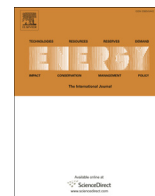
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Getting fair institutional conditions for district heating consumers: Insights from Denmark and Sweden

Leire Gorroño-Albizu ^{a, b, *}, Jaqueline de Godoy ^c

^a Aalborg University, Department of Planning, Rendsburggade 14, 9000 Aalborg, Denmark

^b Mondragon Unibertsitatea, Operations Management, Loramendi 4, Arrasate, 20500, Spain

^c Aalborg University, Department of Energy Technology, Pontoppidanstræde 101, Aalborg East, 9220, Denmark



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ABSTRACT

District heating is expected to play an important role in the EU for the implementation of a low carbon energy system with high shares of renewables. Empirical examples from several countries show that district heating companies can misuse their monopoly position, hampering district heating adoption. To address this issue, it is necessary to develop and implement institutional frameworks that promote fair conditions for consumers. However, it is still unclear how to do this. This article reviews the institutional conditions implemented in Denmark and Sweden from the start of district heating until the present and analyses why different institutional configurations have managed or failed to promote fair conditions for consumers. The analytical framework for consumer power in natural monopolies is applied. The data is collected via a structured literature review, interviews with experts and other data sources such as resolutions of consumer complaints, relevant stakeholders' websites and legal documents. The results indicate that local ownership, transparency and communication have been of key importance to reduce prices in both countries. Further research is necessary to fully understand how the institutional conditions have influenced product and customer relation quality. Lessons from Denmark and Sweden are outlined.

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1. Introduction

District heating (DH) –together with energy efficient buildings and individual heat pumps– could play an important role in the EU for the implementation of a low carbon energy system with high shares of renewable energy [1]. DH allows to utilise local resources that are otherwise difficult to use (such as waste heat from industrial processes and power plants) and to integrate larger shares of variable renewable energy in the system, resulting in environmental and economic benefits [1]. Some EU countries (particularly the Nordic and Baltic countries) have already reached significant shares of DH [2]. However, there is still a large untapped potential for the expansion of DH in the EU [3]. To realise that potential and the benefits DH offers, it is crucial to develop and implement supportive institutional conditions that will promote the adoption

of the technology. Most importantly, institutional conditions should safeguard consumers' interests and rights. This is fundamental to encourage consumers to choose DH over other heating solutions and, thus, to achieve the necessary consumer connection rates to make DH implementation and continuation economically feasible in targeted locations; i.e. where socio-economically beneficial. However, despite research on DH strategies and practices, it is still unclear how to do this.

DH systems are natural monopolies [4] of a local nature. Consequently, unlike in electricity and gas systems, there is little space for competition between producers as well as retailers. Therefore, DH production, distribution and retail are often integrated under the same company. This has several implications including that dissatisfied DH consumers cannot choose another DH supplier –only to invest in another heat supply system. Therefore, the consumer lock-in effect is stronger with DH than with other heat supply technologies (e.g. individual heat pumps or natural gas boilers) that are also dependent on natural monopolies but (have been regulated to) offer consumers the possibility to change their retailer. The particularities of DH demand the design of specific institutional conditions that safeguard consumers'

* Corresponding author. Aalborg University, Department of Planning, Rendsburggade 14, 9000 Aalborg, Denmark.

E-mail addresses: lga@plan.aau.dk, lgorrono@mondragon.edu (L. Gorroño-Albizu).

interests and rights.

Empirical examples from various European countries show that DH companies can misuse their monopoly position and the consumer lock-in effect, resulting in disproportionate heat prices [5], price discrimination to attract new customers [4], complex bills [6] and tariff structures [7] that discourage DH demand reductions, lack of security of supply [8], few hours of availability [9], lack of flexibility at household level resulting in too low [9] or high [10] indoor temperatures, poor customer service [9], etc. Such practices – exacerbated by significant reductions in industrial heat demand and strong marketing campaigns conducted by natural gas and electricity utilities encouraging a swift from DH to individual heating – resulted in important disconnection rates in Central and Eastern European countries in the post-communist transition period and have posed important challenges for DH revitalisation e.g. in Romania [10]. These bad practices also raise concerns in countries with immature DH sectors. For example, in the UK, it is feared that these practices will diminish consumers' trust in and preference for DH, hindering DH adoption, while ethical concerns are also raised [9]. Ethical concerns have also been expressed in Denmark [11], where a strong public debate (with different views on the reasons and magnitude of the problem and adequate solutions) has taken place in the last years regarding the effectiveness of the existing regulation to promote cost optimisation and lower DH prices.

Given the evidence of poor practices by (some) DH companies and the need to both protect consumers and encourage DH adoption, discussions - and confusion - on how to develop and implement institutional conditions that effectively promote fair conditions for DH consumers continue in several European countries. This study intends to support the ongoing discussions by providing new insights from Denmark and Sweden. To this end, the study leverages the analytical framework for “consumer power in natural monopolies” [12], which distinguishes four dimensions of consumer power (or categories of institutional conditions) concerning natural monopolies: “state regulative power”, “ownership power”, “buying power” and “communicative power”.

Previous studies have described one or more of the dimensions; for example: Magnusson [13] analyses changes in DH ownership in Sweden, Åberg et al. [14] analyse whether market competition exists in Sweden between DH and ground source heat pumps (i.e. buying power), Odgaard and Djørup [5] review DH price regulations, Patronen et al. [15] describe DH regulation in Nordic Countries and expand on the various Swedish initiatives to raise consumers' communicative power, and Chittum and Østergaard [16] describe all the four dimensions of consumer power in Denmark. However, no literature has been found on why different institutional configurations managed or failed to promote fair conditions for DH consumers.

As a first step in such analysis, this paper deals with a comparison of two relatively similar DH countries that have succeeded in reaching and maintaining high shares of residential buildings supplied by DH: Denmark (64%) [17] and Sweden (51%) [18]. This is fruitful because, despite similarities, the countries have implemented rather different regulations and governance models during the last decades regarding price and quality control of DH systems. When comparing DH in Nordic countries, Sweden has the largest share of commercial ownership [13] and the softest public regulation for DH [19]. In contrast, Denmark has the largest share of consumer ownership [20] and the strictest public regulation for DH [19]. Furthermore, there have been some examples of DH companies misusing their monopoly position both in Denmark [5] and in Sweden [21]. Thus, a long-term and systematic analysis of these two countries will advance the understanding of effective institutional conditions to promote DH in European countries.

The study is guided by the research questions below:

1. What institutional conditions related to the four dimensions of consumer power have been implemented in Denmark and Sweden?
2. What issues indicating unfair conditions for DH consumers can be identified for the different institutional configurations and why?

Section 2 introduces the theoretical approach and analytical framework of the study. Section 3 presents the applied methodology for data collection and analysis. Sections 4 and 5 answer research questions 1 and 2 respectively. Section 6 summarises the key findings of the study. Finally, section 7 presents and discusses the conclusions.

2. Theoretical approach and analytical framework

This paper studies why different institutional configurations have managed or failed to promote fair conditions for DH consumers in Denmark and Sweden. The examined institutional conditions are the ones defined by the analytical framework for consumer power in natural monopolies [12]. According to this framework, consumer power in a DH company is the result of the combination of four dimensions (or categories of institutional conditions): “state regulative power”, “ownership power”, “buying power” and “communicative power” (see Table 1). The combination may result in various configurations and levels of consumer power. The hypothesis is that there are links between the consumer power conferred by the combination of the four categories of institutional conditions and DH companies' behaviour regarding consumers' interests. It is assumed that the institutional configurations that are effective in promoting fair conditions for DH consumers will encourage DH adoption.

The study focuses on the supply side (see Table 1) because the demand side has similar characteristics for all heat supply technologies and therefore is not specific for DH. Nonetheless, analysing both the demand and supply sides would be relevant for studies with other purposes, e.g. to advance the understanding about the challenges and opportunities to transition into fourth generation (4G) DH systems, where coordination in demand and supply side investments would reduce the overall system costs [7]. Furthermore, the scope of the study is limited to residential DH consumers, who are the most vulnerable consumers in the presence of a monopolistic DH company because of their little bargaining power [22]. Hence, residential DH consumers need the highest level of protection [22].

It is important to highlight that there is a strong interdependence between the communicative power and the other three dimensions of consumer power. Without sufficient information and transparency, it is not possible to exercise the state regulative power, the ownership power or the buying power. Hence, without communicative power, the other three dimensions are reduced to zero.

It is understood that conditions for consumers are fair when DH companies comply with their duty of heat supply and customer relation at satisfactory quality levels while charging a reasonable heat price. This understanding relates to notions about distributional justice by promoting a fair distribution of the benefits of the adoption of DH between consumers, DH companies and the society. Table 2 presents parameters that regulators, DH companies, consumers and other stakeholders could consider when evaluating whether the quality is satisfactory and the price is reasonable. The three categories can be expected to be interrelated. However, they are kept separated for the analytical purposes of the study. The goal

Table 1

The four dimensions of consumer power in a DH company.

The dimensions of consumer power	In relation to	
	The demand side	The supply side (the focus of this study)
State regulative power	Building regulation regarding building codes, access to loans or subsidies for energy renovations, regulation of heat tariff structures, etc. as well as the execution of the regulation through heat planning authorities, etc.	DH regulation regarding mandatory or free connection, heat planning, profits, price setting, price control, investments and the green transition, etc. as well as the execution of the regulation through heat planning authorities, regulatory authorities, etc.
Ownership power	The ownership of the building and the occupants' decision power.	Different ownership models and the influence of consumers on the decisions of the DH company.
Buying power	Heat consumption and heat conservation.	The selection of the heat supply system (DH or not).
Communicative power	The level of complexity of the heating bills, easiness to communicate with the DH company, etc.	Openness and accessibility of information about e.g. DH prices and costs, upcoming investments, benchmarking with other DH companies, alternatives to DH, etc.

Table 2

Parameters to evaluate the fairness of conditions for DH consumers.

Satisfactory product quality	Satisfactory customer relation quality	Reasonable heat price
The necessary temperature and pressure, hours of availability, environmental footprint, effect on local economy, etc.	Available communication channels and their user-friendliness, time and helpfulness of response, energy conservation advice, etc.	Value for money, competitiveness compared to other heat systems, affordability, stability of prices over time, company's profits on DH, promotion of energy conservation, etc.

of the study is not to assess the level of Danish and Swedish DH consumers' satisfaction with the product, customer relation or heat prices but to understand why different configurations of institutional conditions have been (un)successful in influencing DH companies' practices to get fair conditions for DH consumers. To do this, a thorough analysis of the institutional frameworks implemented in Denmark and Sweden is carried out and indicators of unfair conditions for DH consumers traced. The indicators are traced by collecting data about DH problems and customer complaints related to the parameters presented in [Table 2](#) (see section 3 for more details).

3. Methodology

As a first step in the analysis of why different institutional configurations manage or fail to promote fair conditions for DH consumers, it was decided to focus on experts' understanding and views on the issue. Experts have deep insights about institutional frameworks, indicators of unfair conditions for DH consumers and the causal relations between the two as well as a long-term perspective. Therefore, collecting and analysing experts' insights is necessary to develop the fundamental understanding of the issue and is helpful to guide further research steps on the topic, which could include a more thorough study of consumers' views.

The data were collected via a structured literature review, semi-structured interviews with experts and other data sources such as resolutions of consumer complaints, legal documents and relevant stakeholders' websites. A thematic analysis of the data was carried out utilising a codebook based on [Tables 1 and 2](#) in section 2 to (1) describe the institutional conditions and assess the dimensions of consumer power in different periods, (2) identify and describe indicators of unfair conditions for DH consumers and (3) examine the causal links between different combinations of institutional conditions and unfair conditions for DH consumers. [Fig. 1](#) presents the applied methodology.

Due to the versatility and coverage of both engineering and social science content, the Scopus database was used to retrieve peer-reviewed scientific articles written in English about DH in Sweden and Denmark. Firstly, relevant articles were selected by their titles and abstracts. Secondly, the selected articles were analysed. Unrelated articles were also dismissed at this stage. Thirdly,

additional literature was found as references in the already selected articles and suggested by colleagues and the interviewed experts. In total, 76 pieces of literature were reviewed, including peer-reviewed articles, reports, books and book chapters.

Semi-structured interviews with experts in Denmark and Sweden were held to clarify doubts, fill information gaps and discuss the preliminary findings. Only the interview with the Swedish DH company was conducted before the second step in the literature review had been concluded. [Table 3](#) presents the interviewed experts and the focus of the interviews. The same questions were asked to several experts to account for possible disagreements. The interviews were recorded and transcribed for their analysis. In two cases, follow-up questions were asked and answered by email. The text referring to the information obtained in the interviews was checked by the interviewees and corrected by the authors when necessary.

The understanding of unfair conditions for DH consumers obtained from the literature review and expert interviews was complemented with the study of consumer-started initiatives and consumer complaints handled by the Danish Regulatory Authority and the Swedish Board of DH. It is acknowledged the potential to gain additional insights (about issues that could be occurring in DH systems as well as about how these issues influence the levels of DH consumers' satisfaction, perception of fairness or DH adoption) by e.g. surveying and interviewing consumers. However, this is not the focus of the study and it is understood that the general overview of indicators of unfair DH conditions for consumers provided by the consulted data sources is sufficient for the purpose of the study presented in this paper – a first step in the analysis of why different configurations of institutional conditions manage or fail to promote fair conditions for DH consumers.

For further steps, it is recommended to consider other data sources and analysis (such as the review of media articles or DH companies' meeting minutes) to expand on the understanding of how higher or lower levels of consumer power influence the achievement of fair conditions for DH consumers. The analytical framework and findings presented in this paper could be part of the preparatory work for such further research steps as well as for a more thorough study of consumers' views.

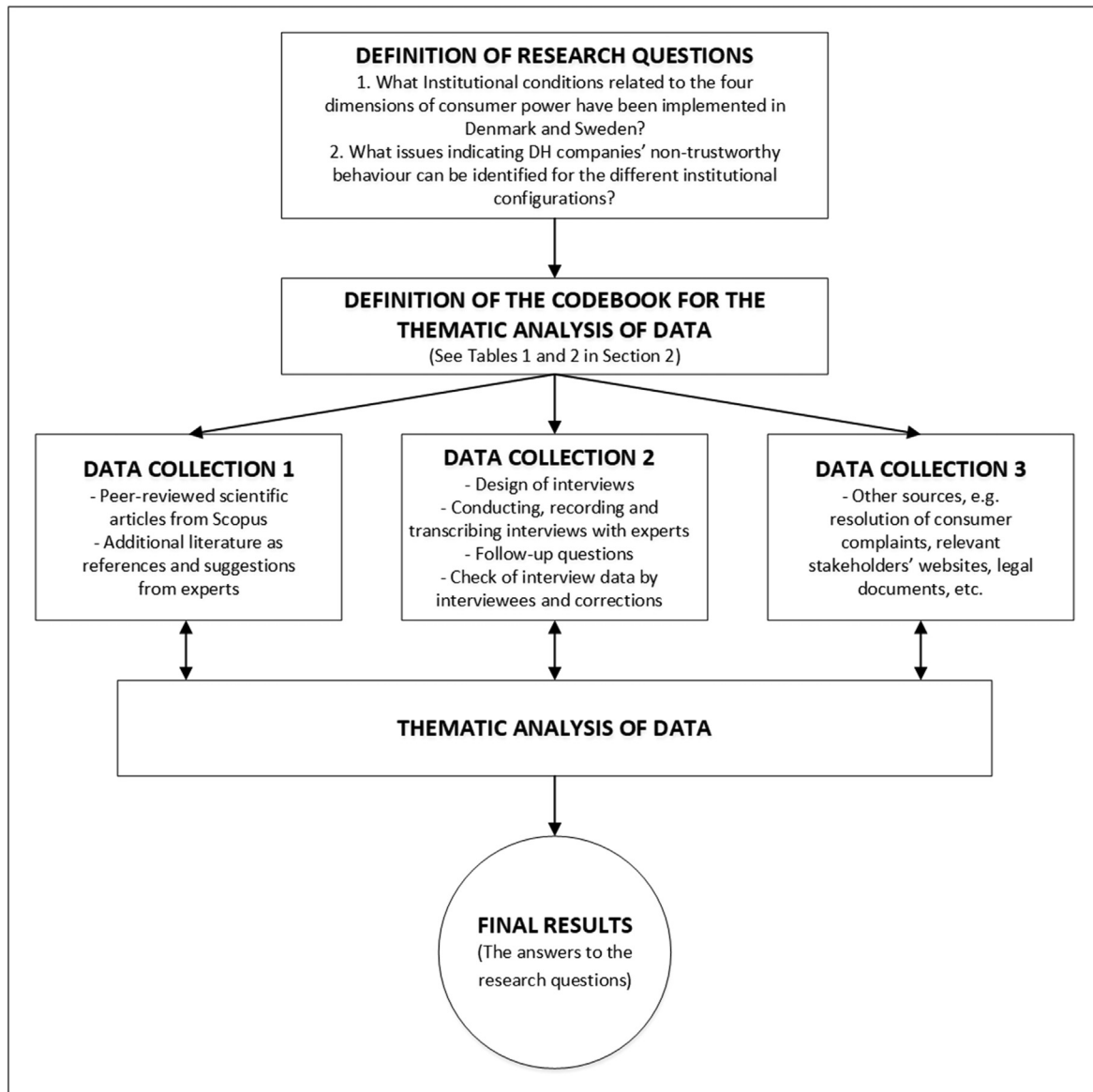


Fig. 1. Methodology: an iterative process between three data sources aiming at filling information gaps, clarifying doubts and corroborating findings.

Table 3

The interviewed Danish and Swedish DH experts. The names of the expert and his/her organisation are only disclosed if he/she has granted the permission to do so.

Interviewee number	Country	Type of Stakeholder	Name of Organisation	Name of Expert	Focus of the interview
1	Denmark	Policy maker/ Industry	Danish Energy Agency, Heat Division (20 years of experience); currently Freelance Consultant	Ole Odgaard	Historical perspective; state regulative, buying, ownership and communicative powers; DH issues; current debate on changes in state regulative power
2	Denmark	Industry	Dansk Fjernvarme – The Danish District Heating Association	Nina Detlefsen	Buying, ownership and communicative powers; DH issues
3	Denmark	Industry	Danish Board of District Heating (DBDH)	Morten J. Duedahl	International perspective on Danish consumer power; state regulative, buying, ownership and communicative powers
4	Denmark	Researcher	–	Anonymous	DH issues; current debate on changes in state regulative power
5	Sweden	Researcher	Lund University	Jenny Palm	State regulative, ownership and communicative powers; DH issues
6	Sweden	Researcher	Linköping University	Dick Magnusson	State regulative, ownership and communicative powers; DH issues
7	Sweden	Researcher	Halmstad University	Sven Werner	Historical perspective; state regulative, buying, ownership and communicative powers; DH issues
8	Sweden	Industry	Energiföretagen Sverige - Swedenergy	Daniel Lundqvist	Buying and communicative powers; DH issues
9	Sweden	Industry	Göteborg Energi	Ulf Hagman	Buying, ownership and communicative powers

4. Institutional conditions for district heating in Denmark and Sweden

Figs. 2 and 3 present the level and configuration of consumer power in DH companies resulting from different combinations of institutional conditions in Denmark and Sweden in different periods and for the most common ownership models implemented in these countries. By the end of the three periods, DH accounted for about 30 % [23], 57 % and 64 % [17], respectively, of the residential heat market in Denmark and for approximately 30 %, 47 % and 51 %, respectively, in Sweden [18].

In Denmark [24] and Sweden [21], DH started as local initiatives, applying the cost-based pricing principle and with the purpose of cheaper heat, lower air pollution and improved indoor environment. Both countries have introduced policies that promoted DH with the goal of increasing security of supply, energy efficiency and greener heat production. In spite of these similarities, differences are observed already in the first period of DH implementation; in Sweden, the DH sector was dominated by municipal ownership in the period 1948–1995 [13]; in Denmark, municipal ownership has been implemented in the large- and medium-size urban areas and consumer cooperatives in the small-size ones (Interviews 1–3) [20]. These differences obey to cultural dissimilarities between the two countries (Interviews 3–5).

In the second period, the differences accentuated with the introduction of contrasting policies and DH regulation as well as ownership changes related to the liberalisation of the electricity sector in Sweden (Interview 7) [13]. Denmark has enacted strong policies and regulations to develop and expand DH (which in some localities (Interviews 1 and 2) [25] have resulted in very low buying power for the consumers due to the mandatory connection and the obligation to remain connected) and to control the monopolistic DH companies for example with cost-based pricing regulation and the standard DH investment framework [16]. Sweden removed the cost-based pricing regulation for municipal companies in 1996 [26], has focused on market competition and consumers' buying power and implemented softer public regulations with no price regulation [21].

The third period is characterised by important improvements of consumers' communicative power in both countries, with increased transparency through, for example, regular publication of DH prices by the regulatory authorities, access to financial and

technical reports and the creation of the Swedish District Heating Board to mediate between DH consumers and companies on prices and other issues in accordance with the District Heating Act [27]. The Swedish District Heating Board has handled 274 mediation applications in the period 2008–2019, however not all of them have led to an agreement between the consumer(s) and the DH company [28]. The Board's work has received positive evaluations, but its mediation role without powers to judge in the issues has been pointed out as a weakness [29]. In Sweden, besides public regulation, initiatives such as the Nils Holgersson Report [30] and the Price Dialogue [31] –started by associations which represent consumer interests and DH companies– have also contributed to increasing transparency (Interviews 6–8). Since 1996, the Nils Holgersson Report has informed annually about DH and other commodity prices for a standard house in all Swedish municipalities. Established in 2011, the Price Dialogue defines rules for the transparency of DH companies towards their customers about DH price changes and the reasons behind them. DH companies must apply to become members of the Price Dialogue and their membership is revised on an annual basis in accordance with the compliance of the rules. In October 2020, 44 DH companies are members of the Price Dialogue. However, the representation of residential consumers in the Price Dialogue is mainly through housing associations and companies; i.e. large residential customers (Interviews 5 and 9) [32]. Nonetheless, the Price Dialogue has received positive evaluations by independent consultants as well as the Energy Markets Inspectorate [31]. Both Swedish and Danish experts have stated that DH consumers have access to a lot of data but have also pointed out that it can be difficult for a regular consumer to understand all the information (Interviews 2, 3 and 5–8). Finally, Denmark has slightly increased consumers' buying power in the third period by abolishing the right to request mandatory connection to the local DH system for newly built buildings and the impossibility to impose the obligation to remain connected after 2018 [33]. Moreover, a few medium-size DH companies have decided to remove the obligation to remain connected and “make their consumers free” (Interviews 2 and 3).

Local ownership, cost-based pricing and high levels of transparency and communicative power (Interviews 1–3 and 5–8) are common in both countries despite differences in regulation. Municipal companies and consumer cooperatives supply about 94 % of the DH demand in Denmark [34]. In Sweden, local

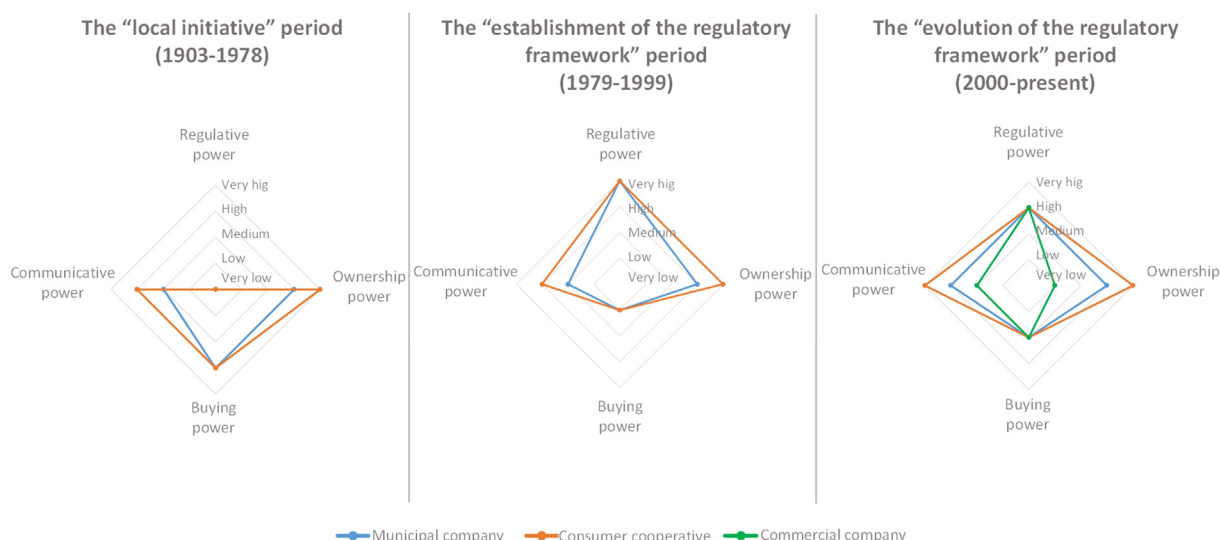


Fig. 2. Consumer power in DH companies in Denmark in the three different periods. Consumer power is shown only for the most common ownership models [20].

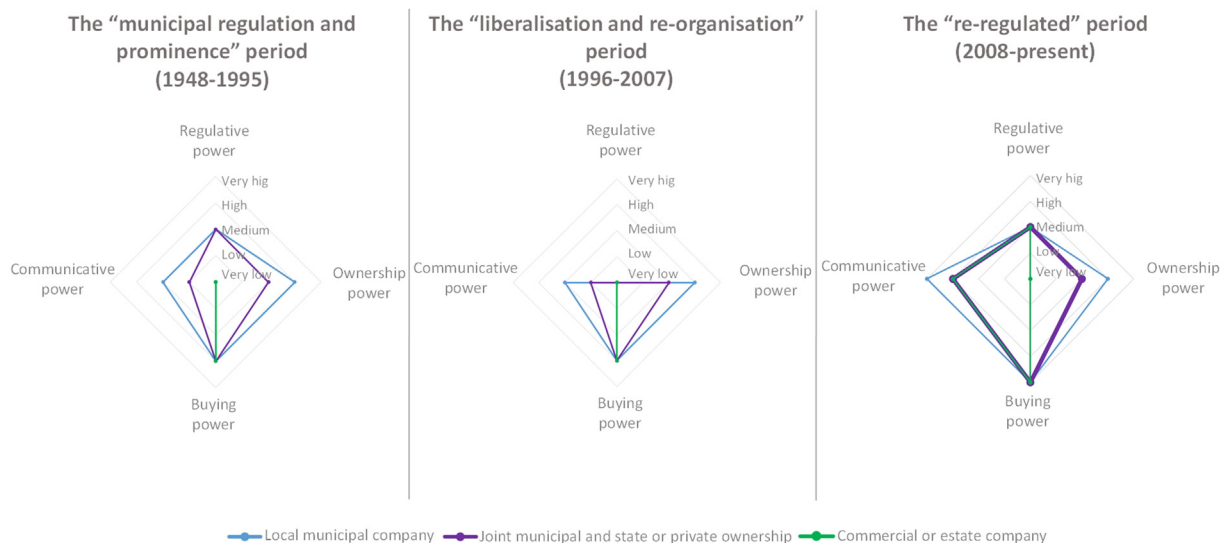


Fig. 3. Consumer power in DH companies in Sweden in different periods. Consumer power is shown only for the most common ownership models [13].

municipal companies supply about 63 % of the DH demand [13]. In a study on DH prices in Sweden, Åberg et al. [35] found out that 63 % of the municipalities and 11 % of the commercial companies that participated in the study apply cost-based pricing (voluntarily, as this is not requested by law), whereas all the other municipal and commercial companies as well as the state-owned company Vattenfall apply market-based pricing. Market-based pricing means that the DH company sets the DH price carefully considering the cheapest heat supply alternative (Interview 8). The high levels of transparency and communicative power in Denmark and Sweden are promoted by the public regulation for DH as well as cultural aspects; the use of media by citizens and other stakeholders to raise issues of common concern (like DH) and debate them is very common [36] (Interviews 1, 3 and 6–8) and municipalities and consumer cooperatives tend to be very transparent (Interviews 1–3 and 5). However, commercial companies –and municipal companies applying the market-based price principle (Interview 8)– can be more opaque and avoid full disclosure of costs to prevent competition to take advantage of that (Interviews 1, 5 and 8). Therefore, it is possible to conclude that DH companies' transparency as well as prices have an ownership and values component (see sections 5.2.1 and 5.2.4 for more details).

Consumer cooperatives or local municipal companies confer high and very high levels of consumers' ownership power. In consumer cooperatives, each DH consumer holds one vote, board members are elected annually or biannually, and strategic plans or decisions are voted on in general assemblies. Furthermore, consumers have the power to dismiss the board of the cooperative if they are discontent with their management (Interviews 2 and 3). In municipal companies, the ownership power is exercised indirectly via the municipal elections [16] (Interviews 3, 5–7 and 9). In joint municipal and state-owned or commercial companies, ownership power decreases as local DH consumers have very little power over the state-owned or commercial company's decisions (Interviews 1, 3 and 5–7). It could be correct to assume that, in a joint ownership model, 50 % municipal shares results in consumers' ownership power being medium and lower shares result in low or very low ownership power. In distant municipal companies, consumers' ownership power is also very low (Interviews 6 and 7). In Denmark, ownership power in commercial DH companies is slightly higher than in Sweden because the public regulation requires that a majority of DH board members are elected by local DH consumers or

by one of the local municipal boards [37]. However, commercial companies have not always followed the Danish regulation in this respect (see e.g. Ref. [38]).

5. Indicators of unfair conditions for district heating consumers in Denmark and Sweden

Tables 4 and 5 present the issues identified in Denmark and Sweden that could indicate unfair conditions for DH consumers. The issues are explained further in the following sub-sections.

5.1. Dissatisfactory product or customer relation

Literature and expert interviews did not reveal major issues regarding customer dissatisfaction with product or customer relation quality. However, Duedahl mentioned that heavy arguments have happened in general assemblies in Denmark, resulting in the DH board changing direction to accommodate disagreements or being substituted (Interview 3). This could explain why almost no reference to dissatisfactory product or customer service has been found in the reviewed literature. It could also be because Nordic countries are well-known for their modern and well-functioning DH systems, which are often used as "best practice" examples for benchmarking (see e.g. Ref. [44] for Denmark and [45] for Sweden).

It seems correct to conclude that the quality of the product has been very high in Denmark and Sweden, providing high levels of comfort to consumers with consumer controlled indoor temperatures, heat supply 24/7 all around the year and very short periods of DH unavailability (Interviews 2, 3, 5 and 8) –except for a few incidents (Interviews 4 and 7). Furthermore, Danish [23] and Swedish [46] policies and regulations have promoted increasingly environmentally friendly DH production (Interviews 7 and 9), supported by considerable research on the topic [21] and industry guidelines (see e.g. Ref. [47] for Denmark and [48] for Sweden). Nonetheless, there have also been some issues; the most salient ones are poor maintenance (regarding e.g. late detection and reparation of temperature faults and water leakages) or late replacement of pipes and other system components. Faults in substations and consumers' system seem to be still a quite common issue both in Denmark [40] and in Sweden [21] –even if an increasing number of DH companies are already addressing it [49]. In contrast, other maintenance and component replacement issues could be limited to just a

Table 4
Indicators of unfair conditions for DH consumers in Denmark in different periods.

Unfair conditions for DH consumers	The “local initiative” period (1903–1978)	The “regulatory framework establishment” period (1979–1999)	The “evolution of the regulatory framework” period (2000–present)
Dissatisfactory product or customer relation	No data found	- A few accidents [39]. (Interview 4) - A few cases of poor maintenance of the DH system. (Interview 4)	- A few accidents [39]. - A few cases of poor maintenance of the DH system [5] or consumers' system [40]. - A few cases where old technology has not been replaced with the best available technology. (Interview 2)
Unreasonable heat prices	No data found	- Financial issues and high DH prices, particularly in the green field plants and other DH systems using natural gas [23]. (Interview 1)	- Financial issues and high DH prices, particularly in some small-scale DH systems [5]. (Interviews 1 and 2) - High DH prices in commercially owned DH companies [5]. (Interview 1) - It can be difficult for the Regulatory Authority to identify all the cases of law infringement or questionable practices by DH companies [5]. (Interviews 1 and 4) - Low pressure to improve productive efficiency in DH companies [11]. - High fixed costs reduce energy conservation in connected buildings [7].

Table 5
Indicators of unfair conditions for DH consumers in Sweden in different periods.

Unfair conditions for DH consumers	The “municipal regulation and prominence” period (1948–1995)	The “liberalisation and re-organisation” period (1996–2007)	The “re-regulated” period (2008–present)
Dissatisfactory product or customer relation	- A few cases of poor maintenance of the DH system [41]. - A few accidents [39].	- Protests against the use of coal in Stockholm [42]. - Lack of security of supply in a few DH systems due to the bankruptcy of a DH company [8]. - A few accidents [39].	- High return temperatures due to temperature faults at customer substations and secondary heating systems [21]. - A few accidents [39].
Unreasonable heat prices	No data found	- Significant increases in DH prices, particularly in Stockholm and Uppsala [21]. - High price increases in a few DH systems after the bankruptcy of a DH company [8]. - Strong debate on whether DH ought to be allowed to make profits or not [21] and on the ethics of “indirect municipal tax” collection (Interview 7). - Low pressure to improve internal productive efficiency [43].	- Commercially and state-owned DH companies tend to have higher DH prices [35]. - It can be difficult for the Regulatory Authority to identify all the cases of law infringement or questionable practices by the DH companies [22]. - Complex DH bills limit energy conservation, behavioural changes, etc. [6] (Interview 8) - Changes in DH prices after investments in supplementary heating systems prolong the payback period of investments [6]. (Interview 8) - Diverse opinions on whether DH ought to be allowed to make profits or not and on the ethics of “indirect municipal tax” collection (Interviews 5 and 7).

few “poorly managed” DH systems. Generally, these issues do not impact consumer comfort but can reduce the system’s efficiency and result in higher DH prices.

Regarding customer relation, the collected data indicates that the quality was just acceptable in the first periods. In recent years, significant improvements have been observed where consumers are not seen as “heat load” any longer but as customers (Interviews 3, 6 and 8) [32]. The change is related to increased levels of consumers’ buying power, which has made some DH companies adopt marketing strategies and reflect on their business models to remain competitive (Interview 3) [32].

5.2. Unreasonable district heating prices

Several concerns and issues regarding DH costs and prices were identified.

5.2.1. High district heating prices and price increases due to low consumer power

Price increases or high prices have been observed in periods or situations with low consumer power. In Denmark, problems occurred in commercially owned DH companies (Interview 1) [5]; in Sweden, in the “liberalisation and re-organisation” period [21]

(Interviews 5 and 7).

In 2008, the Danish Regulatory Authority investigated the costs of DH systems owned by E. ON [50], finding firstly the company being opaque and secondly unreasonable DH prices resulting from the mother company selling services at high prices to the daughter DH companies (Interview 1) [51]. To solve the high price issue, some of the DH systems owned by E. ON were bought back by the local consumers or the local municipality and prices decreased sharply in the following years [5].

In the “liberalisation and re-organisation” period, DH companies in Sweden increased their prices, particularly in Stockholm and Uppsala [21]. There were several reasons that fostered the price increases, including raises in energy and CO₂ taxes and the poor technical situation of some DH systems, which required investments for renovation [41] (Interview 8). However, increases in revenues and profits were also observed [52], resulting from the new business logic and values in DH [41]. There were also sudden and substantial price increases in some DH systems when the bankruptcy estate took over the management of the system after a company's bankruptcy [8]. In the “re-regulated” period, DH price increases have been more subtle, particularly after 2013 [53] (Interview 8). The main reason is lower biomass prices (Interview 7), but the increased transparency provided by the Price Dialogue

and greater competition between DH and individual heating in multifamily buildings might also be a contributing factor (Interview 8). Palm and Werner argue that there are no important issues with DH prices in Sweden (Interview 5) – except the threat of biomass prices increasing in the coming years (Interview 7). Nevertheless, it is worth noting the price difference between DH systems based on their ownership. Municipal DH companies (especially those maintaining the cost-based price setting principle (Interview 7)) tend to have lower DH prices than commercial or state owned companies [35].

5.2.2. Policy induced financial issues and high district heating prices

Since the end of the 1990s, a recurrent concern is the financial issues and high DH prices of some DH companies in Denmark. These can be the result of bad managerial decisions and/or national policies (Interviews 1 and 2). For example, in the end of the 1990s, some small DH companies suffered financial problems due to changes in the economic conditions for natural gas and CHP [23] – to deal with this, the Danish Government and natural gas companies supported those DH companies financially [23]. The problem showed weaknesses in the standard methodology for the economic calculations of DH investments in the 1990s, which was not as quality assured as nowadays (Interview 1). Financial issues and high DH prices, in particular in some small companies (Interviews 1–3), reoccurred resulting from policies limiting technology choices [23]. In order to alleviate the policy induced issues, several actions have been taken, for example: in 2013 and 2015, small DH systems in natural gas areas were allowed to install 1 MW biomass boilers in order to reduce DH prices [23]; in 2017–2018, 29 DH companies with small-scale natural gas CHP units were granted subsidies summing to approximately EUR 6.87 million in order to pay for up to 15 % of the investment in an electric heat pump [54]; and, in 2019–2023, approximately EUR 9.4 million could be granted to customers of DH systems with unsustainable economies to abandon DH and install individual heat pumps [55]. It must be mentioned that most small DH companies are well run and competitive and that only some have suffered from bad investment and/or managerial decisions (Interview 2).

5.2.3. Low external pressure to improve productive efficiency

Both Denmark and Sweden have had concerns about low external pressure to improve productive efficiency in DH companies. Productive efficiency relates to the lowest possible cost of producing a product or a service at a certain quality and requires best-practice managerial and technological processes. Productive inefficiencies were seen as an issue in the “liberalisation and reorganisation” period in Sweden [43], but not in the “re-regulated” period (Interviews 6 and 7). Increased buying power of the consumers, resulting from greater competition between DH and other heat supply technologies (Interviews 7–9) [32], is thought to have contributed to reducing productive inefficiencies (Interviews 6 and 7). In contrast, productive inefficiency has been the focus of hot debates in Denmark in the last years.

Different stakeholders have diverse opinions and understandings about the magnitude of productive inefficiencies in Danish DH companies, the causes and suitable solutions. Based on two economic models, the Regulatory Authority estimates that DH companies could cut their costs by EUR 110–204 million per year in the period 2022–2030 [11]. The Regulatory Authority claims that the lack of competition and the cost-based price setting regulation do not incentivise productive efficiency to the extent free market competition would and that this is why productive efficiency varies greatly between DH companies. To tackle the problem, the Regulatory Authority recommends replacing the cost-based regulation with a revenue cap regulation combined with general and

individual requirements for cost reductions calculated via benchmarking (using a centralised data-based model). The possibility to eliminate restrictions in DH companies’ technology choices is also mentioned.

Other stakeholders state that the problem of productive inefficiencies is limited to a few DH companies (Interview 2), i.e. about 5–10 % (Interview 1). Moreover, several experts seem to agree that the issue results from information asymmetry, agency problems and lack of expertise (Interviews 1–4). They argue that –at least in most companies (Interview 2)– the high internal cost optimisation pressure in municipal or consumer-owned DH companies compensates for the low external pressure resulting from the cost-based regulation and the low market competition (Interviews 1–3). Moreover, according to Odgaard, the regular publication of DH prices has introduced an element of competition between DH companies (Interview 1). The Regulatory Authority seems to disagree with this understanding [11]. This could be due to the results of the economic model analysis and economic theories on natural monopolies. However, economic literature and theories neglect the impacts of ownership in natural monopolies regarding consumers’ decision-making power and access to information. Therefore, such theories could be misleading in the case of municipal or consumer ownership [56].

The benchmarking solution proposed by the Regulatory Authority has been criticised for, amongst others, focusing on cost reduction requirements without providing any information or tools to accomplish the reduction and, hence, not addressing directly the causes of productive inefficiency (Interviews 1 and 4). An alternative solution could be the creation of a task force based at the Danish DH Association to evaluate DH companies’ productive efficiency every third or fourth year and provide customised consultancy (on non-profit basis) on managerial decisions and on how to carry out improvements (Interview 1). Another alternative is implementing a different type of benchmarking, carried out by a qualified third party (such as the Danish DH Association) at a cost for the DH company and is confidential and resulting in recommendations for improving productive efficiency (Interview 4). Finally, the Danish DH Association suggests an “agreement based regulation”, where the DH sector commits to a common cost reduction goal –without strict individual goals for each DH company (Interview 2).

5.2.4. The regulatory authorities’ limitations in controlling district heating companies

Hult [22] and Odgaard and Djørup [5] highlight weaknesses in monitoring DH companies and, hence, in exercising the state regulative power. The reason is that the Regulatory Authorities depend on data provided by the DH companies. Lundqvist mentioned that few staff have been assigned to monitoring DH in Sweden in the last years. The reason could be that the increased transparency and market competition has led the Authorities to consider that consumer power has increased and that the need for them to monitor the DH companies is low (Interview 8).

In Denmark, the investigations on the costs [50] and the lack of compliance with consumers’ representation on the board [38] of DH companies owned by E. ON started only after consumers’ complaints and broad media coverage (Interview 1). This and other examples (see e.g. Ref. [57]) prove the impossibility of the Regulatory Authority to discover all law infringements and questionable practices without consumers’ support. Similarly, the investigation of DH price increases in Stockholm [58] and the Swedish national investigations that resulted in the design and implementation of the DH Act of 2008 [21] only started after multiple consumer complaints and a strong debate in the media about DH price increases in Sweden [41]. Thus, consumers’ communicative power

plays a crucial role in monitoring and controlling the monopolistic DH companies.

5.2.5. Unreasonable price tariff structures and complex district heating bills

In recent years, there has been an increasing concern about DH price tariff structures, the complexity of DH bills and how these influence DH consumers' decisions. In Denmark, a high share of fixed costs in DH bills results in negative net present values for a considerable share of possible energy conservation measures and, therefore, could be preventing energy conservation in connected buildings [7]. Odgaard argues that the share of fixed DH prices is not that high (i.e. about 25 % as a weighted average) and that there is room for DH consumers to act on their heat demand (Interview 1). On the other hand, Detlefsen argues that the problem is smaller now since changes have been made in DH tariff structures in some DH companies (Interview 2). Even so, residential buildings' heat demand has reduced only 4.7 % in the period 2008–2018 [17], in contrast to the 40 % reduction that would be necessary to optimise the cost of transitioning into 4GDH systems and a 100 % renewable energy system in Denmark by 2050 [7]. To this end, stronger incentives will be necessary [7].

In Sweden, some studies have highlighted the complexity of the DH bills, which may prevent behavioural changes or energy conservation because it is not clear if or how much the bill would reduce [6]. Furthermore, some consumers have complained about changes in DH tariffs after they had invested in a supplementary heat supply system such as a heat pump or solar collectors [6] (Interview 8). According to Lundqvist, the changes in DH tariffs have been corrections meant to promote behavioural changes and investments that contribute to reducing the overall costs of the DH system (Interview 8) [6]. Lundqvist also highlighted that customers who participate in the Price Dialogue are more capable of understanding DH bills (Interview 8). Furthermore, some DH companies have started to provide consultancy services for their customers about actions to reduce their energy demand and bills [32] (Interview 9). This forms part of the companies' business strategies to keep their market shares [32].

5.2.6. Ethical considerations on price setting

The DH price increase in Sweden after the liberalisation sparked a strong debate on whether DH –being a natural monopoly– ought to be allowed to make profits or not [36] and on the ethics of indirect municipal tax collection in municipal DH companies (Interview 7). Consumer complaints and the debates were broadly covered by the media, creating pressure on politicians and DH companies (Interviews 7 and 8) [41]. Currently, there are diverse opinions about marketability of DH and indirect tax collection by municipal DH companies in Sweden –as shown by choices of cost-based or market-based price setting [35]–, but it is not a strong debate anymore (Interview 7).

Another valid discussion could be on whether or not the profits of DH stay within the local community [20]. Local ownership can be essential so that cost reductions in DH companies provide local benefits, either in the form of lower energy bills (with cost-based pricing) or local development projects (with market-based pricing).

6. Key findings from Denmark and Sweden

The analysis of different combinations of institutional conditions and indicators of unfair conditions for DH consumers in Denmark and Sweden makes it possible to identify important lessons for the design of effective institutional conditions to promote fair conditions for DH consumers and, in this way, foster consumers' adoption of DH:

- Free choice of heat supply technology alone does not put sufficient pressure on DH companies to set reasonable DH prices. It must be supplemented with regulation, high communicative power and possibly high or very high ownership power.
- To ensure free choice of heat supply technology, individual heating solutions must be available at a competitive price. However, from a socio-economic perspective, DH can be cheaper than individual heating, especially in areas densely populated and/or with excess heat [3] (Interview 2). Therefore, creating market competition can result in additional costs for society due to the economic incentives that would be necessary and the reduction in the connected heat demand density.
- Strong price regulation (such as the cost-based regulation in Denmark) does not ensure reasonable heat prices, unless high or very high ownership power is in place and coupled with high communicative power. Furthermore, it could be important to address issues such as information asymmetry, agency problems and lack of expertise.
- Ownership of DH companies influences DH prices and transparency. Under the same regulation, consumer cooperatives and municipal companies result in lower DH prices and higher transparency than commercial or state-owned companies. In Sweden, companies with cost-based pricing are more open about their costs than those with market-based pricing (Interview 8).
- With the right combination of policies and regulations, local consumer cooperatives and local municipal companies can develop and run DH systems and contribute greatly to DH implementation. Cultural aspects may influence the choice of ownership.
- Regulatory Authorities might not be able to identify all law infringements or questionable practices by the DH companies. Transparency, access to information and media coverage are important to monitor and control DH companies. However, for this to work, Regulatory Authorities and policy makers must address the issues, protecting consumers' interests and rights.
- Management of DH companies requires knowledge and expertise, which some companies may lack leading to poor managerial decisions. Thus, standard guidelines for investment decision-making, merging of small companies and customised expert support can mitigate the problem.
- Short-term cost reduction approaches may lead to e.g. poor system maintenance and higher future costs (Interviews 3 and 4).

Transferable lessons between Denmark and Sweden are:

- Denmark could implement strategies to improve consumers' communicative power, like the Price Dialogue and the Swedish DH Board –imperative for commercial companies, but also relevant for municipal companies and consumer cooperatives.
- Sweden could consider boosting consumer-friendly dialogues (Interviews 5 and 6) and increasing consumer ownership power through policy support for local municipal companies or consumer shareholding (Interview 5) or intensifying consumer representation in the boards of DH companies. However, when asked about the improvements in ownership power, the Swedish experts found them quite improbable (Interviews 5 and 6) and even unnecessary –given that DH poses no major problems in Sweden at the moment (Interview 7).

7. Conclusions and discussion

The article presents a systematic analysis of the causal links

between different combinations of institutional conditions (related to the four dimensions of consumer power) and indicators of unfair conditions for DH consumers in two Nordic countries: Denmark and Sweden. The analysis has focused on experts' insights. It is concluded that institutional conditions that lead to high consumer power are decisive to lower DH prices. Whether a "free market" approach (like in Sweden) or a "strict regulation" approach (like in Denmark) is applied, local ownership, transparency and communication are necessary to reduce DH prices. Regarding customer satisfaction with product or customer relation quality, the reviewed literature and expert interviews did not reveal major issues. Further research could consider other data sources (such as customer surveys, media articles and DH companies' assembly minutes) as well as other countries (with mature and immature DH sectors) to advance the understanding of effective institutional conditions to promote satisfactory product and customer relation quality in DH and of additional DH price issues that might not have been identified in this study.

Even if Denmark and Sweden have applied very different regulatory frameworks and governance models for DH, there are also significant similarities in the cultures of these two countries, e.g. tradition for municipal ownership and planning, highly democratic values, responsive policy makers and regulatory authorities, etc. Other EU countries may (or may not) share these cultural aspects. Thus, complementary studies that analyse the transferability of Danish and Swedish lessons and the causal links between institutional conditions and fair conditions for DH consumers in other EU countries are necessary.

Different countries, regions and local communities in the EU have a higher or lower level of experience with and preference/reluctance for municipal companies and consumer cooperatives in the energy sector. However, these ownership models are increasingly common across the EU and the new EU Directives support their implementation. Moreover, targeted policies may support the implementation and development of such ownership models. In cultures with high reluctance towards such ownership models, other alternatives could be joint ownership models, having a majority of democratically and annually or biannually elected consumers representatives in DH company boards or leasing or concession contracts.

Finally, it would also be relevant to expand the Danish and Swedish analysis by examining how the issue of trust in DH is understood and assessed by different stakeholders (including heat consumers) beyond the theoretical framework used for this study. Lastly, the analytical framework for consumer power in DH companies could also be used to advance the understanding about the challenges of implementing or transitioning into 4GDH systems, which requires coordination between the heat demand side and the heat supply side investments to reduce system costs [7].

Credit author statement

Leire Gorroño-Albizu, Conceptualisation, Methodology, Validation, Investigation, Formal analysis, Data curation, Writing – original draft, Visualisation, Project administration. Jaqueline de Godoy, Conceptualisation, Methodology, Investigation, Writing - Reviewing and Editing.

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.

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References

- [1] Connolly D, Lund H, Mathiesen BV, Werner S, Möller B, Persson U, Boermans T, Trier D, Østergaard PA, Nielsen S. Heat Roadmap Europe: combining district heating with heat savings to decarbonise the EU energy system. *Energy Pol* 2014;65:475–89. <https://doi.org/10.1016/j.enpol.2013.10.035>.
- [2] Bertelsen N, Mathiesen BV. EU-28 residential heat supply and consumption: historical development and status. *Energies* 2020;13:1894. <https://doi.org/10.3390/en13081894>.
- [3] Möller B, Wiechers E, Persson U, Grundahl L, Lund RS, Mathiesen BV. Heat Roadmap Europe: towards EU-Wide, local heat supply strategies. *Energy* 2019;177:554–64. <https://doi.org/10.1016/j.energy.2019.04.098>.
- [4] Wissner M. Regulation of district-heating systems. *Util Pol* 2014;31:63–73. <https://doi.org/10.1016/j.jup.2014.09.001>.
- [5] Odgaard O, Djørup S. Review of price regulation regimes for district heating. *Int J sustain Energy plan Manag* 2020;29:127–40. <https://doi.org/10.5278/ijsep.3824>.
- [6] Sernhed K, Gäverud H, Sandgren A. Customer perspectives on district heating price models. *Int J sustain Energy plan Manag* 2017;13:47–60. <https://doi.org/10.5278/ijsep.2017.13.4>.
- [7] Hvelplund F, Krog L, Nielsen S, Terkelsen E, Madsen KB. Policy paradigms for optimal residential heat savings in a transition to 100% renewable energy systems. *Energy Pol* 2019;134:110944. <https://doi.org/10.1016/j.enpol.2019.110944>.
- [8] Palm J. District heating as a secure heat supply - a question of regulation. *Energy Environ* 2007;18:747–60. <https://doi.org/10.1260/095830507782088668>.
- [9] Which? Turning up the heat: getting a fair deal for district heating users. 2015.
- [10] Poputoaia D, Bouzarovski S. Regulating district heating in Romania: legislative challenges and energy efficiency barriers. *Energy Pol* 2010;38:3820–9. <https://doi.org/10.1016/j.enpol.2010.03.002>.
- [11] Frederiksværk. Forsyningstilsynet *Effektiviseringspotentialet i fjernvarmesektoren*. 2020.
- [12] Hvelplund F. Fra fællesje til fjernejerkskab og monopolkontrol: det danske eksempel. In: Christensen E, Christensen P, editors. *Følleleder i forandring*. Aalborg: Aalborg Universitetsforlag; 2007. p. 169–95.
- [13] Magnusson D. Who brings the heat? – from municipal to diversified ownership in the Swedish district heating market post-liberalization. *Energy Res Soc Sci* 2016;22:198–209. <https://doi.org/10.1016/j.erss.2016.10.004>.
- [14] Åberg M, Fåltling L, Lingfors D, Nilsson AM, Forssell A. Do ground source heat pumps challenge the dominant position of district heating in the Swedish heating market? *J Clean Prod* 2020;254. <https://doi.org/10.1016/j.jclepro.2020.120070>.
- [15] Patronen J, Kaura E, Torvestad C. *Nordic heating and cooling. Nordic approach to EU's Heating and Cooling Strategy* 2017.
- [16] Chittum A, Østergaard PA. How Danish communal heat planning empowers municipalities and benefits individual consumers. *Energy Pol* 2014;74:465–74. <https://doi.org/10.1016/j.enpol.2014.08.001>.
- [17] Danish Energy Agency. *Energistatistik* 2018. 2019. Copenhagen.
- [18] Swedish Energy Agency Statistics. *Energy Sweden* 2019. 2020.
- [19] Sandberg E, Sneum DM, Trømborg E. Framework conditions for Nordic district heating - similarities and differences, and why Norway sticks out. *Energy* 2018;149:105–19. <https://doi.org/10.1016/j.energy.2018.01.148>.
- [20] Gorroño-Albizu L, Sperling K, Djørup S. The past, present and uncertain future of community energy in Denmark : critically reviewing and conceptualising citizen ownership. *Energy Res Soc Sci* 2019;57:101231. <https://doi.org/10.1016/j.erss.2019.101231>.
- [21] Werner S. District heating and cooling in Sweden. *Energy* 2017;126:419–29. <https://doi.org/10.1016/j.energy.2017.03.052>.
- [22] Hult D. *Kan man skapa förtroende med lagstiftning?* 2016.
- [23] Danish energy agency Regulation and planning of district heating in Denmark; [Copenhagen];.
- [24] Dansk fjernvarme. *Dansk Fjernvarme i 50 år. 1957-2007* 2007.
- [25] Energjansanalyse Ea. *Konveks; deloitte Konkurrenceanalyse af fjernvarmesektoren*. 2017. Copenhagen.
- [26] Infrastrukturdepartementet RSED. *E ellag (1997:857)*. 1997.

- [27] Infrastrukturdepartementet RSED. *E fjärrvärmelag (2008:263)*. 2008.
- [28] The Swedish District Heating Board. *Fjärrvärmenämndens årsredogörelse 2019*. 2019. Stockholm.
- [29] Andrén L. klimatsmart.se. Utvärdering av Fjärrvärmenämnden. 2011.
- [30] Nils Holgersson homepage.
- [31] kansli P. *Prisdialogens utvärdering*. 2020.
- [32] Lygnerud K. Challenges for business change in district heating. *Energy Sustain Soc* 2018;8. <https://doi.org/10.1186/s13705-018-0161-4>.
- [33] Energi FK. *Lov om ændring af lov om varmforsyning og lov om planlægning. LOV nr 1712 af 27/12/2018* 2018.
- [34] Forsyningstilsynet. *Fjernvarmestatistikken december 2019. 2020. Frederiksværk*.
- [35] Åberg M, Fälting L, Forssell A. Is Swedish district heating operating on an integrated market? - differences in pricing, price convergence, and marketing strategy between public and private district heating companies. *Energy Pol* 2016;90:222–32. <https://doi.org/10.1016/j.enpol.2015.12.030>.
- [36] Magnusson D. Swedish district heating-A system in stagnation: current and future trends in the district heating sector. *Energy Pol* 2012;48:449–59. <https://doi.org/10.1016/j.enpol.2012.05.047>.
- [37] Miljø- og Fødevarerministeriet. *Lov om ændring af lov om varmforsyning. LOV nr 451 af 31/05/2000* 2000.
- [38] Energitilsynet E.ON *Varme Danmark Aps - Opfyldelse af en bestemmelse i varmforsyningsloven om forbrugerindflydelse*. 2008.
- [39] Andersson S, Abrahamsson E-M, Werner S. *Fjärrvärmeolyckor* 2009.
- [40] Østergaard DS, Paulsen O, Sørensen IB, Svendsen S. Test and evaluation of a method to identify heating system malfunctions by using information from electronic heat cost allocators. *Energy Build* 2019;184:152–62. <https://doi.org/10.1016/j.enbuild.2018.12.004>.
- [41] Magnusson D, Palm J. Between natural monopoly and third party Access - Swedish district heating market in transition. In: *Karlsen RW, Pettyfer MA, editors. Monopolies: theory, effectiveness and regulation*. Nova Science Publishers, Inc.; 2011. ISBN 9781613243541. p. 1–33.
- [42] Rutherford J. The vicissitudes of energy and climate policy in Stockholm: politics, materiality and transition. *Urban Stud* 2014;51:1449–70. <https://doi.org/10.1177/0042098013500088>.
- [43] Westin P, Lagergren F. Re-regulating district heating in Sweden. *Energy Pol* 2002;30:583–96. [https://doi.org/10.1016/S0301-4215\(01\)00126-4](https://doi.org/10.1016/S0301-4215(01)00126-4).
- [44] Culig-toki D, Kraja G, Dora B, Vad B, Krklec R, Møller J. Comparative analysis of the district heating systems of two towns in Croatia and Denmark. *Energy* 2015;92:435–43. <https://doi.org/10.1016/j.energy.2015.05.096>.
- [45] Nuorkivi A. *To the rehabilitation strategy of district heating in economies in transition*. Helsinki University of Technology; 2005.
- [46] Di Lucia L, Ericsson K. Low-carbon district heating in Sweden - examining a successful energy transition. *Energy Res Soc Sci* 2014;4:10–20. <https://doi.org/10.1016/j.erss.2014.08.005>.
- [47] Dansk Fjernvarme. *Water Treatment and Corrosion Prevention. Recommendations* 2015.
- [48] Halmstads energi och miljö; FVB sverige *fjärrvärmecentralen. Tekniska bestämmelser FV09-1, juni 2009*. 2009.
- [49] Månsson S, Kallioniemi P-O, Thern M, Van Oevelen T, Sernhed K. Faults in district heating customer installations and ways to approach them: experiences from Swedish utilities. *Energy* 2019;180:163–74. <https://doi.org/10.1016/j.energy.2019.04.220>.
- [50] Energitilsynet *Energitilsynets undersøgelse af E.ON's prisfastsættelse - resumé*. 2009.
- [51] Energitilsynet *E.ONs concerninterne samarbejdsaftaler*. 2012.
- [52] Andersson S, Werner S. *Fjärrvärme i Sverige 2005;2003*. Västerås.
- [53] Energiföretagen Sverige *Fjärrvärmepriser2020*.
- [54] Danish Energy Agency *15 værker får støtte til store varmepumper Available online: https://www.mynewsdesk.com/dk/energistyrelsen/pressreleases/15-vaerker-faar-stoette-til-store-varmepumper-2562721* (accessed on Jul 15, 2021).
- [55] Danish Energy Agency *Grundbeløbets ophør og grundbeløbsindsatsen Available online: https://ens.dk/ansvarsomraader/varme/grundbeloebets-ophoer-og-grundbeloebetsindsatsen* (accessed on Jul 15, 2021).
- [56] Hvelplund F, Djørup S. Consumer ownership, natural monopolies and transition to 100% Renewable Energy Systems. *Energy* 2019;181:440–9. <https://doi.org/10.1016/j.energy.2019.05.058>.
- [57] Forsyningstilsynet *afgørelse om rønne varme A/S' henlæggelser for 2017-2020*. 2020.
- [58] Hellmer S. Switching costs, switching benefits and lock-in effects - the re-regulated Swedish heat market. *Energy Environ* 2010;21:563–75. <https://doi.org/10.1260/0958-305X.21.6.563>.