

# Heating the Future: Overcoming Challenges and Gaining Stakeholder Support for District Heating Transformation

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**Abstract.** District heating plays an important role in many studies and scenarios for reaching greenhouse gas neutrality in Germany's heating sector. In some scenarios, the share increases to up to 30 % of the final energy demand for heat supply in buildings. Expanding and transforming district heating will not occur without significant effort; it will take a deliberate approach and appropriate measures to successfully achieve these goals. Technical and organizational challenges must be addressed, along with securing support and promoting social acceptance and active societal support among the various stakeholders. Therefore, in this research, barriers, and potential solutions are analyzed for the seven main stakeholder groups involved and affected by the extension and transformation of district heating in Germany. Furthermore, this study examines and discusses methods to increase acceptance and active societal support in Denmark, the Netherlands and France, based on literature, interviews and two stakeholder workshops. Consequently, measures to increase acceptance of and active societal support for district heating in Germany are specified.

**Keywords:** District Heating, Stakeholder Analysis, Active Societal Support, Acceptance, Political Measures

## 1. Introduction

The transformation and expansion of district heating (DH) in Germany is essential to reduce greenhouse gas emissions in the heating sector. This includes building and expanding DH systems as well as the integration of renewable energy and waste heat. It is a complex system transformation in which many stakeholders with individual interests and agendas are involved. To ensure the active support of all relevant stakeholders and to increase acceptance, coordination and cooperation are necessary. While the energy transition discourse in the past has largely focused on technical challenges and solutions, socio-economic and socio-cultural aspects as well as possible conflicting goals have often been neglected [1]. Yet, the transformation of our energy system is closely tied to social structures and requires the active support and personal contribution of the population. Therefore, considering acceptance as a multidimensional and complex construct (see [2,3]) and stimulating active participation of diverse societal stakeholders and institutions, tend to be considered central success factors for the complex transformation of DH.

The aim of this paper is to analyze the state of knowledge on active societal support and acceptance of DH. This includes barriers and facilitating factors, societal and individual strategies, measures, and existing policy instruments, both in the national and in the European context. Based on the assessment, ideas for new political and societal measures, strategies, and instruments, which can contribute to overcoming barriers and increasing the societal acceptance of DH, are developed. The focus is on Germany with its specific market and political structure.

## 1.1 Importance of District Heating Transformation

In 2021, approximately 134 TWh of DH were generated and 122 TWh district heat (end energy) used in the different consumption sectors in Germany (compare [4,5]). DH accounted for approximately 10 % of the total heat demand in Germany [4], and 8 % of the heat demand of private households [5]. In several scenarios for the transformation of the German energy system, the share of DH in the heat supply of buildings (space heating and hot water in residential and commercial buildings) rises to around 30 % in 2045/2050 [6]. In 2021 the share of renewable energies in DH generation was only about 22 % while approximately two-thirds were generated from fossil fuels, mostly from natural gas and coal [5]. To achieve the goal of climate neutrality in 2045, large amounts of renewable heat and unavoidable waste heat must be integrated in DH systems in just two decades. In the European Union, a strong increase of the share of DH in space and water heating from 12 % to up to 24 % with significant differences between Member States in 2050 is projected in some scenarios [7].

The expansion and decarbonization of DH are a fundamental transformation process associated with enormous investments, which need the support of all stakeholders involved in DH supply or affected by the expansion and transformation of DH. Ambitious policies are needed to guide and support this transformation process. Therefore, barriers must be overcome. Furthermore, the acceptance and the willingness of the various stakeholders involved to support the transformation must be increased. However, the latter is a particular challenge due to the high need for coordination. The transformation of DH, therefore, is a complex system transformation for which technical, economic, political, social, psychological as well as organizational and planning aspects on European, national and particularly local/ municipal level must be considered.

## 1.2 Concept of Acceptance and Active Societal Support

Several studies have highlighted the importance of giving greater importance to the social dimension of the energy transition (see, for example, [1,8,9]). There are numerous publications, particularly in the social sciences, that analyze the conflicts related to societal issues, often using renewable energies as an example [10,11]. The term "acceptance" is frequently used in energy transition discourses as well as in specific energy transition projects. It is considered important to ensure or increase acceptance in order to successfully implement a planned technical solution. However, this narrative tends to be regarded as difficult from different perspectives [10]. Research on the acceptance of renewable energy projects indicates that "acceptance" is a multidimensional construct and, therefore, complex [2,3]. Several terms are frequently used in the context of technology-related acceptance research. These include acceptability, (social) acceptance, support, and attitudes. Yet, according to Svhweizer-Ries and Rau [3], acceptance is a multidimensional concept. The evaluative dimension measures how a project is assessed by the stakeholders, ranging from "positive" to "negative". The second dimension specifies the behavioral activity as either "passive" or "active". If a person shows no recognizable behavior, such as no protest or support, this is classified as passive. If actions in one of the two directions can be observed, for example through founding or joining an energy cooperative investing in renewable energy technologies, this is considered active. However, according to Devine-Wright et al. [12], the research has focused excessively on the resistance and rejection of renewable energy technologies, overlooking support for renewable energies and a multi-stakeholder perspective. Upham et al. [13] focus more strongly on the context of

acceptance and the importance of different groups of actors with different organizational levels and social functions. The authors discuss the roles and functions of actors who influence the design of the energy system through their attitudes, intentions and actions. Individuals can thereby take on different social roles, for example as end users and politicians.

As acceptance is often portrayed in public as merely a passive acceptance of changes to the energy system - contrary to the multidimensionality of the term used in scientific discourse, as described above - we also use the term "active societal support" (see also [14]). This term reflects and emphasizes the goal of "sparking a self-sustaining social dynamic" ([14], p. 20), which ultimately characterizes the energy transition as a joint effort of a pluralistic society. The aim of policymakers and other decision-makers should therefore be to promote social ownership (and thus also social acceptance through the involvement and support of social actors to take an active role) of the energy transition.

A key question is the extent to which communities/citizens can be empowered to drive and shape the energy transition themselves and to contribute and realize their own ideas [15]. For promoting public involvement, information provision and transparency early in the planning process are essential. Public engagement has been found to be particularly relevant when individuals' opinions are not only heard, but can actually impact the decision-making process [16]. Furthermore, trust in the involved parties is associated with perceptions about energy policies and systems, and thus their acceptability (see also [17]). Participatory processes and the associated necessary support mechanisms (e.g., through appropriate political instruments and the provision of financial resources) seem necessary in order to involve various interest groups in the energy transition and enable proactive, independent advancement (see [18,19]).

In the realm of district heating, the following aspects of acceptance (see [2]) are relevant:

- At the socio-political level, the approval or rejection of, political support for or opposition to the expansion of heat networks and the required renewable heat generation capacities in general;
- At the level of local acceptance, the approval or rejection, political support or opposition to local projects for the construction of heat networks and the required renewable heat generation capacities;
- At the level of market acceptance, the willingness to connect to a heating network or the rejection of the same.

Market acceptance and active societal support are of crucial importance for the realization of grid-based heat supply projects since these projects are only economically viable if a sufficient number of consumers are connected.

## **2. Methodology**

### **2.1 Stakeholder Analysis**

The analyzed stakeholders involved in and/ or affected by the transformation of district heating in Germany are energy supply companies, municipalities, planning offices, SHK (sanitary, heating, air-conditioning) craft, building owners and tenants, (organized) citizens, associations, and other stakeholders. In the analysis, the various stakeholders are described according to their specific roles in the current system, actor-specific challenges, the required acceptance, and support services as well as facilitating factors with respect to the transformation of DH and the increase of acceptance and active societal support. Challenges and strategies are clustered into the following categories:

- social: e.g. belonging and participation, equality and gender aspects, social status, conflict potentials,

- psychological: e.g. confidence, sovereignty, prospects,
- Organizational and planning: e.g. infrastructure planning/synchronicity, execution, further education/training,
- political: e.g. political support, political influence, legal framework/legal guidelines,
- economic: including costs, ownership, market environment, business models, expected returns, revenues, regional added value, income distribution,
- technical: e.g. synchronization of grid temperatures and temperature requirements of consumers; availability of local renewable and waste heat sources; data basis for heat planning.

The analysis is mainly based on a structured literature review. Since little (scientific) literature was available for some stakeholders, the literature review was complemented by interviews with representatives of the stakeholder group. For the assessment and description, a consistent structure was developed. The main barriers and associated facilitating/supporting services and measures were summarized in tables. In a last step, the stakeholder-specific findings were compared and aggregated to identify the most relevant barriers and most promising instruments/measures to increase acceptance and active societal support for DH expansion and transformation. The results were discussed in a stakeholder workshop (see chapter 3.3).

### **3.2 Country analysis: Denmark, France, and the Netherlands**

The objective of the district heating sector analyses conducted in Denmark, the Netherlands, and France is to examine and to extract sector characteristics and advancements that may prove valuable to the discourse on the future development of district heating in Germany. To a large extent, the analyses followed the structure applied for the stakeholder analysis in Germany, i.e. mainly categories for describing barriers and strategies (social, psychological etc.). In each country analyzed, we describe the market structure, political and regulatory framework, and main stakeholders to examine and categorize the state of district heating development and its acceptance among various stakeholders. Furthermore, the general participation culture was assessed. The assessment is mainly based on a structured literature review complemented by interviews with relevant stakeholders, e.g. national agencies, and citizen energy associations. The results were compared with the current German framework for DH to identify promising instruments and measures, which could be transferred to the German context to increase acceptance and active societal support for DH expansion and transformation. The results were discussed in a stakeholder workshop (see chapter 3.3).

### **3.3 Stakeholder Workshops**

To discuss the preliminary findings of the stakeholder and country analysis, two workshops were conducted. At a first online workshop conducted on 28 March 2023, the topic of how active societal support for DH systems could be retained was discussed. The aim was to present and to discuss the identified stakeholder-specific barriers and strategies with relevant national stakeholders. Representatives from planning and consulting, municipalities, DH companies, tenant and owner associations, consumer protection and research participated in the workshop. Barriers and strategies along typical project phases were discussed from the perspective of building owners, municipalities, organized citizens, and DH companies. Results were documented using an online-collaboration tool. Participants rated the barriers and strategies according to their relevance.

The second workshop focused on experiences in the three analyzed countries, Denmark, France, and the Netherlands. Organized as a hybrid-event, this European exchange focused on securing societal support for heat networks. Relevant stakeholders from the three countries provided inputs and results from our research were presented. In three groups, the most crucial elements and instruments were discussed in depth and evaluated according to pre-defined

criteria. These criteria were “general relevance of the measure/ instrument”, “promotion of active societal support”, “regional value creation and networking,” “profitability”, “price transparency”, “acceleration of the expansion of pipeline-bound heat supply”, and “insertion into political framework”. Representatives from national ministries and agencies, unions/ associations, research, consulting, and municipalities participated in the workshop. The results of both workshops were integrated in the further research, especially for the identification and development of measures to increase acceptance and active societal support for DH in Germany.

## **4. Results**

### **4.1 Stakeholder Analysis**

#### **4.1.1 Stakeholder Description**

As mentioned above, the stakeholder groups energy supply/DH companies (municipal, cooperative, private), local self-government/municipalities (administration, local politics), planning offices, plumbing, heating and cooling crafts, building owners and tenants, (organized) citizens, and interest groups/associations and other stakeholders were analyzed. For DH expansion and transformation, DH companies and municipalities are the core stakeholders. Therefore, both are described more detailed in the following, whereas the other stakeholders are described in aggregated form.

DH companies operate the DH systems on-site. In Germany, they are fully integrated companies, i.e. they generate, distribute, and supply the generated heat to end customers. This gives DH companies a great deal of room for maneuver as they can plan and implement efficiency measures themselves throughout the entire system, from generation to delivery to end customers [6]. In Germany, the majority of DH companies are owned by municipalities [20]. Besides, there are some private DH companies as well as cooperatives; the latter are mainly located in rural areas [21,22]. According to Beier et al. (2020) [23], there are around 1,000 municipal utilities in Germany. 550 of the utilities operate their own DH networks according to Clausen (2017) [24]. As a partner to local authorities in urban development, municipal DH companies are key to the success of the local heating transition, among other things due to their role in providing services of general interest (see [23,25]). The energy transition will significantly change the existing business models of energy supply companies. A shift in the importance of grid-based energy supply (DH, electricity, gas) is to be expected. While electricity and DH will continue to be important in the long term, gas will become less important as a fossil fuel and sales will decline. The fossil-free DH supply to customers will therefore remain a secure business area in the future. However, energy supply companies will also have to consider new business models and focuses for the future, such as the provision of energy services [23].

Local self-government/municipalities have a central role to play in the planning of new and existing DH systems. They play various roles in relation to the decarbonization and the expansion of DH. As political representatives of the citizens, the municipal council is authorized to make important decisions regarding the heat supply [26]. Municipalities act as consumers of heat for public buildings, provided that the buildings are connected to the DH system [26]. The municipal administration itself is responsible for urban planning, the definition of development plans (which may also include requirements for heat supply), the preparation and implementation of (civil engineering) measures and ultimately the management of the entire municipality. In addition, local authorities are often already active in the heat supply sector as municipally-owned companies or shareholders of municipal utilities and are therefore the ones who make decisions regarding strategy and investments for the DH transformation [27]. Municipalities are important intermediaries: In the area of municipal climate protection, action is often aimed at informing, advising or motivating target groups to take action [28]. In this function and through

corresponding "soft" measures, municipalities can contribute to the densification of DH systems in existing buildings as part of municipal heat planning [28]. According to Beier et al. [23], the heat transition can only be successfully implemented if municipal utilities and local authorities work together and act as partners in urban development. In Paar et al. [28], municipal companies are seen as key players in the area of climate protection and, in particular, in the area of DH. Strengthening them is therefore important for the implementation of corresponding projects and increases the municipalities' room for maneuver. In this context, support for the re-municipalization of the energy supply, including the foundation of new municipal utilities and cooperatives, is regarded as key.

In comparison, the other stakeholders do not play as central a role as utilities and municipalities and are thus only briefly described below:

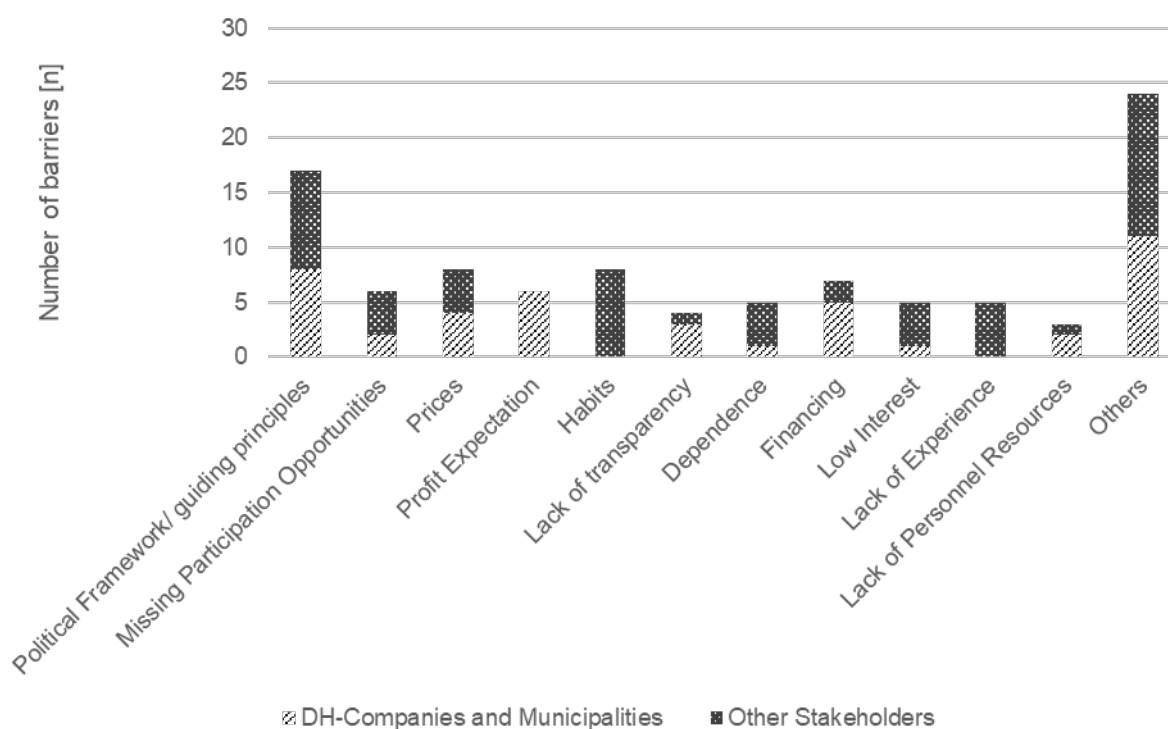
- Planning offices: Engineers, architects and planners carry out feasibility studies when planning a heating network [26] and often accompany the entire planning process [29,30];
- Plumbing, heating and cooling crafts advise on heating systems and the integration of renewable heating systems in buildings; they are responsible for the on-site installation, maintenance and optimization of heating systems and thus for the installation of house substations;
- Building owners and tenants have a high importance in terms of investment in new technologies, but participation in heating networks is more difficult due to building-specific heat planning;
- (Organized) citizens can influence local decisions and get involved in initiatives both in favor of and against DH. They can also organize themselves collectively in order to invest in and operate DH systems;
- Interest groups, associations and other stakeholders at federal and state level as well as intermediaries are networkers, (knowledge) mediators and drivers of innovation (including the expansion and conversion of local DH-systems). They represent interests and point the way for or against the expansion of DH and ensure its thematic visibility.

#### **4.1.2 Main Barriers to DH Expansion and Transformation**

The identification of barriers and approaches to increase acceptance and active societal support in the context of transforming and expanding DH is based on a multitude of publications:

- DH companies: [23,24,26,31–41]
- Local self-government/ municipalities: [23,24,26–28,31,38,42,43]
- Other stakeholders: [6,24,26,29,30,43–83]

To summarize the findings, the identified barriers are clustered. The results are shown in Figure 1.



**Figure 1:** Clustered barriers for expanding and transforming district heating systems from the perspective of district heating companies and municipalities as well as other stakeholders.

Most barriers are seen in the context of the political framework and guiding principles, both for DH companies and municipalities as well as other stakeholders. This comprises policies and guidance on a national level, but also support and guidance on local level as well as within DH companies (see [6,34,35]). Uncertainties concerning future technological and strategic developments regarding technologies and energy carriers, at both national and local levels, hinder the development of transformation strategies and investment decisions. This, in turn, has a negative impact on the acceptance of expanding and transforming DH systems by municipalities, DH companies, and other stakeholders. Additionally, current legislation can hinder the expansion and connection of existing buildings to DH systems.

For DH companies and municipalities, prices (DH prices, prices for fossil fuels), profit expectations and financing are also of major importance. On the one hand, the persistently low prices for fossil fuels have a negative impact on the profitability of emission-free alternatives, both for heat supply for DH systems and installations in single buildings. This reduces the acceptance of alternative heat supply options for DH as well as the connection to emission-free DH-systems. Furthermore, expanding and transforming DH systems is related to high investments. Difficulties in obtaining long-term debt capital is therefore negatively influencing the acceptance for the transformation by different stakeholders, amongst other DH companies [23].

Although the barrier of missing participation opportunities is not mentioned as frequently as others, it is closely linked to some of the other factors, such as (perceived) dependency, lack of experience, and opacity. Therefore, providing opportunities for participation is considered crucial in maintaining and gaining acceptance and active societal support for DH. The same applies to opacity. Missing transparency concerning prices and pricing mechanisms, (political) strategies, upcoming construction works and the (expected) future role of different technologies and energy carriers was mentioned as an essential barrier for many of the assessed stakeholders.

### **4.1.3 Approaches to Increase Acceptance and Active Societal Support**

Overall, the identified stakeholder-specific barriers to the acceptance of and active societal support for DH can be addressed by different measures and instruments. However, addressing the barriers is associated with challenges. Individual interests must be considered or negotiated. Barriers should be addressed in a way that acceptance of DH increases among as many stakeholders as possible. Furthermore, as many stakeholders as possible should be addressed in such a way that they actively shape and support DH transformation and expansion. Several approaches for increasing the acceptance and active societal support of DH among all stakeholders were identified. active societal support

Major success factors and strategies for increasing the acceptance of and support for active societal support of DH include municipal heat planning, transparency, consistent and target-oriented political frameworks, the reorganization of municipal financing, and financial support for participation in planning. Municipal heat planning as a process can ensure clarity on a local level regarding the future structure of heat supply for all stakeholders. If the process is transparent and central stakeholders are involved, it creates transparency, which might influence trust in the decision-making process and stakeholders [84]. Furthermore, municipal heat planning can help stakeholders adjust to the future structure and adapt business models if necessary.

Lack of transparency as one central barrier for many stakeholders relates to several facets as mentioned above. These facets have a different relevance for different stakeholders. Price transparency is of major importance for consumers, transparency regarding upcoming construction works is important for utilities that want to invest in DH. Clarity regarding the future role of technologies and energy carriers is important for most assessed stakeholders. At the local level, municipal heat planning can increase transparency. All other aspects must be addressed on a higher level. Price transparency requirements are, for example, regulated on a national level.

A consistent and targeted policy framework for expanding and transforming DH is essential, as DH is seen as central for the heat transition. This comprises appropriate funding and a consistent regulatory framework. With the launch of the Federal Grant Programme for Efficient District Heating Systems (BEW) in 2022, an important step was made to address the need of financial resources/support. It is important that sufficient funding is permanently available in the coming years. Furthermore, a clear focus is placed on energy efficiency, DH and decentralized renewable heat supply, amongst others, in future amendments of the Buildings Energy Act (GEG). In addition, barriers to connecting to DH systems must be removed (Heat Supply Ordinance) and DH must become a financially attractive option for customers (pricing/components).

As many stakeholders want to receive information and be actively involved in the transformation and expansion of DH, participation options should be established. Appropriate opportunities can increase the acceptance of DH among many stakeholders and enable active societal support. For participation processes, neutral and competent facilitators are important. They must carry out the processes in a fair, purposeful, and efficient manner. Municipal heat planning provides an opportunity to implement structured participation formats. In addition, various stakeholders, including citizens and municipalities, may express interest in participating and benefiting financially from the expansion and transformation of DH. Therefore, it is important to create financial participation opportunities.

## **4.2 Learning from Denmark, France, and the Netherlands**

In European Member States, the status of DH varies greatly. DH systems have been established in Denmark for decades and their share in heat supply is high. In France and the Netherlands, DH is still in the early stages of development. The countries assessed also differ in



terms of (price) regulation, acceptance, and participation of citizens in expanding and transforming DH.

Due to their long tradition in different other economic sectors, cooperatives operate a large part of DH systems in Denmark, especially in rural areas [20,21]. Thereby, the local population is strongly involved and actively designs DH systems. In France, DH is dominated by a few large companies and participation is not yet widespread [85]. Constructing and operating DH systems is seen as a public task and not as an area in which individuals become active [86,87]. This is not necessarily negative for expanding and transforming DH systems, especially when there is a high level of trust in and commitment of the (local) public sector. However, the interest in being actively involved in expanding and transforming DH was increasing in the past years [88]. In the Netherlands, attempts are being made to actively involve the local population in the course of the design of the gas phase-out and the associated neighborhood approach [89]. In the three assessed countries, the importance of municipalities and their associations in the heat transition and thus in DH is emphasized. The most relevant findings are:

- Common understanding of goals in the area of heat supply across all federal levels and political affiliations positively affect the transformation of heat supply. Reliability and thus planning security are thereby created for all stakeholders. Furthermore, it is important for the socio-political acceptance and (political) communication.
- Municipalities are the central stakeholders in the expansion and transformation of DH. They must be put in a position to fulfil this task and therefore need sufficient financing and (personnel) resources for planning, approving as well as actively involving relevant stakeholders and the public in transformation processes. Financing of their tasks must be provided structurally (e.g. by national bodies) rather than depending on revenues from DH.
- Identifying challenges municipalities and other stakeholders face, sharing learning experiences between municipalities and forwarding the synthesized information to the next higher governance level, that in turn might adjust regulation or create additional capacity, appears relevant for an efficient and inclusive transformation process (systematic horizontal and vertical learning).
- Active participation and financial opportunities for the population are important aspects for the local acceptance of DH and for achieving active societal support of the transformation at the local level.
- Appropriate price regulation and price transparency are paramount to increasing trust and the market acceptance of district heating as they operate as local monopolies. Municipal companies and cooperatives are often characterized by higher transparency and lower prices, amongst others, due to lower profit expectations than private companies.
- Assessing the economic viability of DH based on social or economic benefits for the public (macroeconomic perspective) can help enable lower heat prices in DH systems. This is likely to increase acceptance of DH. However, the macroeconomic perspective can lead to reduced company profits, which can reduce the investment aspirations of DH companies. It is not necessary to adapt the Danish non-profit principle. However, a greater focus on societal benefits/profits should be weighted higher than individual profits.
- For the necessary investments in DH, financial support and favorable financing conditions are needed. This not only includes subsidies, but also favorable loans, which are particularly relevant with a view to the economic expectations of investors. Furthermore, it contributes to enabling low heat prices, which has a positive effect on the market acceptance of consumers.

### 4.3 Political Measures to Increase Acceptance and Active Societal Support

Based on the analysis of the stakeholders in Germany and experiences gathered in Denmark, France, and the Netherlands, the following measures are identified as essential to and supportive in increasing acceptance and active societal support: systematic vertical learning, price transparency, price regulation, transparency of relevant information, and financing participation processes. Central elements of these measures are developed and described below.

By establishing **systematic horizontal and vertical learning** processes for planning DH systems in municipalities, several key barriers are addressed. Amongst others, know-how is created on a municipal level, which supports faster planning and approval of DH projects and appropriate stakeholder involvement. Learning processes should be established throughout all relevant governance levels from the municipalities to the national level. On a municipal level, this encompasses dialogue with relevant stakeholders, the identification of challenges as well as adjustment and support needs. For horizontal learning, formats for exchange between municipalities must be established. Through these formats, the most relevant needs can be identified to develop measures for adjustment and support. For the vertical learning process, the aggregated information from the municipal level is communicated to the federal state level and adjustment and support strategies lying within the responsibility of the federal states can be developed. At the highest level, information from all federal states is collected and communicated to the national level. This is of major importance with a view to barriers which can only be addressed on national level. The process guarantees that important barriers are identified and addressed on the relevant governance level. To establish the process, relevant stakeholders must be identified, and structures established. Furthermore, a common evaluation and communication procedure needs to be developed.

**Price transparency** refers to complete and accurate knowledge of the current market prices of relevant goods [90]. Consumer protection stakeholders have repeatedly described price transparency in the DH market as inadequate (e.g. [91,92]). By increasing price transparency in the DH sector, the comparability between the price levels of different DH systems is improved. This provides DH customers with an indication of where they stand with their individual DH price compared to other DH providers and thus increases trust and acceptance. Similar systems in, for example, Denmark and Sweden have proved to increase transparency and acceptance for many years. These concepts can be used as a blueprint and must be adjusted to the German context. A central element is establishing a price transparency platform that offers price information for typical consumers like single and multi-family buildings. Furthermore, central figures explaining possible price differences between DH systems should be provided, e.g. the share of renewable energies in the heat supply. It was recently announced that such a platform will be available in April 2024 [93]. It is not yet foreseeable whether all requirements from consumer protection organizations will be met. The platform, which is developed and established by the three main DH associations of Germany, is a first step in and starting point for increasing price transparency.

**Price regulation** is the targeted influencing/control of the prices of economic goods by a state institution (e.g. regulatory authority) on the basis of its sovereign powers. Price regulation is generally found in monopoly markets where it serves to protect consumers. In the natural monopolies of electricity and gas networks, for example, this results in the regulation of network charges. The DH market also corresponds to a natural monopoly. Unlike the unbundled electricity and gas markets, the DH market is vertically integrated. Price regulation would therefore have to cover all stages of vertical integration so that not only the transmission prices (network charges) but also the entire end customer price would have to be subject to regulation. The price regulation of district heating pursues objectives on two different levels:

- consumers: Stronger regulation of pricing and thus protection of subscribers from excessive prices,

- district heating companies: Transparency about pricing in the costs of the transformation to a decarbonized DH supply; protection against public accusations of charging excessive prices.

There are several options for price regulation: mandatory ex-ante price regulation, i.e. price authorization; ex-post price regulation; voluntary price certification. In Germany, the anti-trust authorities are responsible for monitoring abuse. However, whether the respective authorities with their current mandate and resources have the capacities for price control and approval, must be assessed. Another option is to transfer these tasks to the Federal Network Agency (BNetzA) as it has the necessary competences. Independently from the definition of the responsible authority, a political agreement is needed, which is currently difficult to achieve.

Improving the **transparency** and thus the comparability of DH systems and companies would increase the acceptance of customers. Currently, information is difficult to find on websites of DH companies. There is no standardized nomenclature for the provision of information or standardized specifications for the place and manner of information provision. Publication and transparency requirements are defined in the District Heating Ordinance (AVBFernwärmeV) and an amendment could improve the transparency. There are generally two options for improving transparency: relevant information (must be defined) can be published on a central platform, which would also allow the comparison of different DH systems (compare price transparency). DH companies would need to provide the relevant information in a pre-defined format. Another option is that the accessibility of information on DH companies' websites is improved. For example, the name of the respective subpage or the document name can be specified if the information is provided for download.

**Participation processes** need time as well as financial and personnel resources. Currently, there is no funding available for municipalities and DH companies to establish good participation processes for DH projects. However, participation in planning processes as well as financial participation opportunities are seen as key to improving acceptance and active societal support. Both aspects are addressed in the following: (i) financing participation (information, workshops, active involvement) and (ii) attractive conditions for creating financial participation opportunities. The latter can, on the one hand, improve the active societal support of energy transition and, on the other hand, help provide the needed financial resources for the huge investments in DH. With the federal funding program Efficient Heating Networks (BEW), Germany has a funding program for the expansion and transformation of DH. It therefore makes sense to integrate the financing of participation processes and the incentivization of financial participation by citizens into the BEW. It could be provided by a subsidy bonus in addition to the defined basic subsidy.

## 5. Conclusion

It is projected that district heating will significantly gain in importance in the future based on extensive scientific studies. The transformation and expansion of DH require the support of various stakeholders, whose active involvement and acceptance are critical. Both can be supported by a consistent and targeted policy framework committed to promoting and expanding DH. A consistent and targeted policy framework can help to overcome existing barriers. Among the assessed stakeholders, DH companies and municipalities are of major importance for transforming and expanding DH systems. They invest in the systems and are responsible for approving projects on the local level. Municipalities are, furthermore, shareholders in DH companies and can thus directly influence investment decisions. For an increased acceptance, the support of citizens is crucial. They are also relevant for an active participation in/active societal support of the transformation process. A broad societal support of relevant stakeholders including the wider public for transforming and expanding DH systems brings several advantages, e.g.:

- faster approval of DH projects,
- less opposition and delays due to complaints,
- future perspectives for relevant stakeholders,
- active participation of citizens,
- additional private capital for the necessary investments.

The identified measures show a great potential for increasing the acceptance and active societal support of DH among several relevant stakeholders, especially DH companies, municipalities, and consumers. Organizing participation processes is, however, often associated with substantial efforts and require personnel and financial resources. The main measures and instruments are:

- systematic horizontal and vertical learning,
- price transparency,
- price regulation,
- transparency of relevant information,
- financing participation processes.

The implementation of these measures takes time, but the measures have the potential of a long-lasting positive impact. Besides the measures listed above, there are many additional measures and instruments, which have the potential to positively influence acceptance and active societal support for transforming and expanding DH systems. One key instrument is municipal heat planning, which has been mandatory for all municipalities in Germany since 1 January 2024. Organized as an ongoing process, municipal heat planning can, on the hand, provide orientation for all relevant stakeholders by developing a consistent plan for the local heat transition. On the other hand, it offers the opportunity to get actively involved in the planning process as well as the implementation of the developed plan.

## Author contributions

Benjamin Köhler, Jessica Berneiser: Preparation, creation and/or presentation of the published work, specifically writing the initial draft (including substantive translation).

Veit Bürger, Jessica Berneiser, Caren Herbstritt, Katja Hünecke: Preparation, creation and/or presentation of the published work by those from the original research group, specifically critical review, commentary or revision – including pre- or post-publication stages.

## Competing interests

The authors declare that they have no competing interests.

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