From policy to action: assessing the effectiveness of heating and cooling plans — a case study on heating and cooling plans of municipalities in Baden-Württemberg, Germany

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Abstract

Strategic heating and cooling (H&C) planning has been recognized as an effective tool for driving the decarbonization of heating and cooling systems in urban areas. Consequently, the revised Energy Efficiency Directive (EED) now mandates municipal heating and cooling planning for municipalities with a population exceeding 45,000. Similarly, in Baden-Württemberg, a federal state in Germany, a comparable law has been in effect since 2020, requiring the development of heating plans by the end of 2023. Approximately 100 municipalities in Baden-Württemberg are subject to this legislation. The main target of these heating and cooling plans is to devise action strategies and measures to enhance energy efficiency, as well as provide climate neutral heating supply. Notably, this law stipulates that at least five measures must be specified in the heating plans, with implementation starting within five years after development of the heat plan at the latest. This paper examines the heat plans published in Baden-Württemberg until December 2023, with a focus on the proposed implementation measures. The aim is to evaluate the effectiveness of these measures in reducing greenhouse gas emissions. To achieve this, we categorize the measures into six different areas of action and three levels of intensity. The results indicate that the majority of measures are planned within the area of action ***District heating and cooling and waste heat***, while the fewest measures are found in the area ***Planning and conception***. In the areas of action ***Increasing efficiency and renovating buildings*** and ***Feasibility studies***, predominantly minor measures are employed, suggesting that the emphasis is not on improving energy efficiency and thus reducing heat demand. The findings of this study can assist policymakers and stakeholders in developing effective heating and cooling plans, thereby facilitating the decarbonization of heating and cooling systems in urban areas.

Introduction

Heat supply is playing an increasingly important role in the context of energy and climate policy. In the European Union, around half of energy consumption is used for heating and cooling. However, only 25 % of this energy came from renewable sources in 2022 (Eurostat 2023). In order to achieve climate targets and accelerate decarbonization, a rapid switch to renewable energy and waste heat in heat supply is essential.

The recent challenges in the energy sector, in particular the gas shortage, have led more and more countries and the European Union itself to focus intensively on the issue of heat supply. In contrast to the electricity sector, the supply of heating and cooling is an extremely local issue that must be tackled at municipal level. Therefore, measures to reduce energy demand in heating and cooling and to increase the share of renewable energy and waste heat at local level are crucial.

A proven tool for implementing these measures is heating and cooling planning (Chittum and Ostergaard et al. 2014 & Billerbeck et al. 2022). In Denmark, for example, heat planning has been an integral part of urban planning since 1979 and is mandatory (Köhler et al. 2021). The importance of heat planning has also been recognized at European level, as provided for

in the Recast of the Energy Efficiency Directive[1] (EED). According to this, municipalities with more than 45,000 inhabitants are obliged to carry out heat planning. However, the requirements of such heat planning are only roughly described and the specific content is not yet clearly defined. The directive still has to be transposed into national law by the member states, with specifications and a deadline being set.

Despite the lack of specification, various guidelines and directives already exist to support the heat planning process. One example of this is the EU project Act!onHeat, in which a workflow[2] that can serve as a basis for carrying out heat planning has been developed. Corresponding guidelines have also already been developed at municipal level in some German federal states, such as Baden-Württemberg and North Rhine-Westphalia. Overall, it is clear that the topic is attracting more and more attention at European and national level and that information and guidance on this topic is being published on an ongoing basis.

In Germany, heat planning at national level and addressing all states, has been enshrined in law in the "Heat Planning Act" since January 2024. According to this, smaller municipalities (under 100,000 inhabitants) must submit heat planning by mid-2028 and larger municipalities (over 100,000 inhabitants) by mid-2026. The German state of Baden-Württemberg played a pioneering role as it had already introduced heat planning before the national law. Accordingly, all municipalities in Baden-Württemberg with a population of 20,000 or more are required to prepare a heating plan by the end of 2023. These plans are also to be published, but it is not clearly specified where and by when. The content of the plans must include: An inventory analysis, a potential analysis, the creation of heat supply scenarios, a heat transition strategy and the involvement of the relevant stakeholders is required.

This is the starting point for this paper. The focus is on examining the measures proposed in the heating plans of the municipalities in Baden-Württemberg and assessing their contribution to decarbonization. A measure describes the implementation of an initiative that makes a positive contribution to climate protection and the energy transition. These can either be physical implementations such as the expansion of district heating networks, or also the establishment of a new funding program or the performance of a feasibility study. The proposed measures are categorized according to their area of action and level of detail. The aim is to gain sound insights and derive recommendations for future heat planning processes in order to enable an efficient and sustainable transition to a decarbonized heat supply.

The remainder of the paper is a follows: The next section describes the current literature on heat planning. Section 3 describes the methodology and data used. Section 4 provides a brief overview of heat planning in Germany compared to other EU countries and presents the results of the analysis of the measures from the heat plans. Section 5 discusses the results and section 6 contains the conclusion.

1. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules/energy-efficiency-directive_en

2. https://actionheat.eu/workflow

Literature on heating and cooling planning

In recent years, heating and cooling planning has received increasing attention. This can be explained by scientific findings, growing awareness of political and economic actors for decarbonization potentials in the heating and cooling sector, the growing realization that optimal heating decarbonization pathways involve both individual decisions and system-wide decisions and the new regulations on European level (Billerbeck et al. 2022; Muncan et al. 2023). Looking at the existing literature, there are only a few scientific contributions to date. Chittum and Østergaard (2014), for example, investigated how energy planning in Denmark has supported the development of cost-effective district heating systems. Likewise, Harrestrup and Svendsen (2014) also study heat planning for fossil-fuel-free district heating. Their work is based on a case study of the Copenhagen district heating area. They state that successful long-term strategies must ensure that costs are minimised and that investments in energy savings and new heating capacity are optimised and carried out at the right time.

Furthermore, there is a branch of literature focusing on methods and tools for energy and/or heat planning, reaching from overarching assessments of different approaches to specific methodologies or guidelines. Johannsen et al. (2021), for example, identify important specifications and critical design principles for future energy system modelling tools designed for municipal planners. Their results show that future tools for municipal planning purposes need to combine the need for systematic analyses with concrete and implementable initiatives while balancing analytical complexity with operational simplicity.

The literature on instruments for decarbonizing the heating and cooling system emphasizes the electrification of the heat supply via heat pumps. Kleinbrahm et al. (2023), Liu et al. (2021) and Weidner and Guillén-Gosálbez (2023) state that in the context of local energy transition planning, a strong electrification of the heat supply through the use of heat pumps, best fed by renewable energies for example through the local expansion of photovoltaic systems, has a strong decarbonizing effect. This is also the evaluation of Pakera et al. (2023), who also see an important role for this technology in substituting natural gas for peak load coverage. In a case study for Spain, Borge-Diez et al. (2022) emphasize that heat pumps are an effective tool for decarbonizing both existing and new buildings. According to Weidner and Guillén-Gosalbez (2023), hydrogen-based building heating technologies in contrast are not a cost- and environmentally-competitive solution compared to electrification solutions. In addition to heat pump solutions, scholars highlight other instruments for decarbonizing heating and cooling systems. Kleinbrahm et al. (2023) point out that the use of biomass and geothermal energy to cover the base load of municipal heating requirements can significantly reduce CO_2 emissions. In addition to expanding the use of waste heat and heat from biomass, Pakera et al. (2023) also emphasize the need to expand thermal and waste heat storage capacities to store excess heat. In addition to instruments for heat generation, some authors also emphasize the need for energy-saving measures (Liu et al. (2021). Kleinbrahm et al. (2023) for example propose the retrofitting residential buildings.

A third branch of the literature examines the policy and regulatory guidelines, their implementation by local authorities and administration and beneficial overarching governing conditions for a successful implementation of decarbonizing heating and cooling plans. Part of the body of research examines a supportive regulatory and policy context for the successful decarbonization of heating and cooling systems, highlighting the role of a strong regulatory framework and financial support by the national government. Billerbeck et al. (2023) find that policy frameworks with more regulations and support mechanisms tend to lead to a higher share of renewable and waste heat in district heating, while they emphasize other factors such as "high renewable potentials, suitable climatic conditions, low dependency on oil and gas or in general an early focus on climate policy" (Billerbeck et al. 2023) may also explain a high renewables share in district heating. This is also confirmed by Bertelsen et al. (2021), who observe that to overcome the challenges of the local implementation of a decarbonized heat infrastructure, strong regulatory and financial support from the state is needed. However, both groups of authors, as well as Djørup et al. (2019), emphasize that regulations and district plans must be tailored to local conditions. These can be for example existing infrastructure (Bertelsen et al. 2021), useful technologies, user preferences, legislation or market designs (Djørup et al. 2019). Djørup et al. (2019) therefore emphasize that it is difficult to transfer policies and regulations which work in one specific region to other contexts.

Another research branch focuses on the role of local authorities and administrations in the successful implementation of policies and regulations for the decarbonization of heating and cooling systems. Wade et al. (2022) observe that successful decarbonization of the heat supply and the increase in energy efficiency in buildings depends on the capacities of local authorities in the fields of responsibility, political authority, finance, personnel capacity and knowledge e.g. in data analysis to implement national government regulations and policies. This can be addressed by increasing financial means by the national government for local authorities and programs to enhance their capabilities. Also Martínez et al. (2022) examine the role of the approach and knowledge level of local actors in the selection of measures in the planning of sustainable heating systems. They observe that local actors focus on the development of district heating networks and the use of heat pumps in their heating plans. However, if the actors are unsure about the choice of a suitable heating technology, they implement building improvements measures. In addition, lack of binding policies in the phase-out of gas use and questions regarding the financing of heat plan measures hinder the local implementation of heat plan measures. This is why the authors call for binding policies and centrally-established support mechanisms.

Another branch of research is investigating how governing structures can support the decarbonization of heating and cooling systems. Sovacool and Martiskainen (2020) find that polycentric governance played an important role in all the cases (China, Finland, Denmark and United Kingdom) studied, which includes involving relevant actors in the heat transition process. This point is also observed by Bertelsen et al. (2021). This approach offers the opportunity for "equitable, inclusive, informative, accountable, protective, and adaptable framework for promoting new heating systems or practices" (p. 14). Other observed aspects for the success of heat transitions were that states coordinated and steered programs and policies, took corrective action, invested in forward-looking measures and thus integrated industry, social actors and households into the heat transition in a supportive manner. Hence the authors conclude that governance is equally important as the policies and technologies applied.

As summarized above, the literature to date examines which technologies, policies and regulations can support the transformation of the heating and cooling sector, the challenges in local implementation of regulations and policies, and beneficial governance. A structural, comprehensive analysis of which policy measures municipalities use in their heating and cooling plans has not yet been observed for Germany. Hence, this paper contributes to the existing literature with an assessment on implementation measures specified in published heat plans.

HEATING AND COOLING PLANNING IN EUROPE

Heating and cooling planning is already well established in a few European countries. Denmark has been a pioneer in the field of heat planning since 1979 when it became mandatory to develop strategic plans (Köhler et al., 2021). One result of Danish heat planning is the significant share of district heating in residential heat supply (Chittum and Østergaard, 2014). Projects for the expansion of district heating had to demonstrate that their implementation was economically more advantageous than decentralised heat supply. Moreover, heat planning was supplemented by regulatory and financial measures to incentivise the use of renewable energies in the district heating. Overall, heat planning is not merely an administrative task in Denmark, but a political concern whose objectives and importance have been recognised by stakeholders at all political levels (Ea Energy Analyses and Viegand and Maagøe, 2019).

Switzerland has also implemented energy planning, whereby not only the heat sector is considered, but every form of energy supply and utilisation. Thereby, energy planning is the responsibility of the cantons, resulting in variations in specifications and regulations across different cantons (Köhler et al., 2021). Depending on these specifications and regulations, heat plans may include measures for implementation. However, all plans are based on an analysis of demand and supply options.

Similarly, in Austria heat planning is part of spatial energy planning. Salzburg, Styria and Vienna are frontrunners in Austria (Rehbogen 2019). Spatial energy planning in Austria involves more or less the same steps and aspects as heat planning in Germany.

In the Netherlands, heat planning is still relatively new. The heat planning consists of three elements: transition vision, implementation plan and regional energy strategy. Moreover, all municipalities in the Netherlands receive an analysis and dataset of the status quo from the responsible bodies (Köhler et al. 2021).

Overall, we see that there are heterogenic approaches to heat planning in Europe. While the literature on the existing approaches does not allow for a conclusive analysis, it shows that implementation measures are an important subject in several heat planning approaches in Europe. Moreover, the approaches have the same overall aim of reaching a decarbonized and climate-neutral heat supply. Time and experience will tell which heat planning approaches are more successful in reaching this target.

Data and methodology

The data we use in this paper is based on the published heat plans in Baden-Württemberg. A total of 104 municipalities in Baden-Württemberg are required by law to carry out municipal heat planning. Most of the heat plans were carried out by external service providers, while the municipal utilities and cities had an advisory role. The structure of the published heat plans is more or less identical. A heat plan usually includes the following chapters: inventory analysis, potential analysis, target scenario and finally a description of the municipal heat transition strategy with a catalogue of measures. This catalogue forms the starting point for the analysis carried out in this paper.

The method used in this paper is based on the following steps:

1. Desk research of heat plans
2. Creation of codebook
3. Evaluation of measures and categorization according to codebook

Information on the implementation of heat planning could be found in all municipalities. However, at the current time (January 2024), only 30 heating plans had been published on the websites of the individual municipalities; it is these plans that are analysed in this paper. In addition, municipalities with over 100,000 inhabitants that have not published a heating plan were explicitly contacted by e-mail. Most likely the missing heat plans will be published by the end of February 2024, but can therefore not be included in the present paper.

The second step was the creation of a codebook, which serves to categorize the measures. This is based on the literature presented in chapter 1 and is divided into two dimensions. The first dimension is the area of action, which describes the type or characteristic of the measure. Thereby, the areas of action are divided into two planning areas and four technical areas. The planning areas are ***Strategic planning and conception*** and ***Feasibility studies***. ***Strategic planning and conception*** includes all measures that are of a strategic or advisory nature and also the installation of working groups or public relations work. ***Feasibility studies*** are all measures aimed at carrying out a feasibility study for a specific project. In the case of technical areas or measures, a distinction is made between the expansion of renewable energies for electricity generation, the expansion of renewable energies for H&C generation, the expansion and conversion of district heating and cooling (DHC) networks and the renovation of buildings. The second dimension is the level of intensity, which describes the size or impact of the policy measure. The level of intensity for technical measures always refers to the scale of the measures. Measures at individual building level are minor measures, measures for apartment buildings or smaller blocks of buildings are moderate measures and measures at neighborhood or district level are major measures. Table 1 shows the complete codebook for classifying the individual measures.

The third step is the evaluation and categorization of the measures identified. The measures were assigned to the categories in Table 1. If a measure could not be clearly assigned to a category, it was assigned to the category in which the level of intensity is greater. An example of this is the measure "Construction of a new heating network and examination of the integration of a geothermal storage facility". This measure could be assigned to both the ***DHC and waste heat*** category and the ***Feasibility study*** category for testing the integration of the heat storage facility. In this case, the measure is assigned to the ***DHC and waste heat*** category, as the measure represents a major measure here and would only be a minor measure in the ***Feasibility study*** area. In principle, it would also be possible to allocate the measure to both categories, but then a comparable evaluation of the municipalities based on the number of measures would not be possible, as there would be double-counting.

Table 1. Codebook for area of action (dimension 1) and level of intensity (dimension 2).

Dimension 1 / Dimension 2	Planning and conception	Renewable energies – electricity	Renewable energies – H&C	DHC and waste heat	Efficiency and renovation	Feasibility studies
Minor measure	working group, non-binding strategy, campaigns	PV in buildings	RES heating systems (building level)	Dismantling of natural gas network or marginal DHC network expansion	Efficiency and renovation (single family buildings)	Basic checks without binding measures
Moderate measure	working group with powers, non-binding strategy, campaigns	Land for PV	RES heating systems (neighbourhood level)	Expansion of DHC networks	Efficiency measures for industry and apartment buildings	Binding measures
Major measure	Binding strategy and working group for further analyses	Land for investment intensive technologies, e.g. wind	RES in DHC and larger neighbourhoods, e.g. planning of geothermal energy	New DHC networks	Efficiency and renovation measures at neighbourhood level	Binding measures and pilot projects

(Notes: DHC = district heating and cooling; RES = renewable energy sources, PV = photovoltaic).

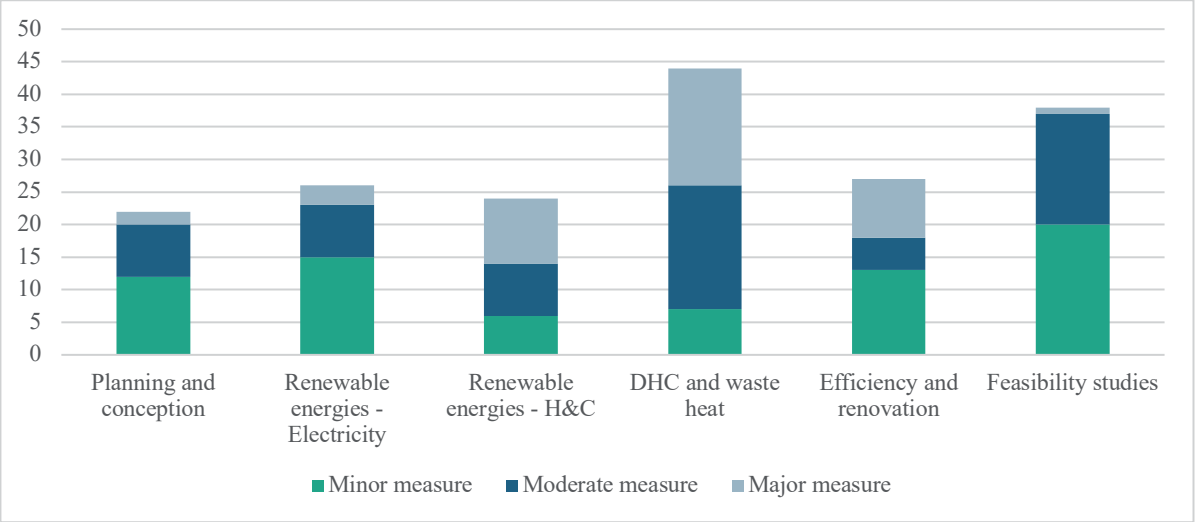

Figure 1. Area of action of the measures.

Results

The following section presents the results of the analysis of the proposed measures in the heat plans of municipalities in Baden-Württemberg, Germany. First the results of the evaluation according to the area of action (dimension 1) and then the combined evaluation with the area of intensity (dimension 2) are presented.

AREAS OF ACTION OF THE MEASURES

First, the proposed measures were analyzed and categorized based on the area of action. The results of this analysis are presented in Figure 1. It becomes clear that the majority of measures can be attributed to the category of ***DHC and waste heat***. This indicates that the transformation and expansion of heat networks play a crucial role in heat planning in Baden-Württemberg. Often, new networks are planned or existing ones are expanded.

The second most common measure is the conduction of ***feasibility studies***. These studies serve as an important basis for further transformation, although it remains questionable to what extent measures are actually implemented since they do not involve concrete actions. Frequently mentioned in this context are analyses of the stability of the electricity grid or investigations of waste heat potentials.

In third place are measures in the area of ***efficiency and renovation***. This mostly includes renovation campaigns, where either municipal buildings are to be renovated or additional renovation obligations are imposed on municipal housing companies.

The measures in the areas of **planning and conception**, ***renewable energies – electricity***, and ***renewable energies – H&C*** are mentioned less frequently compared to the other areas of action.

The fewest measures are mentioned in the area of planning and conception. This is worth mentioning, as an original hypothesis was that the municipalities would primarily include such smaller, less costly measures in the heating plan in order to fulfill the legal requirements of five measures. In most cases, this measure involves the establishment of a working group or the installation of advisory centers for renewable energies or renovations.

It is also interesting to look at the renewable energy categories, as the heat plans actually propose slightly more measures for the expansion of renewable electricity generation than for the expansion of renewable H&C. The most common measure is the expansion of photovoltaic systems on roofs or open spaces. In contrast to the other measures, these measures do not directly address the heating sector but the electricity sector, which initially seems unusual for a heating plan. However, the municipalities and municipal utilities are addressing the increasing demand for electricity and also aspects of sector coupling. It can also be assumed that these measures are planned as part of an energy master plan and therefore also help to fulfill the five required measures as part of the heating plan.

In the comprehensive analysis of the 30 heat plans, a total of 181 measures were identified, resulting in an average of 6 measures per municipality. Interestingly, the majority of municipalities have put forward precisely 5 measures, reflecting a consistent approach to addressing heat planning challenges. However, it is worth noting that certain municipalities have gone beyond this average, with Bruchsal, for example, proposing 13 measures.

Figure 2 presents the proposed measures categorized by each individual municipality. The municipalities are arranged in descending order based on their population size. This arrangement allows for a comparative analysis, enabling observation of any potential correlations between population size and the number or intensity of proposed measures. In municipalities with larger populations, the respective planning authorities are also larger. In larger municipalities, entire departments or at least several people are often available for planning tasks. In smaller municipalities, a single person is often responsible for such planning and must also fulfill other tasks in the authority. Remarkably, despite variations in population, there is no apparent correlation between the number or intensity of measures and the size of the municipality. Moreover, the analysis reveals that both minor and major measures have been proposed across municipalities of different sizes. While the emphasis may differ from one municipality to another, it is encouraging to observe a balanced approach with the inclusion of measures at both ends of the intensity spectrum. Notably, there are only

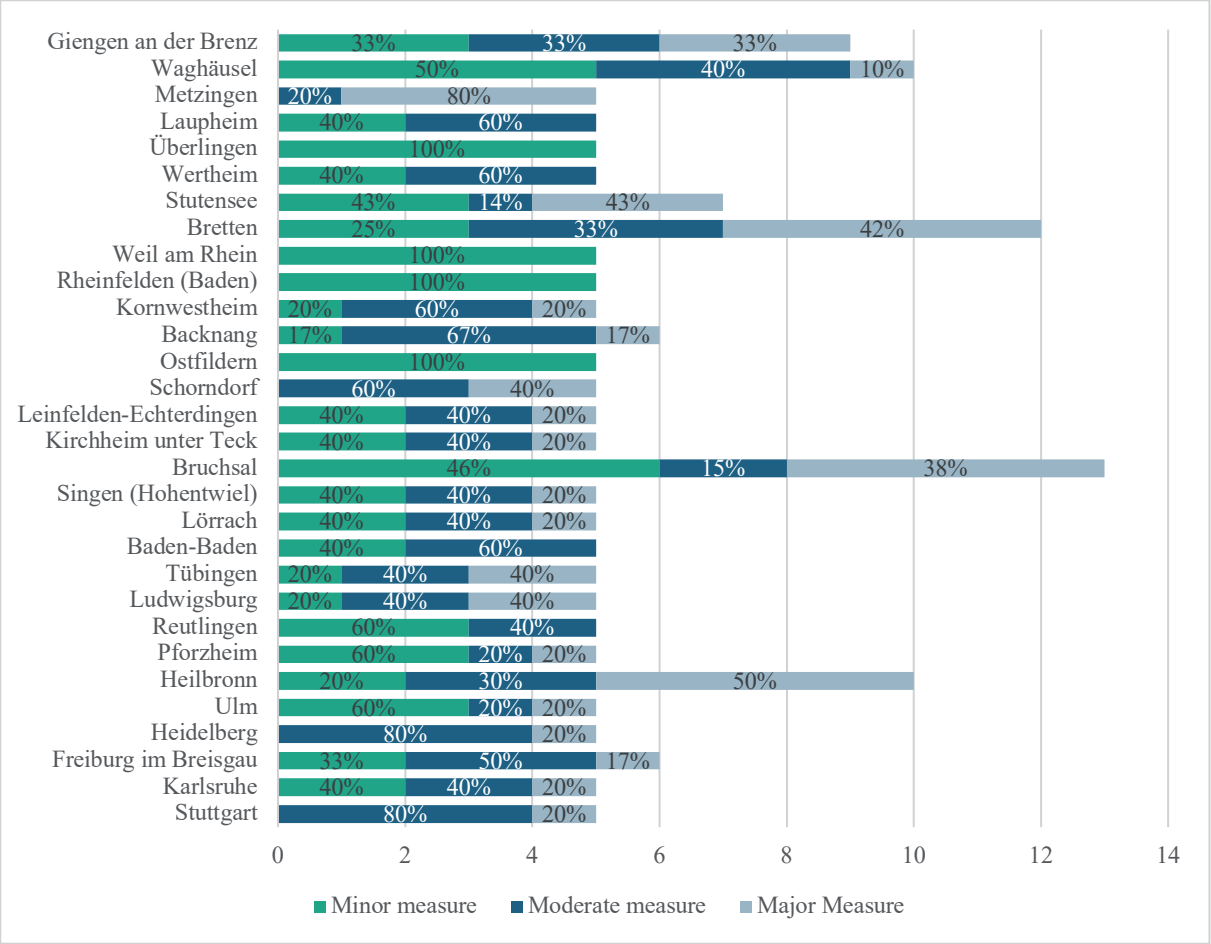

Figure 2. Overview of proposed measures on municipal level.

four municipalities where exclusively minor measures have been suggested. Eight municipalities have not proposed any major measures.

LEVELS OF INTENSITY OF THE MEASURES

In Figure 3, the distribution of different levels of intensity within each area of action is presented. The analysis encompasses all areas of action, including minor, moderate, and major measures.

One noticeable observation is that in the areas of ***feasibility studies*** and ***planning and conception***, predominantly minor measures are proposed. This suggests that in these areas, the focus is on preliminary assessments and conceptual planning rather than the execution of tangible initiatives. It should be mentioned here that our codebook contains major measures in this area, including pilot plants and binding measures.

Conversely, in the domains of ***DHC and waste heat*** and ***Renewable energies – H&C***, a significant portion of the measures are classified as major. This indicates that there is a strong emphasis on substantial actions such as the installation of new district heating networks or the construction of large-scale facilities for renewable heat generation. These major measures are crucial for advancing the transformation and expansion of district heating networks and increasing the utilization of renewable heat sources.

Within the ***renewable energy – electricity*** sphere, the most commonly mentioned measures involve the installation of photovoltaic (PV) systems on rooftops and open spaces. This highlights the recognition of PV as a key technology for renewable electricity generation. Notably, major measures in this context could entail ambitious programs aimed at securing land for future renewable energy projects. Such programs would play a crucial role in facilitating the widespread adoption of renewable electricity generation and meeting sustainability targets.

Discussion

This paper focuses on analyzing the proposed measures in the published heat plans of the federal state of Baden-Württemberg in Germany. However, it should be noted that only 30 heat plans have been published on the corresponding website so far, despite the legal requirement for municipalities to make their heat plans available online. To obtain a more comprehensive understanding, future analyses should include the remaining heat plans to build a larger database. A regression analysis was conducted to examine the influence of population size and financial strength of municipalities on the proposed measures. However, the analysis did not yield clear results, as neither the population size nor the financial strength had a significant impact on the area of action or level of intensity of the measures. Therefore, it cannot be claimed that municipalities with larger populations or greater financial strength are more inclined to implement larger-scale policy measures. It is worth mentioning that when measures fit into two areas of action, they were only counted in the area of action with the higher intensity. An al-

ternative approach would be to split such measures, providing a more detailed understanding of the specific actions proposed. However, this would complicate the analysis of the total number of measures, as it could lead to double counting.

The results show that measures in different categories are identified in almost all plans. This shows that the municipalities have a basic understanding of the complex interrelationships and are not relying on a one-fits-all solution. However, it also became clear from the analysis that only very few measures were backed up with concrete savings values. This means that concrete calculations of the reduction in energy consumption or greenhouse gas emissions were only carried out for very few measures. In order to achieve the climate targets, it is essential to have an estimate of how effective measures are and to what extent they contribute to reducing greenhouse gas emissions. In addition, the role of gas networks has been examined in very few heating plans. In most cases, only the heating system in the target year is considered and in this year gas networks generally no longer play a role. Very few plans address how this phase-out of gas can best be achieved and, above all, how this can be organized in a socially acceptable way.

Future research efforts could focus more on investigating the actual impact of the proposed measures and calculating the reduction in greenhouse gas emissions. For some measures, information on their specific contribution to greenhouse gas emission reductions is, however, lacking.

Furthermore, it is recommended that future analyses consider the heat plans as a whole to enable a more comprehensive assessment of their quality. This includes incorporating and evaluating the existing analyses of the current situation and potential opportunities, in order to gain a better understanding of how the heat planning process was conducted and what steps were taken to achieve the defined goals.

In addition, interviews should also be conducted with the municipalities to find out what the respective motivations were for selecting precisely these measures. These results could help to understand why some measures were not selected and thus help other municipalities in their decision making. It would also be important to gain a better understanding of the current challenges faced by municipalities in order to shape future policy design in a way that minimizes these challenges.

Conclusion

In conclusion, this research paper provides comprehensive insights into the analysis of proposed measures in the field of heat and cold planning. The study focuses on the examination of measures categorized by their area of action and intensity within the heat plans of Baden-Württemberg.

The analysis of the 30 available heat plans reveals several key findings. Firstly, the majority of measures fall under the category of DHC and waste heat, emphasizing the crucial role of transforming and expanding heat networks in heat planning. Secondly, feasibility studies and planning and conception areas predominantly propose minor measures, while major measures are more prevalent in the DHC and waste heat and renewable energies – H&C categories. This suggests the need for further exploration and implementation of substantial actions within the planning and conception areas.

The analysis also demonstrates that the number of measures proposed varies among municipalities, with an average of 6 measures per municipality. Additionally, there is no clear correlation between the population size or financial strength of a municipality and the number or intensity of proposed measures, indicating the importance of tailored approaches to heat planning based on local contexts. Furthermore, the research highlights the need for a more comprehensive analysis of the remaining heat plans, as well as the inclusion of impact assessment and CO_2 emissions reduction calculations in future studies. Additionally, evaluating the quality of heat plans as a whole, including the incorporation of best practices and potential analyses, would provide a more holistic understanding of heat planning strategies.

The analyses also provide important information for the transposition of the EU directive into national law. Care should be taken to ensure that municipalities not only draw up a target scenario, but also formulate measures to achieve it. The codebook developed in this paper can help to provide an assessment

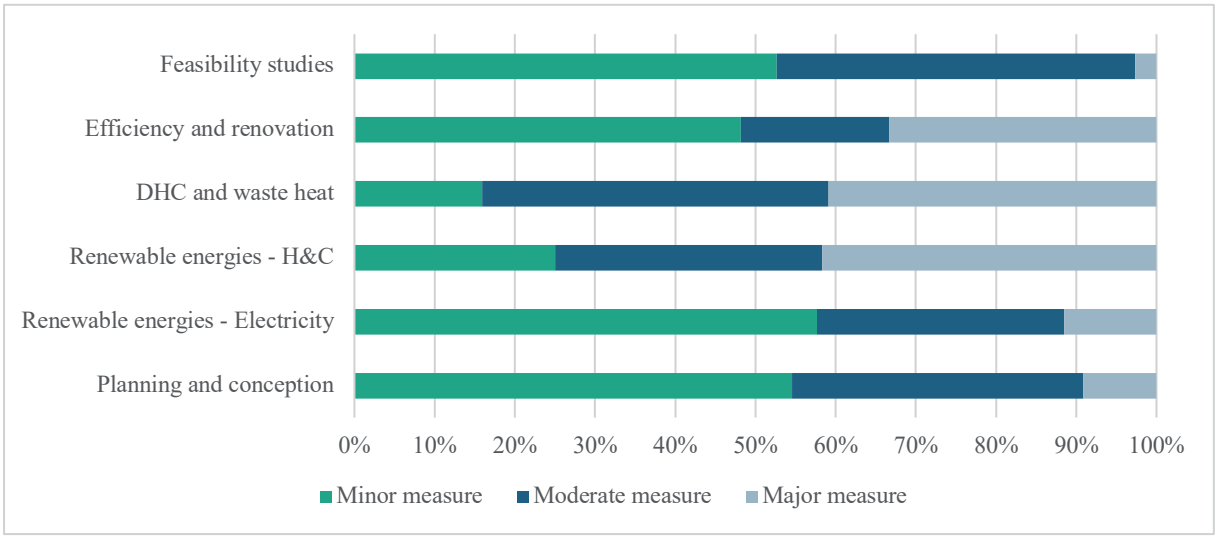

Figure 3. Levels of intensity of the measures.

of possible areas of activity. The results show that many municipalities in Baden-Württemberg have recognized the challenge of the future increase in electricity demand and for this reason are also taking measures to expand renewable energies in the electricity sector. In addition, the role of gas grids should be considered in order to enable a smooth and, above all, socially acceptable exit from fossil fuels.

Overall, this research contributes to the understanding of heat and cold planning by providing valuable insights into the proposed measures and areas of action. The findings underscore the importance of considering a diverse range of measures, tailored to specific local contexts, to achieve sustainable and efficient heat and cold systems. These findings can inform policymakers, researchers, and practitioners in their efforts to develop effective heat planning strategies for Baden-Württemberg and beyond.

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