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Unveiling consumer perspectives on district heating: A Q methodology study

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Abstract

This study uses the Q methodology to investigate consumer perspectives on district heating, combining qualitative and quantitative methods across five research phases: foundation development, statement compilation (the Q-set), participant selection (the P-set), Q sorting and data analysis. The foundation was built using diverse sources yielding 39 statements. Experts from various disciplines were involved in the selection of statements using a two-round Delphi-like method to ensure objectivity. Subsequent steps included recruiting participants with varied perspectives, conducting Q sorting and analyzing data to reveal thought patterns. This research aims to shed light on consumer viewpoints regarding district heating, sustainability and general attitudes, assisting policymakers in promoting environmentally friendly energy practices. This research employs the Q methodology to collect and analyze subjective viewpoints concerning district heating, enhancing our understanding of consumer perspectives and their implications for sustainable energy systems. The results indicate a positive attitude towards district heating with strong support for further research and investment. Additionally, it aims to clarify the paper's results by highlighting the diverse consumer attitudes towards pricing mechanisms. The findings suggest transparent pricing mechanisms influenced by user behavior are more likely to gain acceptance. Four groups were found by using K-means clustering to analyse the data. These clusters showed preferences for longer, steady operating hours with low demand followed by shorter hours with low demand and resistance towards low operating hours with high demand. Future research could explore specific consumer profiles, private data or leverage waste heat from sources.

Keywords: Attitudes, Hungary, New energy, Pricing method, Sustainability, Waste heat.

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1. Introduction

Europe has a number of challenges including climate change, the need to ensure sustainable economic development and social cohesion and the necessity to accomplish an authentic energy revolution in order to overcome current unsustainable tendencies and meet the high standards set by policy. District heating (and cooling) systems must advance in this direction by becoming more cost-effective, intelligent and efficient. There has been less published research on the analysis of district heating (smart) meter data in contrast to electricity smart meter data analysis [1]. District heating (also known as heat networks or tele heating) is a system for distributing heat generated in a centralized location through a system of insulated pipes for residential and commercial heating requirements such as space heating and water heating. The heat is often obtained from a cogeneration plant burning fossil fuels or biomass but heat boiler stations, geothermal heating, heat pumps and central solar heating are also used. It is also widespread and used to generate energy from nuclear power and heat from industry. District heating plants can provide higher efficiencies and better pollution control than localized boilers. According to some research, district heating with combined heat and power (CHP) is the cheapest method of cutting carbon emissions and has one of the lowest carbon footprints of all fossil generation plants [2]. Consumer behavior is the study of how people make buying decisions. It attempts to understand how buyers choose and use products and services. Businesses can determine how to effectively market their goods and services by understanding how customers feel, think and make decisions [3]. Understanding buyers can help marketers connect with them and influence their behavior. One of the most important key elements of sustainability is personal behaviour. Utility firms and customers both benefit from understanding how energy users use their resources as it may help them develop more effective energy management and usage plans. The heat usage of customers is crucial for effective district heating (DH) operations and management. The research process involves five key phases: developing the concourse, creating a set of statements (Q-set), selecting participants (P-set), conducting Q sorting and analyzing and interpreting the data.

Literature, expert interviews and internet remarks were among the sources used for constructing the concourse. A total of 39 statements were identified. An expert panel comprising several fields of expertise used a two-round Delphi-like process to offer ratings and comments in order to ensure neutrality in the selection of statements.

The next steps involve recruiting participants who represent different perspectives, administering the Q sorting process and analyzing the data to identify patterns of thought. The research aims to provide insights into consumer opinions on district heating, sustainability and general attitudes. The findings can support policymakers in promoting sustainable behaviors and guiding society towards more environmentally friendly energy consumption.

2. Literature Review

This chapter examines district heating and consumer opinion. Other aspects such as clustering of measured data have been reviewed [4] and will not be further commented but sometimes be referenced.

2.1. Review of Prices and Pricing Mechanisms in District Heating and the Customer Perspective on it

It was planned to provide the consumer's viewpoint or opinion on district heating but not enough results were published. Almost all documents on the subject of consumer opinion were in relation to pricing or sustainability. The evaluation range was expanded to encompass the various price models in order to widen the base. Similar techniques were used for district heating pricing mechanisms and customer perceptions of DH Radtke [4]. The summary of those methods is shown in Figure 1.

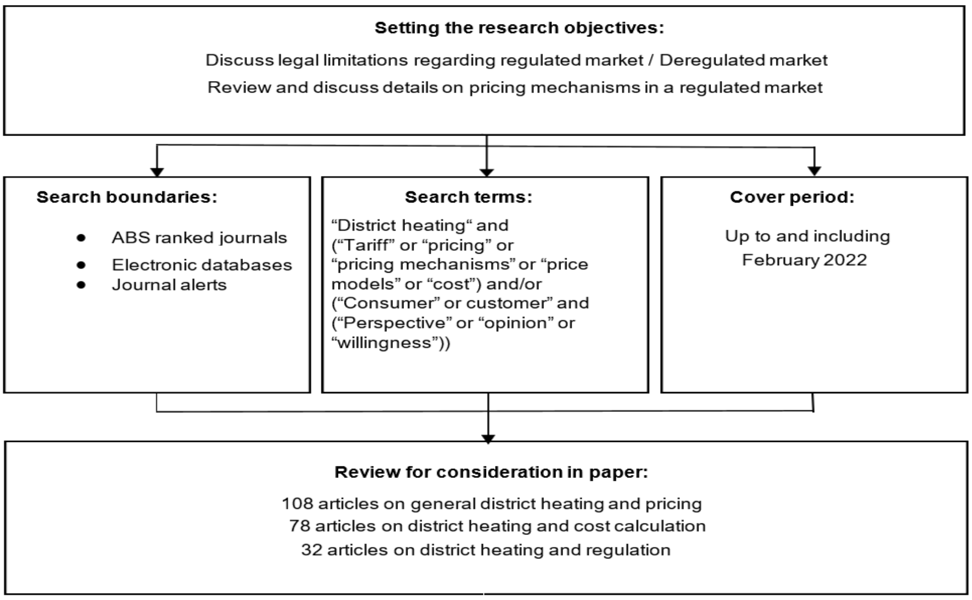

Figure 1.
Summary of the literature review.

Publications with no relationship to controlled pricing processes were completely disregarded, since Hungary operates with regulated prices across all sectors in the energy industry. The most prominent work of Kerekes [5] had to be excluded as it's available only in Hungarian language. It provides an overview of the available biomass and geothermal resources, the technical characteristics and cost elements of the different technologies and estimates the costs of increasing the share of heat generation from biomass, geothermal and CHP in the district heating systems studied.

2.1.1. Details on Prices and Pricing Mechanisms

The most common is the model of the heat energy market operating under two pricing conditions: a) free (liberalized) pricing and b) tariff regulation for consumers [6]. The costs of DH depend on three main factors: (1) the connection costs for customers, (2) the costs of a distribution network which depend on the size of the DH network and its thermal loads and (3) the production costs of thermal energy [7]. Most Swedish traditions were reported by the authors. Correspondingly, the price of heating mainly comprises a connexion fee, a standing cost and a unit cost. Song et al. [8] show the same components but refer to a different name: A fixed component (FxC) is the fixed price a user need to pay for being connected to the network. A fixed component (FxC) is the fixed price a user needs to pay to be connected to the network. Load Demand Component (LDC) is essentially a variable component charged based on the user's consumption pattern (load demand). It usually covers the DH company's non-production costs caused by investment in fixed assets, depreciation, salary, etc. All pricing schemes include energy demand component (EDC) which is based on the user's energy consumption. This component is supposed to cover DH companies' production costs.

They also use three price components such as Bonn [9] which provide the end user with an annual base price, a commodity price and an emission price. District heating is very friendly. Nevertheless, CO2 emissions are also produced when district heating is generated, although these are lower than with many other forms of heat generation. Bonn presents emission certificates for this purpose. A portion of the certificates is given to Bonn at no cost. The other parts need to be obtained separately. This part is distributed equally to all customers for their respective consumption. The consumption measured at the customer's district heating meter is multiplied by the emission price. Similar descriptions are given below [10].

The synergies with power generation in CHP plants in district heating prices have been analyzed by Åberg, et al. [11] and Linden and Peltola-Ojala [12]. The papers wouldn't have been approved because of the deregulated markets under analysis without the price fixing synergy.

The government regulates the price of DH in regulated markets and the regulated price sets the profit margins for DH companies. Li, et al. [7] state that the price of district heating is equal to the sum of the expenditures that must be recovered and fair profits for DH companies. The equation may be explained as follows:

$$Price_{DH} = OA + AD + PP \quad (1)$$

Where OA is operating cost, AD is annual depreciation and PP is permitted profit. This method is called the cost-plus pricing method. Permitted profits (PP) can be calculated as follows:

$$PP = WACC * RAB \quad (2)$$

Where WACC is the weighted average cost of capital and RAB (Regulatory Asset Base) = depreciated fixed cost + new investment + labour cost Li, et al. [7] and Gudmundsson et al. [13]. Under a cost-plus pricing mechanism, DH companies have incentives to increase profits by inflating costs, since permitted profits are usually related to costs. If they are operating at a lower cost than the reported level, the DH companies would be punished through the imposition of a lower level of permitted profits [14]. Consequently, the cost-plus pricing method undermines suppliers' incentives to reduce costs and to upgrade their technologies. In addition, changes in real fuel costs cannot be transferred to consumers due to the use of historic data which prevents DH producers from generating enough profit to budget for necessary maintenance and improvements [15]. The tariff that customers pay will probably not be sufficient to cover expenditures under state-regulated pricing schemes. In these cases, local or regional governments step in to cover the deficit.

The marginal-cost method is widely used in the deregulated market [16]. In a marginal cost-based pricing model, the total price normally involves two parts: fixed cost and variable cost. Equation 3 is given below.

$$\mathrm{MC} = \frac{d(TC)}{\mathrm{d(Q)}} = \frac{d(FC+VC)}{\mathrm{d(Q)}} = \frac{d(VC)}{\mathrm{d(Q)}}) \quad (3)$$

Where TC is total cost, FC is fixed cost, VC is variable cost and Q represents the volume of heat production [17]. VC mainly consists of energy costs, labor costs and other variable operation costs such as the cost of marketing. Energy cost or fuel cost can be calculated as Equation 4:

$$Fuel\ cost = Fuel\ price + Sulphur\ tax + NOx\ tax + Carbon\ tax + Energy\ tax \quad (4)$$

The levelized cost of heat (LCOH) approach is an additional pricing technique that has only been applied in deregulated markets. It is the cost of generating heat for a particular system at a particular temperature of the working fluid. It is an economic assessment of the cost of the heat-generating system including all the costs over its lifetime: initial investment, operations and maintenance, cost of fuel and cost of capital [18]. LCOH is the minimum price at which heat must be sold for a heat generating system at a defined maximum temperature of the working fluid. LCOH is calculated over a 20 year lifetime and it is given in units of currency per kilowatt-hour. For example, $/kWh or €/kWh or per megawatt-hour [19]. The new method only applies to deregulated markets [20] with deregulated prices, the methodology behind was not further researched. LCOH has its origin in the much more deregulated electricity market which is indicated by several papers regarding the levelized cost of energy by De Simón-Martín et al. [20] and Li et al. [16].

The most comprehensive and condensed document for the European market with regard to pricing is Werner [21] work. The outputs from this price collection project consist of a long series of national average district heating prices until

2013 and the corresponding annual revenues and heat sales. 560 annual average national district heating prices have been estimated. Werner [21] gathered an overview of a relatively long time series of district heating prices. The research was done for 23 European countries of which 20 are currently members of the European Union. Additional countries include: Iceland, Norway and Switzerland. The remaining eight EU member countries were not included since district heating is not a typical activity in these countries. Very few systems are operated in Luxembourg, Belgium, Ireland, Portugal, Spain and Greece while no district heating appears in Cyprus or Malta. A significant variance in district heating costs during the investigation was discovered [21]. The study revealed that the highest prices are found in Denmark, the Slovak Republic, Germany, Norway and Sweden while the lowest prices are obtained in Iceland, Bulgaria, Switzerland, Hungary and Poland. Croatia and the United Kingdom show slightly higher prices. The rest shows significantly higher prices.

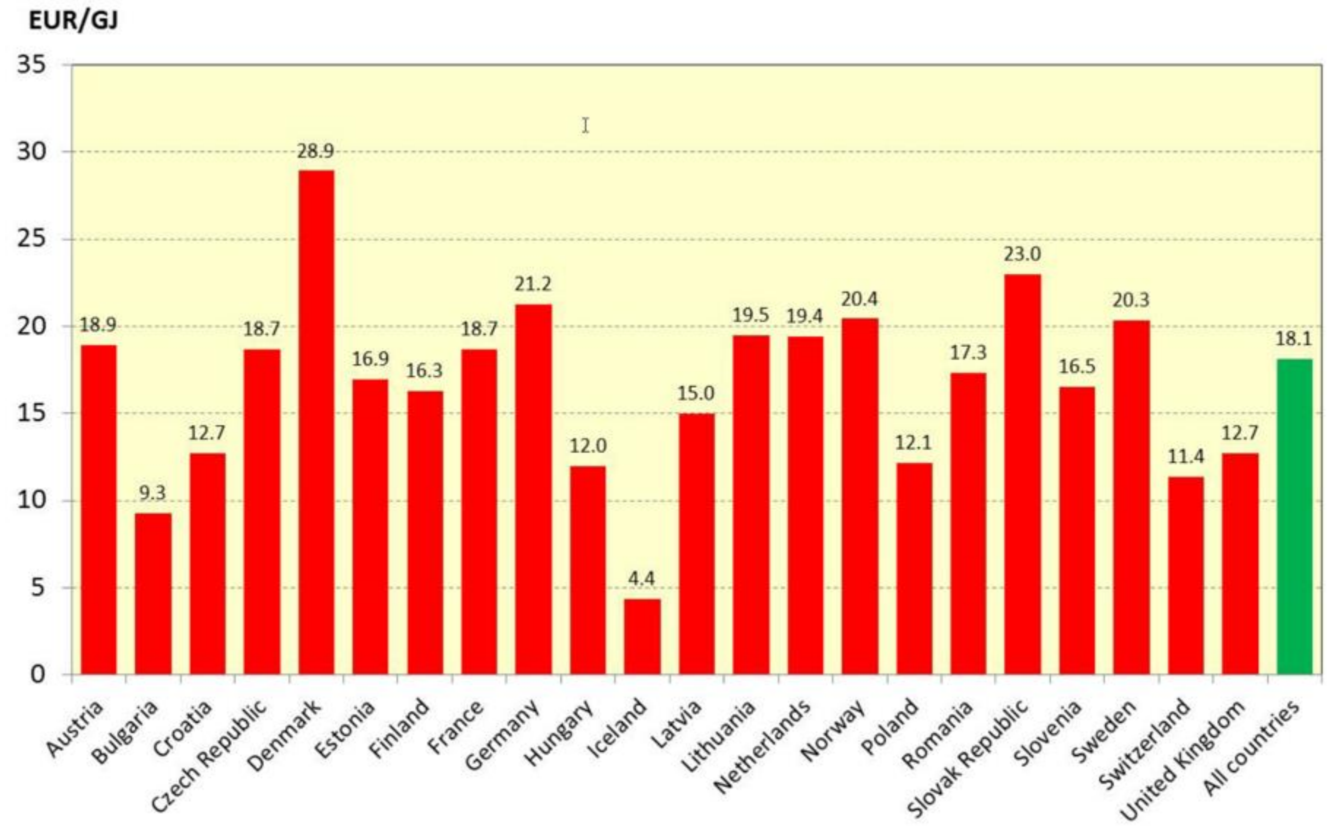

Figure 2.
National average district heating prices for 22 European countries in 2013.
Note: Werner [21].

The research of Werner [21] is based on reliable past figures (as illustrated in Figure 2). The political environment has changed. In Hungary, regulated energy prices have been crucial in supplying electricity, district heating and natural gas to households and as a result of a utility cost reduction program, implemented in several stages starting in 2013, a sharp decline has been seen in these prices. According to Weiner and Szép [22], the utility cost reduction program discourages energy conservation and energy efficiency, erodes the competitiveness of renewables, reduces gross capital formation in the energy sector, deteriorates security of supply and increases energy prices for non-household customers. The efficiency of the applied measures is still doubtful and several negative effects have also been detected. The utility cost reduction programme is anticipated to continue although with possible modifications despite these drawbacks.

2.1.2. Customer Perspectives on Different Aspects of District Heating

Although the number of recognised goods for price and pricing strategies was still very significant, the outcome was manageable from the perspective of the consumer. All the papers found were included in the review. There is a shortage of available information on the customer's perspective in relation to district heating. Only a few relevant papers were identified that dealt with consumer opinion or customer behavior in district heating.

Mouritsen et al. [23] performed a literature review on the transition towards 4th generation district heating (4GDH) with a special interest in how consumers can be meaningfully and strategically included in the transition towards 4GDH. Their goal was to evaluate the consumer role during 4GDH in the transition towards 100% renewable energy systems. They came to the conclusion that direct involvement of consumers is either not yet researched further, (too) difficult or even counterproductive. The authors found details on a free mobile phone app called WATTS (initially provided by the Danish electricity supplier SEAS-NVE) to enable consumers to monitor their electricity consumption based on hourly smart meter data. Several other energy supply companies have joined collaboration with SEAS-NVE with the objective for developing the application so that it can handle several types of consumption (electricity, heat, gas and water). The enhanced application allows consumers to follow their DH consumption hourly, daily, weekly and quarterly as well as their expected heat consumption use based on their consumption in previous years. Users can see their DH costs and are presented with a budgeted DH consumption based on previous consumption patterns. When consumers consume less, more or more than their assigned amount, the colors green, yellow or red are shown. The authors concluded that more information technology (IT) is needed for a better link between the demand and supply sides. It's needed for improving the availability and exchange of information on a specific building's performance. Furthermore, it's needed to link building energy efficiency research with a consumer focus to 4GDH research.

Sernhed et al. [24] observed similar results within their literature review as within this work. The Swedish market for district heating is better researched than any other country. They concluded especially for innovative and more complex pricing models that the most recent studies about price models for DH that were found in scientific journals are Swedish studies. Their work is to research how customers responded to more complex price models (introduced in Sweden). The methodology used to investigate was through focus group interviews and through interviews with companies that have changed their price models. Their results show that several important customer requirements are suffering with the new price models. The most important finding was the dislike of the fact in regard to the new pricing models that energy savings do not provide financial savings when costs are hard to predict and are perceived to be out of control. According to Sernhed et al. [24], factors like weather dependency, sunk costs from fixed assets and new competition on the heat market constitute challenges and business risks for the DH industry that must be considered. The most important finding in regard to any new pricing system in a deregulated (price) market is that dissatisfied customers voting with their feet constitutes another financial risk for the DH business.

Xu et al. [25] researched the dynamic consumer behavior, hydraulic performance and energy consumption of a DH system in China. The other parts of the literature review exclude other areas other than Europe. The addition of this study to our review is explained by the lack of available papers. Traditionally, consumers did not have the possibility to adjust their heat consumption and the billing system was only based on the floor space of an apartment. The systems were operated with constant water flow rates and variable water temperatures. Consumers did not have enough interest in saving energy and always opened their windows to dissipate heat when a room was too hot. The China Ministry of Construction has proposed national heat reforms with the primary objective of implementing a heat metering and billing mechanism in central heating systems to promote energy efficiency prior to the study. Questionnaires were employed as a tool to investigate the ways in which customers' varying temperature preferences, lifestyles and interior thermal environments lead to highly varied behavioural patterns. Tests were conducted based on the responses and the district heating system's hydraulic performance was examined. The authors found that the influence of consumers' stochastic regulation behavior (by using thermostats instead of simply opening the window) on the hydraulic behavior within the district heating system is very minor. Additionally, they found heat metering billing systems can lead to about 10% energy savings compared with traditional billing systems. The main finding is a lack of understanding among consumers about the self-adjustment of a thermostat. The authors recommend providing consumers with advice on how about use controls and their effects. For example, they advise setting radiator thermostats to reasonable levels, turning off the heat before opening the windows, closing the valves in rooms that are not in use and closing all of the valves only when they will be gone for an extended period of time.

Ueno et al. [26] performed a quantitative analysis on an online interactive energy consumption information system (ECOIS). This system was constructed to evaluate the motivating energy-saving activities in nine residential houses. Electricity consumption and space heating were measured in a combined approach as energy savings in total. During the research, the energy awareness and energy-saving activities induced by this system were described and measured based on questionnaires and comparisons of power consumption before and after the installation of an ECOIS. The result revealed that the power consumption of many appliances had been reduced by 9% after the use of ECOIS. Additionally, when daily load curves and load duration curves for each appliance were compared before and after installation, it became clear that the household members were adopting a variety of energy-saving practices such as turning down backup power and improving appliance control. The installation of an ECOIS influenced the energy-saving awareness of the customers.

What will consumers pay for convenience was the question raised by Yoon et al. [27]. A double-bounded dichotomous choice approach was used to evaluate consumer value for convenience in a hypothetical market. They found that families with higher household income, higher heating expenditures during the winter, higher educational achievement and residence in relatively expensive apartments or those with higher living standards assign higher value to the user convenience of DH. When expressed as a percentage of current monthly heating expenditures, the willingness to pay (WTP) for distributed heating over individual heating (IH) in the 800-household sample was 4.03% and for DH users only it was 7.92%. IH users unfamiliar with DH expect little greater convenience (0.1% WTP) whereas the WTP for DH users runs to 7.9% demonstrating consumer loyalty. As a result, their analysis suggests that in order to promote DH, more focus should be given on the numerous outside advantages of DH systems such as convenience, comfort and safety rather than their reduced cost.

Similar research on the WTP for district heating from renewables in private households in Germany was conducted by Krikser et al. [28]. They evaluated the willingness-to-pay for district heating and district heating from renewables compared to gas condensing boilers and heat pumps (individual heating). A technique for implementing market segmentation involved the use of a discrete-choice experiment and the collection of data on attitudes towards sustainability, economic considerations and requests for heat supply providers. These features were then used as dimensions for factor and cluster analysis.

Their results show a preference for "district heating from renewable energies". Other alternatives like district heating from fossil fuels, heat pump and gas rank lower in the analyzed household's opinion. The participants revealed a significant additional WTP for "district heating" just because it is from renewable energies.

3. Research Methodology

A survey for statements has to be conducted and evaluated through quantifying subjective data using the Q-methodology. Q-methodology is used to investigate the perspectives of consumers who represent different stances on district heating, sustainability and general attitude by having participants rank and sort a series of statements.

3.1. Consumer's Opinion on District Heating Using the Q Method

The Q method is a research method developed by William Stephenson to analyze individuals' psychological attitudes. It focuses on differences within individuals rather than their characteristics. The method uses factor analysis to assess a large number of statements with a small number of participants [29]. According to Ramlo [30], the methodological aspects of Q offer the ability to scientifically study subjectivity.

The correlation coefficients calculated show the correlation between people. The Q Methodology allows individuals to express their subjective opinions through qualitative and quantitative methods. The method is useful for identifying distinct viewpoints and generating testable hypotheses. Q-sort procedures are effective for deriving categories and building theory from individual responses. The goal of Q-methodology is to uncover different patterns of thought rather than their numerical distribution in the larger population. Studies using this method typically have small sample sizes and are less influenced by low response rates Valenta and Wigger [31] and Brown [32].

The Q methodology shall be used for retrieving consumers' opinions on district heating and possibly helping policy makers guide society towards sustainable behavior and consumption.

3.2. Defining the Concourse, Developing Q-Set and Selection of P-Set

Various sources and methods for constructing a concourse have been defined by Q-methodologists. For example, scientific literature, expert interviews, focus groups, social media and websites. The information includes all of the current viewpoints and arguments made by professionals, organisations and other subject matter experts. It emphasis on comprehending how and why individuals believe the way they do than on calculating the proportion of the population that has a particular perspective. Therefore, the following questions were applied to define the concourse:

- What influences the opinion on district heating?
- What can be identified as the everyday behavior of consumers?
- Which digital experience is expected and can contribute?
- Is sustainable behavior known to consumers?

Several sources were used in order to identify the assertions including the previously studied literature, expert interviews, lectures and discussions with academics and statements from websites. At the end of the concourse development, 61 statement items were identified with four themes: General district heating, prices, requirements or expectations for software or applications and personal behavior.

The Q method often raises the question of the reliability of the method. A Delphi-like technique was applied in order to objectivize the Q-set definition. The Delphi technique is a structured method to facilitate the consensus of expert opinion. Although initially developed for military forecasting [33], it has been applied to many research areas, for example, healthcare [34]. The technique involves a panel of experts who undertake a series of questionnaire rounds.

A two-round Delphi method was used for this study in order to achieve expert consensus on which statements to include in the Q sample and to further minimize the number of statements. The Delphi component was conducted from December 2021 to January 2022. An international, multidisciplinary team of experts were selected. Experts were defined as researchers or professionals in the area of energy billing or even specializing in heating. Finding experts in the area of district heating was lacking a direct connection and the possibility to interact through online conferencing. Using the broader definition enabled the Delphi-like technique to be applied through MS Teams and Skype meeting (Microsoft Teams (business collaboration tool for communication, file sharing and project work). Skype (originally voice or video calls, now part of teams for business communication).

3.2.1. Round One

A defined number of experts were invited to participate in the first round. They were invited to rate their agreement on statements. In rating each statement, the experts were requested to consider the relevance of each statement based on their experience and their knowledge. The intention is to reduce the number of statements. Experts were advised that participation involved a commitment to several rounds.

3.2.2. Round Two

Panelists were notified at the beginning of the round that statements would be revised as needed in response to feedback. Statements that achieved the median requirement were kept. Any new statements suggested by the panel in round one were included and presented for rating.

The panel members were asked to rate the presented statements according to the following scale: 1) fully relevant regarding the intended research questions. 2) Matches the basic idea. 3) Not very relevant. 4) Shall be replaced.

The feedback from round one was evaluated and quantitatively calculated. Each statement has been given a score. The score determines if the statement is kept within the next round or is replaced by another statement. Statements that had been receiving a score of three were replaced by a statement provided within the free text. The same number of experts received revised statements in round two which was distributed following round one's evaluation. Round two did provide the semi-final set of statements to be used within the Q Methods approach. An additional round was done as the panel members were not familiar with the Q-methodology and the statements had to be shortened more. The general text was kept but the explanatory additional hints were totally removed so the participants could form a strong opinion about each statement. The Q methodology has been criticized for a lack of transparency and detail in the Q sample construction. For example, it has been stated that "the QM (Q methodology) literature remains uncomfortably silent with respect to how to assemble and verify the completeness of a concourse and how to verify or falsify the representativeness of a sample drawn there from" Kampen and Tamás [35]. Therefore, Kirschbaum, et al. [36] and Wallis, et al. [37] proposed a Delphi based approach which was adopted as a Delphi-like approach within this paper. At the end of the process, 39 statements were selected and presented as P-sets to the rating participants.

3.3. Design of the Study Procedure and Selection of Participants

A sorting range with nine categories was used in the study method design where participants conducted a Q sort in accordance with the suggestion for Q samples less than n = 40. The labels were set a little bit wider despite the fact that Webler, et al. [38] recommended adding labels like "least like how I think" to "most like how I think." From "disagree, least preferred , least important" to "agree, most preferred, most important" were created (as shown in Figure 3). The sorting arrangement is supposed to represent a quasi-normal distribution that is symmetrical over the middle and represents a normal distribution. The following arrangement of locations into which participants would sort the statements proved to be the most effective strategy to impose this distribution for the 39 statements.

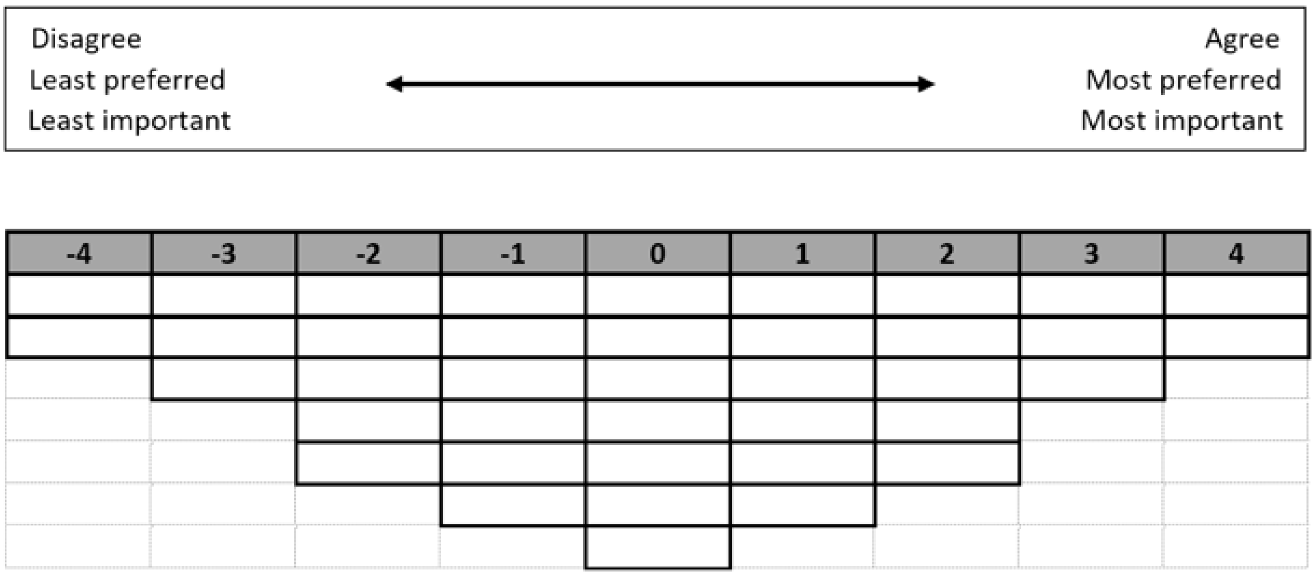

Figure 3.
Q-sorting grid for 39 statements.

The Q sort, a study technique of the Q method can be carried out electronically using software that is already accessible or traditionally by printing out the questionnaire and distributing the statements. This depends on the personal preference of each participant. Some might use paper and scissors while others make use of modern technical devices and use Google Sheets or MS Excel.

The Q methodology combines qualitative and quantitative methods to investigate the subjective views of those directly involved in a particular topic. According to Webler, et al. [38], the number of participants should match the number of statements. A ratio of Q-participants and Q-statements is 3: 1. The highest ratio that should be used is 2: 1. In this research with 39 statements, 13 (39/3 = 13) to 20 (39/2 = 20) participants will have to be expected.

In order to determine some additional criteria, the questionnaire was sent out with the following socio-demographic questions:

1) You are ☐ tenant ☐ owner.
2) In which quartile do you think you are fitting:
☐ High demand & for a short period of time (e.g., some hours a day for only a few month)
☐ High demand & long period
☐ Low demand & for a short period
☐ Low demand & long period
3) You are ☐ employed ☐ self-employed ☐ without paid employment.

4) You are between ☐ <30 years old ☐31 to 45 years old ☐46 to 60 years old ☐ 61 years to 75 years old ☐ > 75 years old
5) You are ☐alone ☐married/living in a partnership.
6) How many persons live in your household? ☐ 1 ☐ 2 or 3 ☐ 4 or 5 ☐ 6 or 7 ☐ 8 or more persons living in the household.
7) You own and use mobile devices (smartphone, tablet, …) ☐ Yes ☐ No
8) You use electronic media for bank transfers ☐ Yes ☐ No
9) You prefer to use ☐ PC, Notebook, Tablet ☐ Smart Phone ☐ none of the before
10) What is your highest educational degree? ☐undergraduate ☐ skilled/specialist worker ☐High school ☐Vocational school, with baccalaureate ☐Higher education (College,- BSc degree) ☐University, Master's degree, Bachelor's degree ☐PhD and above

The U.S. National Institutes of Health which requires the consideration of sex as a biological variable in preclinical studies (for biomedical research). Due to the delicate nature and not always perceived differences between sex and gender in social studies, there is no question included for binary or non-binary identification.

The P-set consists of district heating users in Kaposvár. The opinion of the Kaposvár district heating users shall be explored and analyzed. The Q-sets and the surrounding questionnaire were provided in English and Hungarian to avoid language barriers. The distribution of the questionnaire itself was done by the district heating technical manager of the Kaposvár Municipality Asset Management and Service Co. Zsuzsanna Zanatyné Uitz. The results were gathered, scanned and anonymously sent to me. There is no trace of the participants or any personal data. The survey was not just confidential but truly anonymous. The results will not be gender or sex-biased in order to provide fully inclusive research. Participants could give an incorrect answer but a high level of inaccuracy is not expected.

3.4. Unprocessed Results of the Q-Sorts

The results were transferred into an MS Excel file format for further processing (see Tables 1 and 2). A total of eighteen questionnaires were completed by the participants. However, one had to be eliminated since the answers were not distinct and identifiable (see Figure 4).

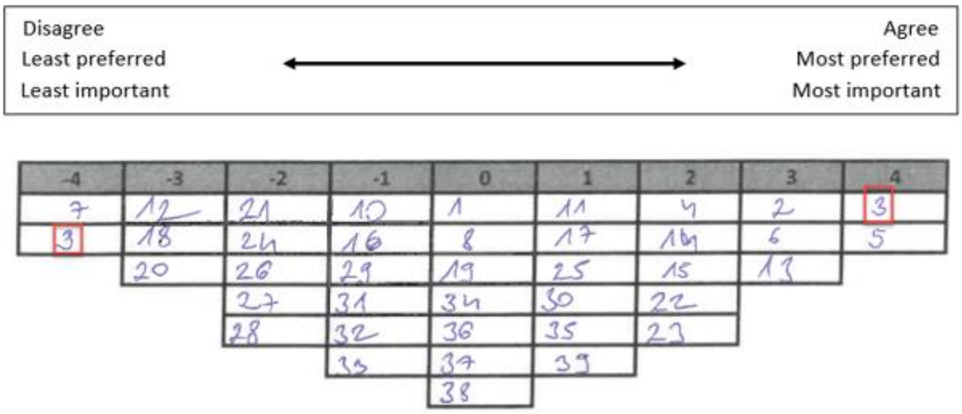

Figure 4.
Result with a none unique answer or self-marked.

The inserted statement 3 on the right-hand side for the rating of 4 can be uniquely identified but the marked value on the left-hand side for -4 could be interpreted as a 3 or a 9. To achieve stable results, only the other 17 responses will be used.

The socio-demographic results show a large tendency to employ working owners of houses or flats. Most participants consider themselves to have a low demand for head but during a longer period of time. Every participant with the exception of one has an electronic device and already uses it for payments. A correlation between the preferred device, age and education was not performed upfront.

Table 1.
Summary of the socio-demographic answers.

Questions/ Participant	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
P01	Owner	Q2	Employed	R4	Single	P1	Yes	Yes	D1	E6
P02	Owner	Q2	Employed	R3	Partnership	P3	Yes	Yes	D1	E2
P03	Owner	Q4	Employed	R2	Partnership	P3	Yes	Yes	D1	E5
P04	Owner	Q4	Employed	R3	Single	P1	Yes	Yes	D1	E3
P05	Owner	Q4	Employed	R2	Partnership	P2	Yes	Yes	D2	E2
P06	Owner	Q4	Employed	R1	Single	P2	Yes	Yes	D2	E4
P07	Owner	Q4	Employed	R2	Single	P2	Yes	Yes	D2	E3

Questions/ Participant	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
P08	Owner	None	Employed	R2	Partnership	P2	Yes	Yes	D1	E5
P09	Owner	Q4	Employed	R2	Partnership	P3	Yes	Yes	D1	E4
P10	Tenant	Q2	Employed	R2	Partnership	P4	Yes	Yes	D2	E5
P11	Owner	Q4	Employed	R3	Partnership	P3	Yes	Yes	D2	E4
P12	Owner	Q4	Employed	R2	Partnership	P3	Yes	Yes	D2	E2
P13	Owner	Q4	Employed	R2	Partnership	P2	Yes	Yes	D2	E4
P14	Owner	Q4	Employed	R4	Partnership	P2	Yes	Yes	D2	E4
P15	Tenant	Q2	Employed	R4	Partnership	P3	Yes	No	D2	E3
P16	Tenant	Q2	Employed	R1	Single	P3	Yes	Yes	D2	E4
P17	Tenant	Q2	Employed	R3	Partnership	P3	Yes	Yes	D2	E4

Explanation for the table: All questions are marked as Q1 to Q10 in the headline of Table 2. Question 1 simply distinguished between owner and tenant. The quartiles found in chapter 3 of this text were used to answer question 2: usage quartile: Q1: high demand and for a short period of time (e.g., some hours a day for only a few months) Q2 = high demand and long period Q3 = low demand and for a short period Q4 = low demand and long period. Question 3 included only three options but only one user group was detected by the answers. For question 4, a range of age was supplied. R1 <30 years old R2 is 31 to 45 years old. R3 is 46 to 60 years old. R4 is 61 to 75 years old. R5 > 75 years old. Q5 was also a two-dimensional question: single or living in a partnership. Q6 was more open, number of persons living in the household. P1 = 1, P2 = 2 or 3; P3 = 4 or 5; P4 = 6 or 7; P5 = 7 or 8; P6 = 9 or more. Here it could happen that people living as a single still had 4 or 5 persons living in the household. Question 7 and 8 were straight forward and simple yes or no questions. Question 9 asked for the preference for electronics device. D1 = PC, notebook, tablet, D2 = smart phone and D3 = none of the before. Question 10 regarding the highest degree earned in education (E) was translated to E1 = undergraduate; E2 = skilled or specialist worker; E3 = High school; E4 = vocational school, with baccalaureate; E5 = Higher education (college , BSc degree), E6 = university, master’s degree, bachelor's degree, E7 = PhD and above.

The majority of the respondents owns the property and lives in a partnership. In regard to reaching education a broad variety can be observed. All participants are employed. The majority of households have more than one person of varying ages living in them.

The results of the Q-sort were also transferred into an MS Excel file format for further processing (see Table 2).

Table 2.
Rated statements by the participants.

Participants/ Statements	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
Statement 1	0	3	-4	0	-1	2	0	-1	1	-2	-4	-4	-4	-4	-4	-3	-2
Statement 2	4	3	4	0	2	4	2	1	4	2	1	-2	-4	3	3	3	3
Statement 3	2	4	3	0	4	4	2	1	3	3	1	2	2	2	4	4	4
Statement 4	3	3	3	-2	3	2	-1	2	4	-1	4	3	3	2	2	3	3
Statement 5	0	1	-1	-2	0	0	3	0	0	1	3	2	4	1	2	2	2
Statement 6	-3	-1	0	-2	1	-1	-2	0	-1	3	0	-1	4	1	1	2	4
Statement 7	1	0	2	1	1	0	-3	2	0	2	2	1	1	-1	1	2	2
Statement 8	0	2	1	-2	-1	0	4	-3	-2	1	1	3	3	-3	0	1	1
Statement 9	-4	-2	-3	-4	-2	-4	-4	-3	-4	-4	-3	-3	-3	0	0	-4	-4
Statement 10	0	-1	1	4	2	1	-4	-1	1	2	-2	0	0	2	-3	-1	-1
Statement 11	1	0	2	1	1	2	1	1	2	2	2	4	2	1	-1	-2	0
Statement 12	-1	-1	2	2	-3	-4	-3	-1	-2	0	2	0	1	-4	2	0	2
Statement 13	1	4	3	-3	4	3	3	2	0	3	3	4	3	-2	4	4	3
Statement 14	1	0	1	-3	-1	2	0	2	1	0	2	3	2	-3	-1	3	0
Statement 15	2	1	1	4	1	1	1	1	1	4	1	2	2	4	2	2	1
Statement 16	3	2	-2	0	-3	0	-3	-1	0	-3	-3	-2	-3	0	-2	-3	-1
Statement 17	1	-1	-1	0	-2	1	-1	1	0	0	2	2	-2	-1	-1	0	0
Statement 18	-2	1	0	1	2	0	-2	1	-1	0	-2	-1	-2	-3	-1	-3	-2
Statement 19	0	2	2	1	-2	0	2	-1	-1	1	1	-4	1	-1	0	0	0
Statement 20	2	1	0	1	-1	-1	3	0	-1	1	3	2	1	2	3	1	0
Statement 21	2	-2	0	1	-2	-1	0	3	-1	-3	1	1	2	-2	1	-4	-4
Statement 22	1	1	1	2	1	0	0	4	3	0	4	1	1	-1	-1	0	0
Statement 23	-2	2	-1	-2	1	1	1	-2	-4	0	0	1	1	-2	-4	-2	-3
Statement 24	-3	2	-1	-1	0	-1	2	-1	1	-1	0	1	-1	0	-3	-2	-3
Statement 25	-1	0	-2	2	0	-2	0	-2	1	-1	0	0	0	-1	-2	-1	-3
Statement 26	2	-4	0	-1	0	2	2	3	3	0	0	1	0	0	-3	-2	-1
Statement 27	-4	-4	-4	-1	3	1	-2	4	0	-4	0	-3	-3	-2	-2	-2	-2

Participants/ Statements	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
Statement 28	-2	-3	-3	-1	-4	-2	0	3	-3	-1	0	-3	-1	-2	0	0	1
Statement 29	-3	0	-2	-1	-1	-3	-2	0	-3	-2	-3	-2	0	-1	-2	-1	-2
Statement 30	-2	-2	-2	-1	2	3	1	0	-1	-3	-1	0	0	0	0	1	1
Statement 31	-1	-2	-1	2	0	-2	1	-2	2	2	-1	-1	0	3	-2	1	-1
Statement 32	0	-3	-1	3	0	-1	-1	0	2	-2	-1	-1	-1	2	1	2	2
Statement 33	3	0	0	3	2	-1	-1	0	-2	-2	-1	0	-2	0	0	1	1
Statement 34	-1	0	-2	0	-2	-2	0	-2	2	4	-1	0	0	1	1	0	2
Statement 35	-1	-2	4	-3	3	1	-1	-2	-2	-2	-2	-2	-2	4	3	-1	-2
Statement 36	-2	-1	0	3	-3	-2	-2	-4	-2	-1	-4	0	-1	3	0	-1	1
Statement 37	-1	-1	2	0	-1	-3	1	-3	0	-1	-1	-1	-2	1	1	1	-1
Statement 38	0	-3	-3	-4	-4	-3	-1	-4	-3	1	-2	-2	-1	0	2	0	0
Statement 39	4	1	1	2	0	3	4	2	2	1	-2	-1	-1	1	-1	-1	-1

The programme R Studio with the "Q method" package [39] was used for the ensuing analysis.

3.5. Qualitative Data Analysis

The analysis starts with a multivariate data reduction technique used by principal component analysis (PCA) to reduce the correlation matrix between Q-sorts into components. The first few components are selected and mathematically optimal rotated in order to obtain a clearer and simpler structure for the data. If the principal components are used to extract factors, the variance equals the eigenvalue. The size of the eigenvalue is used to determine the number of factors. The factors with the largest eigenvalues have to be retained. For example, using the Kaiser Gutman criterion, all the factors with eigenvalues that are greater than 1 should be used according to Braeken and Van Assen [40]. After some experimentation with different sets of factors, the decision for a four-factor model has been taken although a 5-factor model would have been applicable [41] as visible in Figure 5 for the unrotated factors.

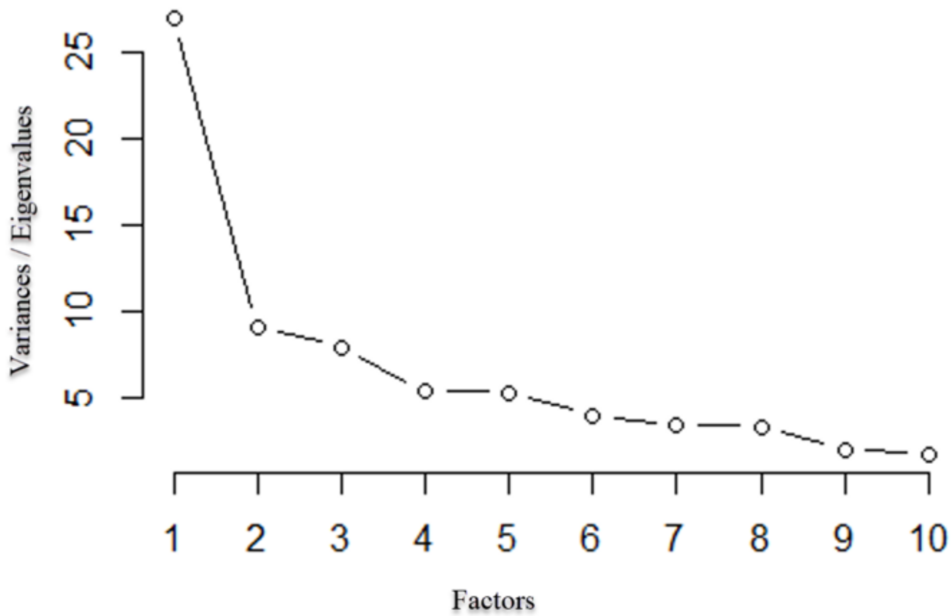

Figure 5.
Screen plot of unrotated factors.

Investigation of factor loadings, eigenvalues, explained variance, factor correlations and composite reliability scores suggests the four-factor solution accounts for 62 % of the variance (see Table 3).

Table 3.
Characteristics of factor loading.

Characteristic per factor	F1	F2	F3	F4
Average reliability coefficient	0.80	0.80	0.80	0.80
Number of loading Q-sorts	6	4	3	3
Eigenvalues	3.19	2.89	2.64	1.85
Percentage of explained variance	18.79	17.02	15.51	10.89
Composite reliability	0.96	0.94	0.92	0.92
Standard error of factor scores	0.20	0.24	0.28	0.28

The total amount of loading Q-sorts was achieved by using 5 factors as indicated by Figure 5. Only the loadings per factor were different but in total only 16 sorts could be directly allocated to a factor. More than 60% of the explanation was already provided by the loading of four components. Therefore, this value was used for additional analysis. The composite reliability is above the recommended value of 0.7 [42] for all four extracted factors.

Unrotated factor loadings are often difficult to interpret [43]. Factor rotation simplifies the loading structure allowing us to interpret the factor loadings more easily. However, one method of rotation may not work best in all cases. Different rotations were tried and the "cluster" rotation was used as it created the most interpretable results.

There are two standard criteria for automatic flagging used in Q method analysis [44]:

1) Q-sorts factor loading is higher than the threshold for a p-value < 0.05.
2) Q-sorts whose square loading is higher than the sum of square loadings of the same Q-sort in all other factors.

In its automatic mode, the PQ Method employs two or more Q sorts with significant loading to 'flag' Q sorts.

$$0.01 = 2.58 * (1 + sqrt(y))$$

y being the number of statements [39]

The used software package "q method" based on 'R' provides the following automated flagging for the factor loadings (see Table 4).

Table 4.
Factor matrix provided by the q method.

Participants	F1	F2	F3	F4
P1	0.31	0.05	0.36	**0.41**
P2	0.59	-0.14	0.11	0.14
P3	0.23	**0.43**	0.27	0.23
P4	0.06	-0.18	-0.11	0.71
P5	-0.30	0.29	0.82	0.09
P6	0.03	-0.03	0.86	0.10
P7	0.68	-0.12	0.01	0.11
P8	-0.02	0.01	0.80	-0.19
P9	0.12	-0.05	0.51	0.56
P10	0.58	0.32	-0.18	0.28
P11	0.66	0.24	0.18	-0.29
P12	0.77	0.07	0.07	-0.12
P13	0.78	0.26	-0.16	-0.29
P14	-0.32	0.50	0.01	0.69
P15	-0.02	0.89	-0.08	-0.04
P16	0.17	0.79	0.08	0.02
P17	0.12	0.81	0.03	0.05

Note: Values calculated after factor rotation; marked values indicating a defining sort (a significant loading) automatically by the "q method".

Participant 3 was automatically included for factor 2, as shown by the bolded noted value. It can be assumed that significance is reached according to the threshold and program logic calculation. Participant 1 reached only a loading of 0.41 (also marked bold in Table 4) on factor 4 and failed to fully load this factor. As the distance to the threshold (as used for participant 3) is not very large (0.0197 in exact numbers), it might be assumed this participant could be loaded with or closely related to factor 4.

Table 5 contains the four factors or main perspectives indicating the agreement or disagreement of the given perspective with each statement.

Table 5.
Factor scores for each of the four extracted factors.

Statements	F1	F2	F3	F4
1	-3	-4	0	-2
2	-1	3	3	3
3	3	4	4	2
4	3	3	3	1
5	4	2	0	-1
6	1	3	0	-1
7	1	2	1	0
8	3	1	-1	-3
9	-4	-2	-4	-4
10	-1	-2	1	4
11	2	-1	2	2
12	0	2	-3	-1
13	4	4	4	-2

Statements	F1	F2	F3	F4
14	2	0	1	-3
15	2	2	1	4
16	-3	-2	-1	0
17	0	-1	0	0
18	-1	-1	1	-1
19	0	0	-1	0
20	2	2	-1	1
21	1	-1	0	-1
22	2	0	2	2
23	1	-4	0	-4
24	1	-3	-1	0
25	0	-2	-2	1
26	0	-3	2	0
27	-4	-3	3	-2
28	-2	0	-2	-2
29	-2	-2	-2	-2
30	-1	0	2	-1
31	0	-1	-2	3
32	-2	1	-1	3
33	-1	0	0	1
34	1	1	-2	1
35	-3	1	1	0
36	-2	0	-3	2
37	-1	1	-3	1
38	-2	1	-4	-3
39	0	-1	2	2

Factor scores presented in Table 5 represent the strength of agreement with all statements. For example, perspective (factor) F4 is in strong disagreement with statement 8 (scoring -3) whereas F1 rather takes the opposite opinion (scoring 3) and perspectives F2 and F3 show an ambivalent opinion (scoring 1 and -1, respectively). The qualitative analysis and interpretation are based on a narrative procedure aiming to link themes and statements together to develop a joint impression of participants' viewpoints. The results are complemented with descriptive data of participants loading on the factors, including information on age and educated number of household members.

Factor analysis assumes that the relationship (correlation) between variables is due to a set of underlying factors (latent variables) that are being measured by the variables. Principal component analysis is not based on the idea that there are underlying factors that are being measured [45]. Table 6 displays a table showing the correlations between the correlations of the rotated factor z-scores.

Table 1.
Relationships between factor Z-scores.

Factors	Factor 1	Factor 2	Factor 3	Factor 4
Factor 1	1.0000	0.5198	0.3967	0.1115
Factor 2	0.5198	1.0000	0.2486	0.2170
Factor 3	0.3967	0.2486	1.0000	0.2260
Factor 4	0.1115	0.2170	0.2260	1.0000

The bolded highlighted value indicates that participant 3 was automatically added for factor 2. Factors 1 and 2 have consensus in several statements.

3.6. Quantitative Data Analysis

The analysis will focus on the distinguishing statements to investigate how the perspectives (factors) differ within this paper. Nevertheless, the consensus statements are also important and should be respected for any further development. Total consensus is with statements.

17: The comparable average consumption should always be indicated with the own consumption.

19: The application should always have several divisions integrated (district heating, electricity, water, gas etc.).

29: I would prefer heat or another energy source to district heating.

The first consensus statements achieved a positive attitude (agree, most important), statement 29 received a complete negative agreement (disagree or least important).

Factor 1: Locally engaged consumers: EU skeptical consumers (keep EU regulation away from district heating).

This group is technically informed and well-educated in regards to the production of energy in a district heating system. They are totally in favor of district heating and see the benefits as they share the opinion that it should be available to as many participants as possible. As long as district heating is available to all consumers, regulation by the government and especially the European Union is not needed. Statement 12 (the state should intervene even more in the energy market and make and enforce regulations regarding the technologies used) was rated neutrally. The local engagement serves as the unifying element for all customers who join factor group 1. Table 7 shows the distinguishing statements of this group.

Table 7.
Table distinguishing statements for factor 1 ($p < 0.05$).

Statement	Q-SV	Z-score
2. There are no maintenance costs, no responsibility, no heat production and no firing inside the properties of the district heating users, therefore, no chimney is required.	-1	-0.28
5. Combined heat and power (CHP) make optimum use of fuels.	4	1.64
8. District heating should also be available in sparsely populated areas (Preferable from local resources).	3	1.61
12. The state should intervene even more in the energy market and make and enforce regulations regarding the technologies used.	0	-0.03
33. The taxation of energy products in Hungary or in the EU must be more closely aligned with the aspect of climate protection.	-1	-0.64
35. The state should let the market regulate prices (Market economy).	-3	-1.17
36. The European Union should become even more involved in the energy industry.	-2	-0.87
37. Only sufficient financial incentives would induce me to change my behavior with regard to heating and ventilation.	-1	-0.59

Factor 2: Smartphone application-skeptic consumers: Only factor 2 rated statement 22 (whether data must be integrated into the application in order to control the heating specifically) with a neutral vote while all other factors considered that more or less mandatory. This group surprised me with their attitude towards new media in the form of applications. Here, the cheapest price is not required and usage data is also needed when the users are at home. Statement 36 (the European Union should become even more involved in the energy industry) was also considered neutral by factor group 2 (see Table 8).

Table 8.
Table distinguishing statements for factor 2 ($p < 0.05$).

Statement	Q-SV	Z-score
5. Combined heat and power (CHP) make optimum use of fuels.	2	0.99
8. District heating should also be available in sparsely populated areas (Preferable from local resources).	1	0.28
11. District heating offers price stability.	-1	-0.44
12. The state should intervene even more in the energy market and enforce regulations regarding the technologies used.	2	0.84
22. Whether data must be integrated into the application in order to control the heating specifically.	0	-0.23
24. When I am not at home, I need information about heat consumption. I would like to have the consumption transmitted through the internet.	-3	-1.44
26. A smartphone application must offer or suggest the cheapest rate for me depending on consumption.	-3	-1.14
32. Laws and technical systems must be adapted so that data protection and security are ensured and consumption data cannot be passed on.	1	0.73
36. The European Union should become more involved in the energy industry.	0	0.01
38. District heating is the most expensive form of heating.	1	0.42

Factor 3: Intrinsically motivated sustainable consumers: Factor scores for factor group 3 indicated a statement. It is mainly the space savings that encourage many customers to buy district heating while all other hold that it is less important (negative rating). This factor group denied at a larger scale governmental and especially European influence and regulation.

The same holds true for additional financial incentives. Two statements indicated that additional financial stimulus would not be needed for sustainable heating and behavior. Additional financial incentives are not needed. Consumers are rather motivated by sustainability itself than additional financial benefits. This group would still like to receive a paper bill which was largely denied by all other groups (see Table 9).

Table 9.
Table distinguishing statements for factor 3 ($p < 0.05$).

Statement	Q-SV	Z-score
1. It is mainly the space savings that encourage many customers to buy district heating.	0	0.16
8. District heating should also be available in sparsely populated areas (Preferable from local resources).	-1	-0.64
10. State-regulated prices prevent expensive investments in sustainable technologies for heat generation.	1	0.43
12. The state should intervene even more in the energy market and enforce regulations regarding the technologies used.	-3	-1.64
18. I would be willing to spend more money on district heating in the case of proven sustainable production.	1	0.50
20. I would be willing to change my habits (Turn off the heating on vacation, ventilate now and then instead of constantly ventilating).	-1	-0.42
27. I always need a paper invoice or bill.	3	1.38
30. Environmentally friendly heating and ventilation does not require financial incentives.	2	1.07
34. No basic charge, district heating prices should be charged exclusively according to consumption.	-2	-1.14
36. The European Union should become even more involved in the energy industry.	-3	-1.62
37. Only sufficient financial incentives would induce me to change my behavior with regard to heating and ventilation.	-3	-1.36

Factor 4: Insulate buildings: state price skeptics: Consumers which are grouped or rather described by factor group 4 (see Table 10) are skeptical of governmental regulations but also would involve the European Union in local problem solving. Laws and information would be the key success factors for successful and sustainable district heating solutions. State regulated prices prevent needed investments. This factor group was the only one that provided a high ranked positive opinion towards the fact that state regulated prices prevent sustainable investments. The other factors denied that statement or ranked it much less positive (see factor 3).

Table 10.
Table distinguishing statements for factor 4 ($p < 0.05$)

Statement	Q-SV	Z-score
1. It is mainly the space savings that encourage many customers to buy district heating.	-2	0.81
8. District heating should also be available in sparsely populated areas (Preferable from local resources).	-3	-1.53
10. State-regulated prices prevent expensive investments in sustainable technologies for heat generation.	4	1.66
12. The state should intervene even more in the energy market and enforce regulations regarding the technologies used.	-1	-0.74
13. Security of supply is always the top priority in a district heating system.	-2	-1.26
14. District heating supports large investments in renewable energies.	-3	-1.35
15. The investments in thermal insulation of buildings should also be supported like the investments in sustainable and CO_2 free production of thermal energy.	4	2.14
31. Users of district heating are becoming more environmentally aware and just need the right information to act in a conscious way.	3	1.53
32. Laws and technical systems must be adapted so that data protection and security are ensured and consumption data cannot be passed on.	3	1.55
36. The European Union should become more involved in the energy industry.	2	1.20

All factors are distinguished with statements 8, 12 and 36. These statements are rated totally different in each factor group. With 3 consensus statements and 3 all distinguishing factors the whole Q-sort seems evenly distributed.

A common socio-demographic factor for each factor group was not possible. For example, group 3 included participants 5, 6 and 8, all having different educational degrees, different preferences for used devices and different partnership. The age range also differs. Only the people living in the household (2 or 3) were unique. The same is true for factor group 4. Therefore, the factor groups represent different attitudes towards sustainability and district heating but there is no unified socio-demographic characteristic identified.

3.7. Summary and Discussion in Consumer Opinion

The four identified factors were given a comprehensible name to identify the attitude towards district heating in general and sustainability in detail together with price sensitiveness. Three statements achieved complete consensus among consumers. Three statements were generally agreed by the customers. Among the most notable was statement 29, which was universally rejected by all participants: "I would prefer heat with another energy source than with district heating."

The consumers seem convinced district heating is the right choice with regard to urban energy systems and sustainable consumption. Additionally, the more smart meters and intelligent artificial agents are used and consumed by smartphone applications. The users prepared with their own devices. Any application dealing with the usage of utilities i.e. water, electricity or in the given case district heating should combine the different divisions and provide an integrated experience. It can be assumed for other divisions but for district heating, it was proven when providing information on average consumption. The cheapest price is not too important, it's important for consumers to be able to compare themselves to the average. How much is one's personal consumption in relation to a chosen comparison group? It would always be possible to adopt one's own habits and behaviour with such knowledge.

The necessity of a paper bill is desired by a very small number of participants. This attitude was a real differentiator for factor group three. The option to access a paper bill will not be the main driving and innovation feature for any future solution. As this group would be willing to spend more money when proven sustainable sources are used for heat generation, it should be possible to convince this group also to overcome the need for printed bills. The trust in smartphone application seems high already as all (except one) participants indicated to use electronical devices for banking already. The consumers would not trust any application to regulate the complete household as the reaction to statement 23 (I would trust an application enough to let it regulate my heating on its own) revealed. Here, the factors provided a very diverse response. Smartphones still need to get more sustainable [46] themselves. They are one key to more digital information and behavioral change. Smartphones can also provide opportunities for better access to advice and sustainable behavior in the form of virtual appointments in areas where people would normally need to travel long distances to receive expert advice.

The answer to statement 7 (more digitalization leads to more environmentally friendly generation processes (e.g., through education and visualization)) was mainly positive or neutral. The consumers agree that digitalization helps to grow environment friendly generation of heat. Digitalization is also able to provide the base figures and transfer the data when needed. Here, the socio-demographic part indicated that the end users are technically able to work with electronical devices and some even prefer the smartphone over a standard PC or laptop. This would support and justify the conclusion [23] for customers in Eastern Europe as well. Any smart meter software has to enable the use of several divisions.

Generally, the attitude towards district heating is positive. It's seen as the key to more sustainability. Although there was no full consensus on statement 9 (no more research and investment should be made in district heating), this statement was rated rather negatively. Conversely, this means consumers would support and approve further research in the area of district heating.

4. Conclusion, Recommendations and Limitations

The aim of this study is to explain the results of the paper. The Q-method revealed that consumers do not require to be informed about the cheapest rate (statement 26: A smartphone application must offer or suggest the cheapest rate for me depending on consumption) but have a rather diverse attitude. Statement 35 (the state should let the market regulate prices (market economy)) was negatively rated by factor group 1 while the other three factors rated that as neutral or surprisingly positive. Germany implemented a state regulated price lately [47] (or will implement the same in early 2023), this finding was rather unexpected.

The reviewed literature was already concluded. New pricing mechanisms and pricing models are more likely to be accepted if the information is transparent and the end users can significantly influence their price by own behavior.

The results of the data analysis suggest that K-means clustering can be performed on large data sets and data sampling can reveal the same number of clusters as the full data set. Four clusters were identified in a two-dimensional space and the results indicate that longer and stable operating hours with low demand are the most preferred followed by low demand with shorter operating hours. The least preferred option is low operating hours with high demand. Further research includes identifying meters and the consumers behind them for cluster #1 from sampled data or performing the analysis for an additional year. Follow-up research could also include private data such as house size and type of use. The results also suggest that the use of waste heat such as that produced by the sugar factory could be enhanced by additional sources.

Four factors were identified in the research to understand consumer attitudes towards district heating and sustainability. The majority of consumers was convinced that district heating is the best choice for urban energy systems and sustainable consumption and was willing to use intelligent artificial agents and smart meter applications to manage their heating. However, there was little interest in accessing paper bills and some hesitation about trusting an app to regulate the household's heating on its own. Digitalization was seen as a way to promote environmentally friendly heat generation through education and visualization and most consumers were technically proficient in using electronic devices. The attitude towards district heating was positive with a majority supporting further research and investment in the area.

4.1. Contribution and Practical Implications

4.1.1. Developing a Dynamic Pricing Method

Actually, Hungary has state-regulated prices and many other European countries (e.g. Germany) are introducing state-regulated prices as well. Nevertheless, the results of the previous chapters of this paper can be used to describe a rather new pricing model. The best pricing method for district heating varies depending on several factors [48] including the characteristics of the system, the customer base and the regulatory framework. Some of the most commonly accepted pricing methods include:

1. Flat rate pricing: This method involves charging a fixed amount per unit of energy consumed regardless of the time of day or season.

2. Time-of-use pricing: This method involves charging different rates based on the time of day with higher prices during peak demand periods and lower prices during off-peak periods.
3. Dynamic pricing: This method involves using advanced metering and billing systems to charge customers in real-time based on the prevailing market price for energy.
4. Conservation pricing: This method involves offering incentives to customers who reduce their energy consumption such as lower rates for those who use energy during off-peak periods.

Ultimately, the best pricing method for district heating will depend on the specific needs and goals of the system and its customers. The first two are quite common and also widely accepted as found within the literature review. Conservation pricing might work for electricity but heating time depends on the outside temperature. When it's warm outside, it's rare to find consumers needing a lot of heat. Dynamic pricing is something that would have to be explored deeper based on the findings of this paper but the idea development shall be started.

Dynamic pricing is a pricing method that adjusts the price of a product or service in real-time based on market conditions and supply and demand. In the context of district heating, dynamic pricing uses advanced metering and billing systems to charge customers for the energy they consume based on the prevailing market price for energy at the time of consumption.

Dynamic pricing can provide several benefits for district heating systems including [16]:

1. Improved efficiency: Dynamic pricing can encourage customers to reduce their energy consumption during peak demand periods when energy prices are highest by charging customers based on real-time market conditions.
2. Increased revenue: District heating systems can increase their revenue and better recover the cost of providing energy by charging higher prices during peak demand periods.
3. Better alignment of supply and demand: Dynamic pricing can help to better match the supply of energy with customer demand reducing the risk of over- or under-supply by adjusting prices based on market conditions.
4. Dynamic pricing can also provide benefits for customers such as increased transparency and control over their energy costs. However, it may also be seen as unfair or confusing by some customers particularly if they are not familiar with how dynamic pricing works.

Dynamic pricing can be an effective pricing method for district heating but it requires careful implementation and communication to ensure that it is well understood and accepted by customers. It involves adjusting the price of energy based on real-time market conditions such as the supply and demand for energy, the availability of alternative energy sources and the cost of producing energy.

Based on the results of the Q-method analysis, it seems that consumers have a positive attitude towards district heating and see it as a key to greater sustainability. They are prepared for the use of smart meters and intelligent artificial agents as long as these devices provide an integrated experience for all utilities and allow for comparison to average consumption. Although the cheapest price is not a primary concern, consumers want to be able to compare their own consumption to others. Digitalization is seen as a way to increase environmentally friendly generation processes and access to expert advice.

A dynamic pricing method for district heating could take into account the different factors identified in the Q-method analysis. For example, the pricing method could incorporate peak periods of high demand and adjust prices accordingly, while also offering a comparison to average consumption for each user. Additionally, the pricing method could take into account the use of sustainable energy sources which would appeal to consumers who are willing to pay more for environmentally friendly options.

However, the pricing method would also need to be accessible through smartphones and provide an integrated experience for all utilities as consumers have a high level of trust in these devices and prefer them over traditional paper bills. Finally, the pricing method would need to take into account the need for further research and investment in district heating, as consumers generally support this idea.

An example of a dynamic pricing method for district heating that incorporates both the K-means clusters [4] and the q-method findings:

1. High demand for a long period of time.
2. High demand for a short period of time.
3. Low demand for a long period of time.
4. Low demand for a short period of time.

The q-method findings indicate that consumers:

- Have a positive attitude towards district heating as a key to sustainability.
- They prefer smart meter devices over traditional paper bills and are willing to pay more for environmentally friendly options.

The dynamic pricing method could be designed as follows:

4.1.1.1. High Demand for a Long Period of Time (Cluster 1)

During peak periods of high demand, prices could be adjusted to reflect the increased usage.

For example, if the average price per unit of energy during off-peak periods is €0.10 during peak periods of high demand the price could increase to €0.15.

Additionally, the price could be made transparent by showing users how it compares to the average consumption of a selected comparison group.

This would allow users to adopt more sustainable habits and make more informed decisions about their energy usage.

4.1.1.2. High Demand for a Short Period of Time (Cluster 2)

Prices could be adjusted to reflect the increased usage during short periods of high demand.

For example, if the average price per unit of energy during off-peak periods is €0.10 during a short period of high demand the price could increase to €0.12.

This would encourage users to shift their energy usage to off-peak periods which would help to balance the demand on the system.

4.1.1.3. Low Demand for a Long Period of Time (Cluster 3)

Prices could be adjusted to reflect the reduced usage during low demand periods.

For example, if the average price per unit of energy during off-peak periods is €0.10 during low demand periods the price could decrease to €0.08.

This would encourage users to continue their energy usage during these periods which would help to balance the demand on the system.

4.1.1.4. Low Demand for a Short Period of Time (Cluster 4)

Prices could be adjusted to reflect the reduced usage during short periods of low demand.

For example, if the average price per unit of energy during off-peak periods is €0.10 during a short period of low demand the price could decrease to €0.09.

Short periods of time mean in this context only a few hours per day. A long period would reflect in several consecutive hours (or even days). This would encourage users to shift their energy usage to the corresponding periods which would help to balance the demand on the system.

Finally, according to the q-method findings, the pricing method may be made available through cellphones and enable the integration of all utilities giving the consumer a more complete experience. Additionally, the pricing method could take into account the use of sustainable energy sources which would appeal to consumers who are willing to pay more for environmentally friendly options. It's important to note that this is just one example and the actual prices and pricing structures used in dynamic pricing for district heating may differ in practice depending on the specific needs and goals of the system and its customers as well as the regulatory framework in place. Dynamic pricing models can vary widely depending on the specific needs and goals of the district heating system and its customers as well as the regulatory framework in place. The example above is just one possible scenario and the actual prices and pricing structures used in dynamic pricing may differ in practice.

4.2. Technical Consumer Information Enablement

A large common part for infrastructural means with a lower part for direct consumption provides less potential for an actual behavior change. Information is the key to success in any new model but in achieve behavior change, information is a key factor. Earlier year's email-based information system was tested and provided to end users with more and more applications running on mobile devices taking over the information part. Within several publications it was proven [49] that even early in grade school the usage and consumption of smart phones and applications are already very common. The growing generation might not even remember what a paper bill is or how that was sent to the end user. In retail business [50], the usage of push notifications is common and broadly researched. The Technology Acceptance Model (TAM) was adopted for the retail use case. However, there is currently nothing comparable available for consumer applications that promote sustainable behaviour. Customers would be thrilled to use and appreciate the opportunity to increase sustainable consumption and awareness through the combination of weather data and smart home applications.

4.3. Critical Thinking Aspects

If the best course to a decarbonized global heating system had been identified; it is unlikely to remain that way due to technological advancements. According to several recent papers, if heat supply electrification is done in a coordinated way that takes into account our principles and general technological advancements, the longer-term effects on energy systems can be minimized. It is apparent that in many countries where space heating demand is significant, some combination of energy efficiency alongside electrification appears important and wider innovation around electrification may further support this pathway [51, 52]. Furthermore, the electrification of heating demand is likely to provide an important route to increase the quantity of renewable energy in energy systems. The idea sounds reasonable and challenging. The only problem is that solar energy generation often performs less well during the primary heating seasons [53]. The efficiency of photovoltaic (PV) systems or the amount of energy they can convert from sunlight is typically around 20%. However, the cost-effectiveness of PV systems is affected by other factors such as electricity production costs, space requirements, resource usage and carbon emissions savings [54]. The maximum amount of electricity a generator can support at the point of connection to the transmission and distribution system during summer and winter is known as the net summer and net winter electricity generation capacity respectively. These are usually determined by performance tests. Two main factors that influence the capacity difference between summer and winter are the temperature of cooling water for thermal power plants and the temperature of ambient air for combustion turbines and water flow and reservoir storage characteristics for hydropower plants [55].

"Heating electrification is one of the biggest mistakes of the energy transition" [56]. Heating electrification is one of the biggest mistakes of the energy transition says Christian Holter who calls for allocating scarce renewable energy resources to economic sectors where they can bring the most in terms of carbon reduction. “It “makes no sense” to bring electric power into heating because winter demand for heat is 5 to 10 times bigger than the entire electricity system which won’t be able to cope [56].

The EU has set a goal to increase the use of renewable energy in heating and cooling by 1.3% annually until 2030 but some experts believe this goal is too ambitious while others think it is not enough to fully decarbonize the energy system by 2050. The challenges in achieving this goal include a lack of education and understanding about renewable energy, difficulties in obtaining financing for long-term investments and a preference for short-term returns on investments over long-term financial exposure. Renewable energy infrastructure projects require long-term perspectives of 25-30 years and returns on investments of 15-20 years to be sustainable. This is where the finance industry and the needs for sustainable development are in opposite directions. The city of Kaposvár is already on the right track. Science could and will support the chosen path. The current work did show the need for additional sustainable heating sources as there are high-demand clusters and also consumers who support further investments in district heating and urban energy systems. The term "urban energy systems" refers to the combination of waste heat use and traditional heat-producing facilities. A single strategy is often found in the literature; it is uncommon to find an approach that combines many sources and supplies. The focus is on electricity as it’s easier to transmit and consume [57].

Recognizing the expectation of the need for a significant level of heat electrification using heat pumps in many countries (with electricity simultaneously being decarbonized). Current research focuses mainly on electricity and tries to electrify several aspects (e.g., cars). It is still not proven that electrification is the right approach but it reduces uncertainties. Thermal energy storage (TES) systems are also an answer to sustainable and greenhouse gas reducing approaches that affect heating [55].

4.4. Further Research Aspects

Additional research about district heating and its effects on energy systems includes:

- Examining the local challenges facing the implementation of renewable energy infrastructure projects and investigating solutions to overcome them.
- Investigating innovative solutions for urban energy systems like waste heat recovery and combined heat and power.
- Examining the potential for demand-side management strategies such as load shifting and peak shaving to reduce the strain on urban energy systems during times of high demand.
- Investigating consumer preferences and behavior in relation to energy consumption and willingness to support further investments in district heating and urban energy systems.

Country-specific distinctions would result in more specific programs dependent on local needs and possibilities. Countries such as Norway with their huge availability of waterpower generations are in need of totally different funding programs than especially East European countries. There is still a gap in research on consumer behavior and expectations in Eastern Europe.

References

[1] A. M. Tureczek, P. S. Nielsen, H. Madsen, and A. Brun, "Clustering district heat exchange stations using smart meter consumption data," *Energy and Buildings,* vol. 182, pp. 144-158, 2019. https://doi.org/10.1016/j.enbuild.2018.10.009

[2] D. Andrews, "Carbon footprints of various sources of heat - biomass combustion and CHPDH comes out lowest " - William Orchard.” Claverton Group," Retrieved: https://claverton-energy.com/carbon-footprints-of-various-sources-of-heat-chpdh-comes-out-lowest.html. [Accessed February 7, 2009], 2009.

[3] Southeastern Oklahoma State University, "Gain a better understanding of consumer behavior," Retrieved: https://online.se.edu/articles/mba/gain-a-better-understanding-of-consumer-behavior.aspx. [Accessed March 20, 2022], 2022.

[4] U. Radtke, "A brief literature review of structuring district heating data based on measured values," *The Ohio Journal of Science,* vol. 122, no. 2, pp. 75-84, 2022. https://doi.org/10.18061/ojs.v122i2.8845

[5] L. Kerekes, "Assessment of price regulation in hungarian district heating systems - REKK," Retrieved: https://rekk.hu/analysis-details/285/assessment-of-price-regulation-in-hungarian-district-heating-systems. [Accessed May 30, 2022], 2022.

[6] V. Stennikov and A. Penkovskii, "The pricing methods on the monopoly district heating market," *Energy Reports,* vol. 6, pp. 187-193, 2020. https://doi.org/10.1016/j.egyr.2019.11.061

[7] H. Li, Q. Sun, Q. Zhang, and F. Wallin, "A review of the pricing mechanisms for district heating systems," *Renewable and Sustainable Energy Reviews,* vol. 42, pp. 56-65, 2015. https://doi.org/10.1016/j.rser.2014.10.003

[8] J. Song, F. Wallin, H. Li, and B. Karlsson, "Price models of district heating in Sweden," *Energy Procedia,* vol. 88, pp. 100-105, 2016. https://doi.org/10.1016/j.egypro.2016.06.031

[9] S. Bonn, "Explanation of the district heating prices from SWB energy and water - SWB energy and water - Stadtwerke Bonn," Retrieved: https://www.stadtwerke-bonn.de/fuer-zuhause/produkte/fernwaerme/erlaeuterung-der-fernwaermepreise-von-swb-energie-und-wasser/. [Accessed November 21, 2021], 2021.

[10] S. Kaiserslautern, "District heating: Our offer for you | SWK Kaiserslautern," Retrieved: https://www.swk-kl.de/en/products-services/energy/district-heating. [Accessed November 21, 2021], 2021.

[11] M. Åberg, J. Widén, and D. Henning, "Sensitivity of district heating system operation to heat demand reductions and electricity price variations: A Swedish example," *Energy,* vol. 41, no. 1, pp. 525-540, 2012. https://doi.org/10.1016/j.energy.2012.02.034

[12] M. Linden and P. Peltola-Ojala, "The deregulation effects of finnish electricity markets on district heating prices," *Energy Economics,* vol. 32, no. 5, pp. 1191-1198, 2010. https://doi.org/10.1016/j.eneco.2010.03.002

[13] O. Gudmundsson, J. Thorsen, and L. Zhang, "Cost analysis of district heating compared to its competing technologies," *WIT Transactions on Ecology and the Environment,* vol. 176, pp. 3-13, 2013. https://doi.org/10.2495/esus130091

[14] D. Poputoaia and S. Bouzarovski, "Regulating district heating in Romania: Legislative challenges and energy efficiency barriers," *Energy Policy,* vol. 38, no. 7, pp. 3820-3829, 2010. https://doi.org/10.1016/j.enpol.2010.03.002

[15] S. Oh and S.-K. Kim, "Impact of heat price regulation on the optimal district heating production mix and its policy implications," *Energy*, vol. 239, p. 122305, 2022. https://doi.org/10.1016/j.energy.2021.122305

[16] H. Li, J. Song, Q. Sun, F. Wallin, and Q. Zhang, "A dynamic price model based on levelized cost for district heating," *Energy, Ecology and Environment*, vol. 4, no. 1, pp. 15-25, 2019. https://doi.org/10.1007/s40974-019-00109-6

[17] J. Zhang, B. Ge, and H. Xu, "An equivalent marginal cost-pricing model for the district heating market," *Energy Policy*, vol. 63, pp. 1224-1232, 2013. https://doi.org/10.1016/j.enpol.2013.09.017

[18] R. Gabbrielli, P. Castrataro, F. Del Medico, M. Di Palo, and B. Lenzo, "Levelized cost of heat for linear Fresnel concentrated solar systems," *Energy Procedia*, vol. 49, pp. 1340-1349, 2014. https://doi.org/10.1016/j.egypro.2014.03.143

[19] V. Stanytsina, V. Artemchuk, O. Bogoslavska, I. Zinovieva, and N. Ridei, "The influence of environmental tax rates on the Levelized cost of heat on the example of organic and biofuels boilers in Ukraine," in *E3S Web of Conferences*, 2021, vol. 280: EDP Sciences, p. 09012.

[20] M. De Simón-Martín, S. Bracco, G. Piazza, L. C. Pagnini, A. González-Martínez, and F. Delfino, *Levelized cost of energy in sustainable energy communities: A systematic approach for multi-vector energy systems*. Cham: Springer Nature, 2022.

[21] S. Werner, "European district heating price series," Retrieved: https://energiforskmedia.blob.core.windows.net/media/21926/european-district-heating-price-series-energiforskrapport-2016-316.pdf. [Accessed November 21, 2021], 2016.

[22] C. Weiner and T. Szép, "The Hungarian utility cost reduction programme: An impact assessment," *Energy Strategy Reviews*, vol. 40, p. 100817, 2022. https://doi.org/10.1016/j.esr.2022.100817

[23] L. K. E. Mouritsen, K. Sperling, M. K. Svangren, and F. Hvelplund, "Consumer involvement in the transition to 4th generation district heating," *International Journal of Sustainable Energy Planning and Management*, vol. 29, pp. 141-152, 2020. https://doi.org/10.5278/IJSEPM.4627

[24] K. Sernhed, H. Gåverud, and A. Sandgren, "Customer perspectives on district heating price models," *International Journal of Sustainable Energy Planning and Management*, vol. 13, pp. 47-60, 2017. https://doi.org/10.5278/IJSEPM.2017.13.4

[25] B. Xu, L. Fu, and H. Di, "Field investigation on consumer behavior and hydraulic performance of a district heating system in Tianjin, China," *Building and Environment*, vol. 44, no. 2, pp. 249-259, 2009. https://doi.org/10.1016/j.buildenv.2008.03.002

[26] T. Ueno, F. Sano, O. Saeki, and K. Tsuji, "Effectiveness of an energy-consumption information system on energy savings in residential houses based on monitored data," *Applied Energy*, vol. 83, no. 2, pp. 166-183, 2006. https://doi.org/10.1016/j.apenergy.2005.02.002

[27] T. Yoon, Y. Ma, and C. Rhodes, "Individual Heating systems vs. District Heating systems: What will consumers pay for convenience?," *Energy Policy*, vol. 86, pp. 73-81, 2015. https://doi.org/10.1016/j.enpol.2015.06.024

[28] T. Krikser, A. Profeta, S. Grimm, and H. Huther, "Willingness-to-pay for district heating from renewables of private households in Germany," *Sustainability*, vol. 12, no. 10, p. 4129, 2020.

[29] S. William, "The study of behavior: Q-technique and its methodology," *American Journal of Sociology*, vol. 61, no. 2, pp. 167–69, 1955. https://doi.org/10.1086/221704

[30] S. Ramlo, "Centroid and theoretical rotation: Justification for their use in Q methodology research," *Mid-Western Educational Researcher*, vol. 28, no. 1, pp. 73-92, 2016.

[31] A. L. Valenta and U. Wigger, "Q-methodology: Definition and application in health care informatics," *Journal of the American Medical Informatics Association*, vol. 4, no. 6, pp. 501-510, 1997. https://doi.org/10.1136/jamia.1997.0040501

[32] S. R. Brown, "Q methodology and qualitative research," *Qualitative Health Research*, vol. 6, no. 4, pp. 561-567, 1996.

[33] N. Dalkey and O. Helmer, "An experimental application of the Delphi method to the use of experts," *Management Science*, vol. 9, no. 3, pp. 458-467, 1963. https://doi.org/10.1287/mnsc.9.3.458

[34] S. Keeney, H. A. McKenna, and F. Hasson, *The Delphi technique in nursing and health research*. Oxford: John Wiley & Sons, 2011.

[35] J. K. Kampen and P. Tamás, "Overly ambitious: Contributions and current status of Q methodology," *Quality & Quantity*, vol. 48, no. 6, pp. 3109-3126, 2014. https://doi.org/10.1007/s11135-013-9944-z

[36] M. Kirschbaum, T. Barnett, and M. Cross, "Q sample construction: A novel approach incorporating a Delphi technique to explore opinions about codeine dependence," *BMC Medical Research Methodology*, vol. 19, no. 1, pp. 1-12, 2019. https://doi.org/10.1186/s12874-019-0741-9

[37] J. Wallis, J. Burns, and R. Capdevila, "Q methodology and a Delphi poll: A useful approach to researching a narrative approach to therapy," *Qualitative Research in Psychology*, vol. 6, no. 3, pp. 173-190, 2009. https://doi.org/10.1080/14780880701734545

[38] T. Webler, S. Danielson, and S. Tuler, "Using Q method to reveal social perspectives in environmental research," Retrieved: https://www.researchgate.net/profile/Stentor-Danielson/publication/273697977_Using_Q_Method_to_Reveal_Social_Perspectives_in_Environmental_Research/links/582a4e1608aef19cb805583d/Using-Q-Method-to-Reveal-Social-Perspectives-in-Environmental-Research.pdf. [Accessed June 03, 2021], 2009.

[39] A. Zabala, "qmethod: A package to explore human perspectives using Q methodology," *The R Journal*, vol. 6, no. 2, pp. 163-173, 2014. https://doi.org/10.32614/rj-2014-032

[40] J. Braeken and M. Van Assen, "An empirical Kaiser criterion," *Psychological Methods*, vol. 22, no. 3, pp. 450-466, 2016. https://doi.org/10.1037/met0000074

[41] C. DiStefano, M. Zhu, and D. Mindrila, "Understanding and using factor scores: Considerations for the applied researcher," *Practical Assessment, Research, and Rvaluation*, vol. 14, no. 1, pp. 1-12, 2009.

[42] J. F. Hair, W. C. Black, B. J. Babin, and R. Anderson, *Multivariate data analysis*, 7th ed. Upper Saddle River NJ: Prentice Hall, 2010.

[43] M. Yamamoto and R. I. Jennrich, "A cluster-based factor rotation," *British Journal of Mathematical and Statistical Psychology*, vol. 66, no. 3, pp. 488-502, 2013.

[44] S. R. Brown, "Political subjectivity: Applications of Q methodology in political science," *Journal of Marketing Research*, vol. 19, no. 1, p. 162, 1980. https://doi.org/10.2307/3151542

[45] DTREG, "Correlation & factor analysis | solution | DTREG," Retrieved: https://www.dtreg.com/solution/correlation. [Accessed December 11, 2022], 2022.

[46] J.-C. Tu, X.-Y. Zhang, and S.-Y. Huang, "Key factors of sustainability for smartphones based on Taiwanese consumers' perceived values," *Sustainability*, vol. 10, no. 12, p. 4446, 2018. https://doi.org/10.3390/su10124446
[47] Website of the Federal Government, "Website of the federal government | Bundesregierung "EU energy council: Reducing prices, securing supplies | Federal Government," Retrieved: https://www.bundesregierung.de/breg-en/search/eu-gas-price-cap-2155126. [Accessed December 30, 2022], 2022.
[48] IEA, "District heating. IEA," Retrieved: https://www.iea.org/reports/district-heating. [Accessed December 20, 2022], 2022.
[49] A. Wohllebe, H. Dirk-Siegfried, R. Uwe, and W. Arabel, "Smartphones and mobile apps: Case study on usage behavior of elementary school students – insights from a rural area in Northern Germany," *International Journal of Interactive Mobile Technologies,* vol. 15, no. 12, p. 184, 2021b. https://doi.org/10.3991/ijim.v15i12.22565
[50] A. Wohllebe, H. Dirk-Siegfried, R. Uwe, and P. Szilárd, "Mobile apps in retail: Effect of push notification frequency on app user behavior," *Innovative Marketing,* vol. 17, no. 2, pp. 102–111, 2021a. https://doi.org/10.21511/im.17(2).2021.10
[51] A. Itten, F. Sherry-Brennan, T. Hoppe, A. Sundaram, and P. Devine-Wright, "Co-creation as a social process for unlocking sustainable heating transitions in Europe," *Energy Research & Social Science*, vol. 74, p. 101956, 2021. https://doi.org/10.1016/j.erss.2021.101956
[52] R. Lowes, J. Rosenow, M. Qadrdan, and J. Wu, "Hot stuff: Research and policy principles for heat decarbonisation through smart electrification," *Energy Research & Social Science*, vol. 70, p. 101735, 2020. https://doi.org/10.1016/j.erss.2020.101735
[53] U.S. Energy Information Administration, "Frequently asked questions (FAQs) - U.S. Energy information administration (EIA)," Retrieved: https://www.eia.gov/tools/faqs/faq.php?id=101&t=3. [Accessed January 15, 2023], 2022.
[54] H. Wirth, "Recent facts about photovoltaics in Germany," Retrieved: https://www.ise.fraunhofer.de/en/publications/studies/recent-facts-about-pv-in-germany.html. 2022.
[55] R. B. Laughlin, "Pumped thermal grid storage with heat exchange," *Journal of Renewable and Sustainable Energy,* vol. 9, no. 4, p. 044103, 2017. https://doi.org/10.1063/1.4994054
[56] S. Frédéric, "Heating electrification is one of the biggest mistakes of the energy transition. EURACTIV," Retrieved: https://www.euractiv.com/section/energy/interview/solar-ceo-heating-electrification-is-one-of-the-biggest-mistakes-of-the-energy-transition/. 2019.
[57] I. Sarbu and C. Sebarchievici, "A comprehensive review of thermal energy storage," *Sustainability,* vol. 10, no. 1, pp. 1-32, 2018. https://doi.org/10.3390/su10010191