

# Strategic heating and cooling planning to shape our future cities: Survey on success factors and challenges of heating and cooling planning in Germany

Anna Billerbeck  
Fraunhofer Institute for Systems and Innovation Research ISI  
Breslauer Str. 48  
76139 Karlsruhe  
and  
University of Freiburg  
Tennenbacher Str. 4  
79106 Freiburg  
Germany  
anna.billerbeck@isi.fraunhofer.de

Markus Fritz  
Fraunhofer Institute for Systems and Innovation Research ISI  
Breslauer Str. 48  
76139 Karlsruhe  
and  
Technical University of Darmstadt  
Franziska-Braun-Str. 7  
64287 Darmstadt  
Germany  
markus.fritz@isi.fraunhofer.de

Ali Aydemir  
Fraunhofer Institute for Systems and Innovation Research ISI  
Breslauer Str. 48  
76139 Karlsruhe  
Germany  
ali.aydemir@isi.fraunhofer.de

Pia Manz  
Fraunhofer Institute for Systems and Innovation Research ISI  
Breslauer Str. 48  
76139 Karlsruhe  
Germany  
and  
Utrecht University  
Princetonlaan 8a  
3584 CS Utrecht  
The Netherlands  
pia.manz@isi.fraunhofer.de

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## Abstract

Strategic heating and cooling (H&C) planning has proven to be an effective tool to drive the decarbonisation of H&C in cities. In this paper, success factors and key challenges of strategic H&C plans are analysed based on semi-structured interviews and an online survey with stakeholders from Germany. The 241 participants of the online survey see CO<sub>2</sub> neutrality as the main objective of strategic H&C plans. The most important success factors are good communication and data availability. Particularly challenging are having common goals, enough staff as well as data availability. Targets and guidelines are more important if the city is obligated to strategic H&C planning. In general, the instrument is seen as effective and suitable to tackle climate change in cities by the participants. The results of this paper can help policy makers and stakeholders to develop successful H&C plans and, thus, to tackle decarbonisation of H&C in cities.

## Introduction

The planning of cities is highly important, as this decides today how we can live sustainably in cities in the future. About 75 % of people are living within cities in Europe (Worldbank 2018). Heating and cooling (H&C) is a big topic for cities as it accounts for about half of Europe's total energy demand, with 75 % still dependent on fossil fuels (Heat Roadmap Europe 2017). Achieving climate neutrality in 2050, therefore, requires a rapid and significant change in the H&C sector.

Due to the local nature of H&C, action needs to be taken at the local level and with the involvement of a wide range of local stakeholders. In this respect, strategic H&C planning has proven to be an effective tool to develop measures locally and to drive the decarbonisation of the H&C sector faster and more efficiently (Chittum and Østergaard 2014). The relevance of strategic H&C planning is also appreciated by the European Commission, which currently discusses H&C planning under the 2021 revision of the Energy Efficiency Directives (EED). The draft of the EED states that Member States shall encourage regional and local authorities to prepare local H&C plans at least in cities with more than 50,000 inhabitants (European Commission 2021). However, strategic H&C planning requires extensive know-how, resources and experience and it is so far unclear which elements lead to successful plans, i.e., plans that result in concrete measures for the decarbonisation of H&C. Furthermore, in many countries, strategic H&C planning is still in its infancy.

Looking at existing literature, there are only a few scientific contributions so far. Often H&C planning is not analysed separately but in the wider context of energy planning. Nilsson and Mårtensson (2003), for example, analysed 12 municipal energy plans that attempted to develop and control local energy systems in southern Sweden. They show that the plans varied regarding the planning process, content, and level of ambition. They also show that the plans follow, in general, national energy policies, i.e., reduction of oil use, improved energy efficiency, and increased use of renewable energy. Similarly, a more recent paper from Weinand (2020), also analyses municipal energy system plans. In this study, 1,235 articles were collected and systematically examined using the R-tool bibliometrix. The

study shows that China is the most important contributor with 225 articles, followed by the USA and Germany. District heating is a core topic in municipal energy system planning, as it is addressed in three of the top five most cited articles. Hence, the analysis provides a good overview of energy planning, however, only a little information is given on success factors and challenges for H&C planning.

The strong connection between energy planning and district heating is also reflected in other studies. Chittum and Østergaard (2014), for example, investigate how energy planning in Denmark has supported the development of cost-effective district heating systems. Lessons from the Danish approach are considered for their relevance to the USA, as there is significant district heating potential, which is still not part of the energy policy discussions. 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 literature branch focusing on methods or tools for energy and/or H&C 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. In contrast, Büchele et al. (2019) present a concrete method for integrated strategic H&C planning applicable for any city or region. This method comprises the calculation of the cost-optimal combination of heat savings with either district heating or individual supply technologies for different building groups located in different areas.

Besides scientific publications, there are several guidelines, which aim to support the process of H&C planning. Mathiesen, Bertelsen (2020) from the Aalborg University in Denmark, for example, presented in a webinar a step-by-step approach to develop an effective H&C plan. They state that a plan should include stakeholder identification and involvement, scenario building, framework conditions, financing and business models. Also in Germany, several federal states developed guidelines (e.g., Peters et al. 2020; Energie- und Klimaschutzinitiative Schleswig-Holstein 2014; Energy Agentur NRW 2011). According to the German guidelines, strategic H&C planning should comprise an analysis of the status quo, an analysis of potentials, concept development (i.e., scenario development) and finally a transition strategy. In parallel to these steps, the involvement and participation of various stakeholders should be envisaged. Thereby, the analysis of the status quo should comprise the collection of all data relevant for H&C planning, e.g., the current H&C demand, greenhouse gas emissions, information on the building stock, information on the supply infrastructure and data on the legal and economic framework. All data should be recorded spatially resolved as far as possible. In the analysis of potentials, both potentials in terms of energy

savings and terms of heat supply should be analysed. It should be clarified whether the potentials could be harnessed through decentralised technologies or with the construction or expansion of a district heating network. In the next step, one (or several) scenario(s) should be developed in which the remaining heat demand is covered by an emission-free heat supply. Finally, to achieve and implement the target scenario, a transition strategy should be developed. This strategy should describe the transformation path and concrete policy measures. In this paper, we understand and define strategic H&C planning as described in the German guidelines.

The existing literature and documents show that there is some expertise in H&C planning, but to our knowledge, there is no empirical analysis of success factors and challenges. This is the starting point of this paper, which analyses success factors and key challenges of German strategic H&C plans based on empirical data collected in 2021. Our analysis is based on semi-structured interviews and an online survey with stakeholders from Germany. In this paper, a description of the current status of H&C planning in Germany, followed by a short analysis of the status in other countries (i.e., Denmark, Switzerland, Austria and the Netherlands) is presented. Based on the interviews and the survey, success factors and key challenges of strategic H&C planning are presented. The results of this paper can help stakeholders to identify and overcome obstacles in advance and so to develop successful H&C plans. Policymakers can use the results to develop support measures for cities that underpin successful strategic H&C planning.

The remainder of the paper is structured as follows: Section 2 describes the data and the methodology used in this paper. Section 3 presents strategic H&C planning in Germany and parallels to other countries in order to contextualise the results of the empirical data analysis of German data. In Section 4, the results of the online survey are presented. Section 5 discusses the results and Section 6 concludes and gives policy implications.

## Data and methodology

For our analysis, we conducted semi-structured interviews and an online survey with stakeholders from Germany. Based on existing literature and documents, we created a semi-structured interview guide along nine questions. In total, six interviews with stakeholders in Germany were conducted, providing first insights into strategic H&C planning. Based on the interviews an online survey was designed, containing 15 questions divided into five thematic blocks (see Table 1). The first block of questions was used to collect general data on the participants. The second block contained questions regarding the objectives, contents and organisation of strategic H&C plans. The third block asked for the participants' assessment of success factors and the fourth block asked for their assessment of challenges. The last block focused on the evaluation of the instrument.

In the survey, a combination of open questions and closed questions were used. Participants were asked to signal their agreement or disagreement to factors or statements by using a 5-point Likert-type scale, which is a psychometric scale commonly involved in research that employs questionnaires (cf. Joshi et al. 2015).

Table 1. Thematic blocks and content of questions in the online survey.

Block	Topic	Content of questions
1	General data	Questions on: <ul style="list-style-type: none"> <li>• Postal code</li> <li>• Job/Workplace</li> <li>• Obligation for H&amp;C planning</li> <li>• Connection to/ involvement in H&amp;C planning</li> <li>• Responsibilities for H&amp;C planning</li> </ul>
2	Objectives, contents and operational points	Assessment of/ opinion on: <ul style="list-style-type: none"> <li>• Objectives of H&amp;C plans</li> <li>• Content of H&amp;C plans</li> <li>• Involved parties/ actors in H&amp;C planning</li> <li>• Time schedule for H&amp;C plans</li> </ul>
3	Success factors	Assessment of success factors/ aspects of H&C planning
4	Challenges	Assessment of challenging factors/ aspects of H&C planning
5	Evaluation	Assessment of suitability and effectiveness of H&C plans

Table 2. Outline of the sample contained in the online survey.

Sample	#	Statistical population	#
Respondents	241	Contacted participants	> 500* (< 48%)
Municipalities/ cities	199	Total municipalities in Germany	10,796 (2%)
Municipalities with obligation for H&C planning**	67	Total municipalities with obligation for H&C planning in Germany	103 (65%)

Notes: \* 500 potential participants were contacted directly and an unknown number of participants were contacted via mailing lists, i.e., in total several thousand potential participants. \*\* The number of municipalities with an obligation for H&C planning is based on the answers of the respondents without multiple counting of the same municipalities.

Around 500 potential participants, including city administrations, state authorities as well as climate- and energy agencies from Germany were contacted directly. Furthermore, several mailing lists from national associations were used to distribute the survey. Hence, we estimate that several thousand were notified of the survey. Participation was possible from end of July until September 2021. In total, we received 241 responses.

The sample is characterised by its significant majority 70 % coming from the federal state of Baden-Württemberg. Moreover, the majority (58 %) of the respondents work in administration, followed by consulting and research (21 %). One-third (34 %) of the participants stated that their city is obligated to carry out H&C planning. Table 2 further outlines the sample and compares it to the estimated statistical population. The sample was analysed using descriptive statistics and comparative analysis.

### Strategic H&C planning in Germany and parallels to other countries

In this section, we present the state of strategic H&C planning in Germany and parallels to other countries, to contextualise the results of the online survey. In Germany, strategic H&C planning is still in its infancy. Only very few cities have pre-

pared strategic H&C plans so far (e.g., Freiburg im Breisgau, Bruchsal or Baden-Baden). However, some cities have developed climate protection concepts or energy plans including the decarbonisation of heat (e.g., Mannheim). Besides, some large district heating companies have prepared transformation plans for their networks (e.g., Berlin).

From a legal perspective, only two federal states have an obligation for H&C planning. Baden-Württemberg has introduced an obligation for municipalities with more than 20,000 inhabitants, which entered into force at the beginning of 2021. It now obliges large cities to prepare a plan by 2023 and to start implementing five measures from the H&C plan within five years of publication. In addition, Hamburg has also introduced an obligation for H&C planning in their Climate Protection Act in 2020. In addition to obligations, in a few states, there is financial support and several states have developed guidelines for H&C planning to provide guidance to cities. An overview of the current status of H&C planning in Germany is presented in Figure 1.

Strategic H&C planning is already well established in a few European countries. For example, since 1979, it is mandatory in Denmark to develop strategic H&C plans (Köhler et al. 2021). The origin of H&C planning in Denmark goes back to the oil crises of 1973 and 1979. In response, a regulatory framework including planning tools such as strategic H&C planning was



Figure 1. Map of obligations, guidelines and support for H&C planning in Germany (see sources in Annex A1).

Note: Financial support in Baden-Württemberg is only available for municipalities that are not obligated to prepare H&C plans.

established (Chittum and Østergaard 2014). The main objective of these new planning tools was the security of supply, which is still one focus topic in today's strategic H&C plans. One result of the strategic H&C planning in Denmark is the high share of district heating in the Danish residential heat supply (Chittum and Østergaard 2014). The experience of heat planning in Denmark suggests that the planning process needs to be locally based and that capacity building and knowledge sharing are key to successful H&C planning (Köhler et al. 2021).

Besides the pioneer Denmark, also Switzerland already introduced strategic H&C planning. Here, energy planning is in the responsibility of the cantons, thus, specifications and regulations can differ by each canton. Examples such as the city of Zurich show the high importance of involving central actors, like district heating or gas network operators (Köhler et al. 2021).

Similarly, in Austria, heat planning is part of energy planning and the responsibility and initiative lie with the individual federal states. Salzburg, Styria and Vienna are frontrunners in Austria. In all three states, the first phase of planning, i.e., the analysis of the current status, is standardised and automated in an overarching project. Thus, cities receive all necessary starting information for H&C planning from this project (Rehbogen 2019).

The Netherlands follows a similar approach regarding data accessibility. Heat planning is still relatively new in the Netherlands but forms the central basis for the phase-out of natural gas. All municipalities in the Netherlands receive an analysis of the status quo, i.e., the first step of strategic H&C planning, from the (governmental) Expertise Center Heat (Köhler et al. 2021). In addition to a report, the results are available in an online tool and a data set for further work is provided (Köhler et al. 2021). Overall, we see that the approaches in Austria and the Netherlands is very different from Germany, where each city is individually responsible for data collection.

## Results of the survey on H&C planning

In this section, the results from the online survey are presented and discussed. First, results regarding objectives, content and operational aspects of strategic H&C plans are provided. Sec-

ondly, the main results of the survey, i.e., the success factors and the main challenges of strategic H&C planning, are presented.

### OBJECTIVES, CONTENTS AND OPERATIONAL POINTS OF A H&C PLAN

The objectives and the content described in the existing literature and documents are reflected in the responses to the online survey. The results of the corresponding questions are presented in Figure 2 and 3, showing the weighted average of the 5-point Likert scale. Even though all objectives are rated rather high with a weighted average above the medium value of the Likert scale, the most important target is reaching CO<sub>2</sub> neutrality (see Figure 2). This is followed by security of supply and the implementation of concrete measures. Furthermore, all listed topics of H&C plans received a high level of approval, whereby renewable potentials, targets as well as measures for implementation were rated higher in comparison (see Figure 3). These results indicate that there is a common consensus on the objectives and content of strategic H&C planning among the respondents.

Figure 4 shows who respondents think should be involved in the development of H&C plans. The figure reveals that the involvement of many different actors is desired by the respondents. Especially the city administration and the local energy supplier should be involved according to the respondents (see Figure 4). Further, Figure 5 shows that in general, the city administration is responsible for the development of the H&C plan. However, in some cases, other parties, like the local energy supplier, an energy or climate agency or an engineering company hold the responsibility. Not shown in a figure, but a further result is that the majority of respondents (77 %) stated that a period between one and two years should be allocated for the planning. Only one-third would allocate three or more years. These results provide a framework for further financing and promotion of H&C plans.

### SUCCESS FACTORS AND KEY CHALLENGES OF STRATEGIC H&C PLANNING

The assessment of different success factors of strategic H&C planning is presented in Figure 6. Thereby, the weighted average of the 5-point Likert scale as well the distribution of the

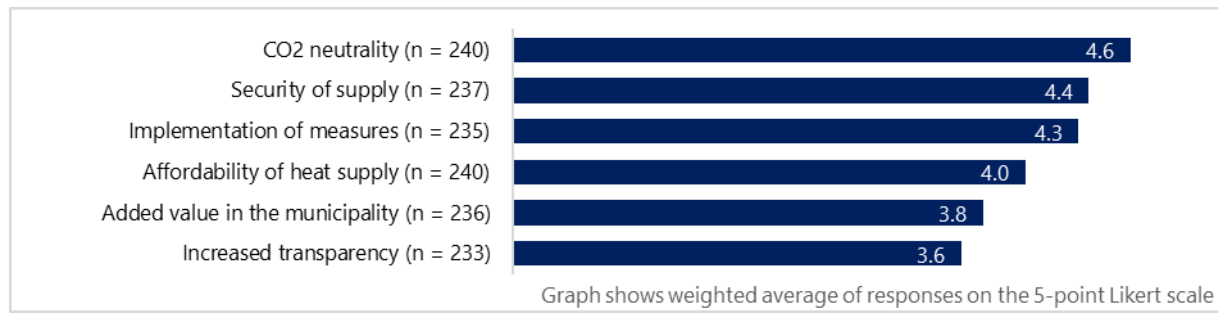


Figure 2. Assessment of objectives of H&C plans.

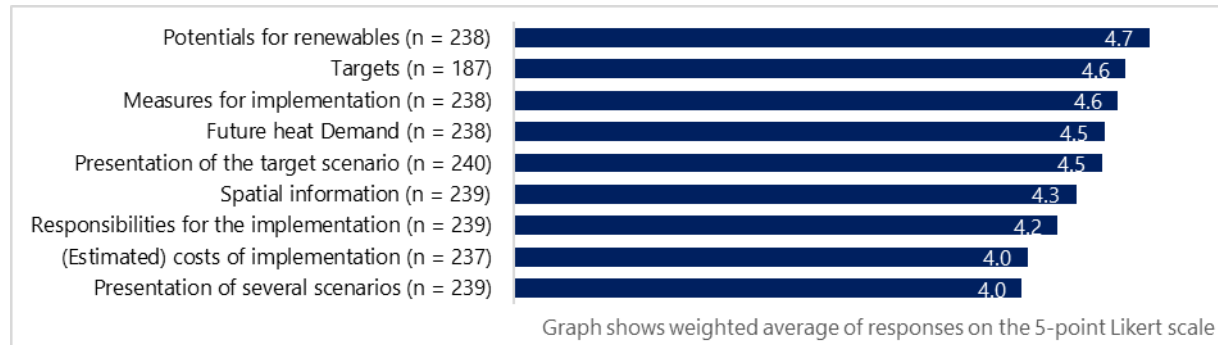


Figure 3. Assessment of topics/content that should be included in a successful H&C plan.

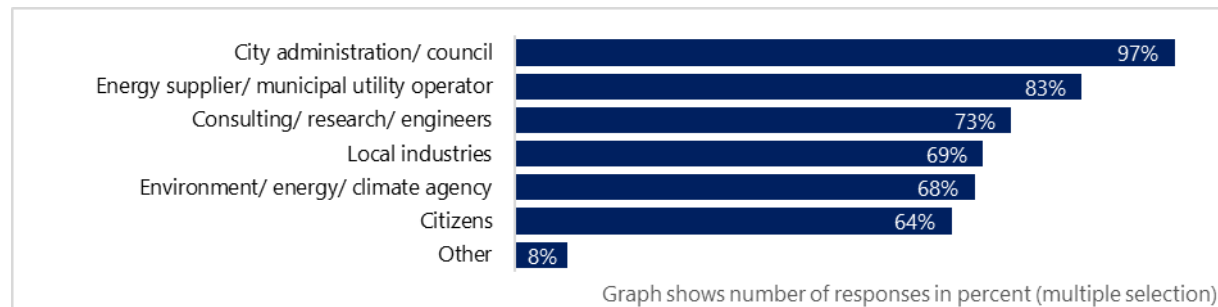


Figure 4. Assessment of who should be involved in H&C planning.

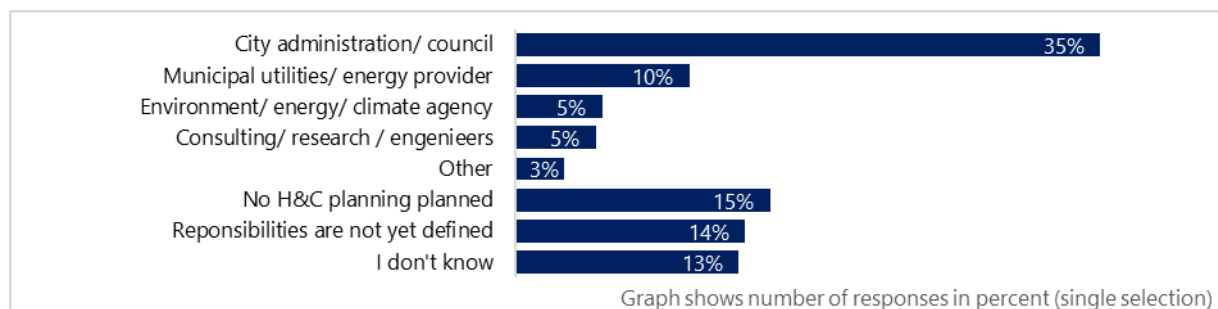


Figure 5. Responsible actors/ parties for H&C planning.



assessment is visualised. All factors are rated above the medium value, indicating that all of them are perceived as rather important.

In comparison, the respondents rated communication as the most important success factor. More than half of the respondents (66 %) consider communication as very important and around one-third (26 %) see communication as important. A large number of actors with different ideas and priorities are involved in H&C planning, which underlines the importance of good communication. It is not uncommon for the municipality itself, the energy supplier, the building authority, a planning office and other actors to be involved (see also Figure 4). We think it is therefore important that these actors are in regular exchange during the process. This is also in line with the perception of H&C plans as a communication tool by some interviewees.

The availability of data is seen as another important factor (see Figure 6). On average, it is rated as the second most impor-

tant element with an assessment of very important or important by 91 % of the respondents. Data on H&C demand and potentials for renewable energies form the basis of H&C planning. Thereby, an appropriate level of data quality must be aimed for. If a lot of effort is spent on data acquisition, there may be too little time for other things and if too little time is spent, conclusions may lead in the wrong direction. Thus, the question of data availability and data quality is essential.

Other important success factors are the definition of responsibilities, enough qualified staff and financial funding as well as city council commitment and support. The support of the city council was emphasised several times in the interviews as an important element. The influence of the city council seems to be a distinctive part that can make a large contribution to success in individual cases. In contrast, citizen participation and exchange with other municipalities are perceived as less important in comparison, while the distribution is less heterogeneous.

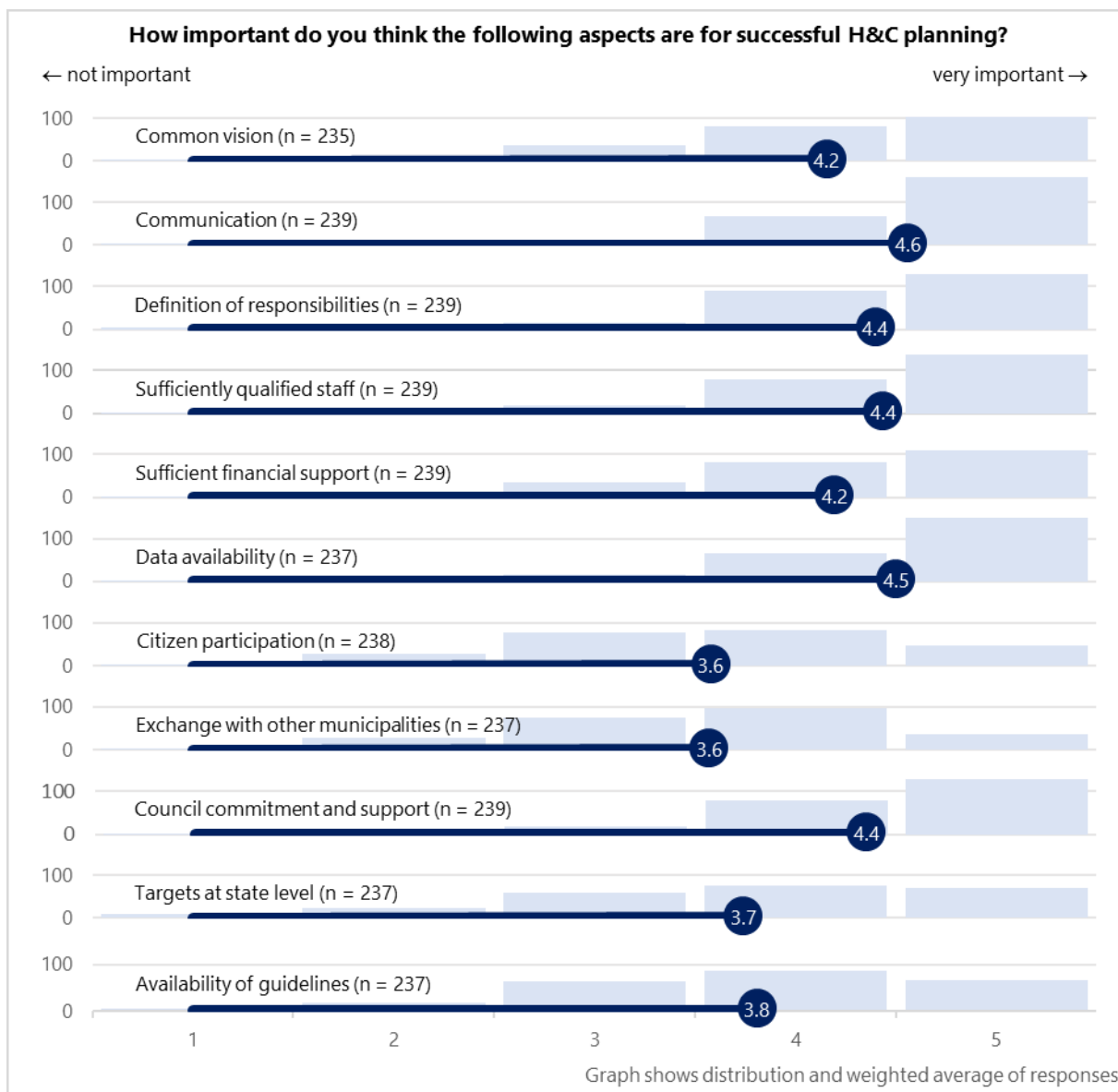


Figure 6. Assessment of success factors for H&C planning.

Further success factors named by the participants in an open question are monitoring, clear methodology, sufficient experience of the contracted parties, presentation of conflicting targets and also more specific elements such as templates for data requests to energy companies or consumers.

The assessment of the respondents of the key challenges of strategic H&C planning is presented in Figure 7.

Again, the weighted average of the 5-point Likert scale as well as the distribution of the assessment is visualised for the challenging factors (see Figure 7). All factors are rated above the medium value, indicating that all of them are perceived as rather challenging. However, compared to the assessment of success factors, the rating of how challenging the factors is, is somewhat lower and the differences between the factors are greater.

As said before, many actors are involved in the process of H&C planning. For this reason, it is often difficult to design a common vision for all actors, as interests may differ. As shown in Figure 7, a common vision is rated as the most challenging factor, whereby 39 % rate is as very challenging and 35 % as

challenging. At the same time, 21 % seem to have a neutral perception of the challenge connected to developing a common vision. Nonetheless, based on the responses, we conclude that a moderated process to develop a common vision seems to be of great importance. Furthermore, the availability of enough staff is perceived as a comparatively great challenge, whereby 38 % see enough staff as challenging and 36 % as very challenging. Starting points for solving this problem can be more staff, but also better structures and interlocking within existing tasks. In addition, the provision of planning instruments that reduce the effort can be helpful. Exchange with other municipalities, availability of guidelines and participation of citizens are perceived as less challenging in comparison, however, all of these factors are still rated higher than the medium value of the Likert scale.

Further challenges, described in an open question are meeting the time schedule and minimising delays as well as data protection and data safety requirements.

Figure 8 provides an overview of the results by arranging the factors according to their importance for success and how

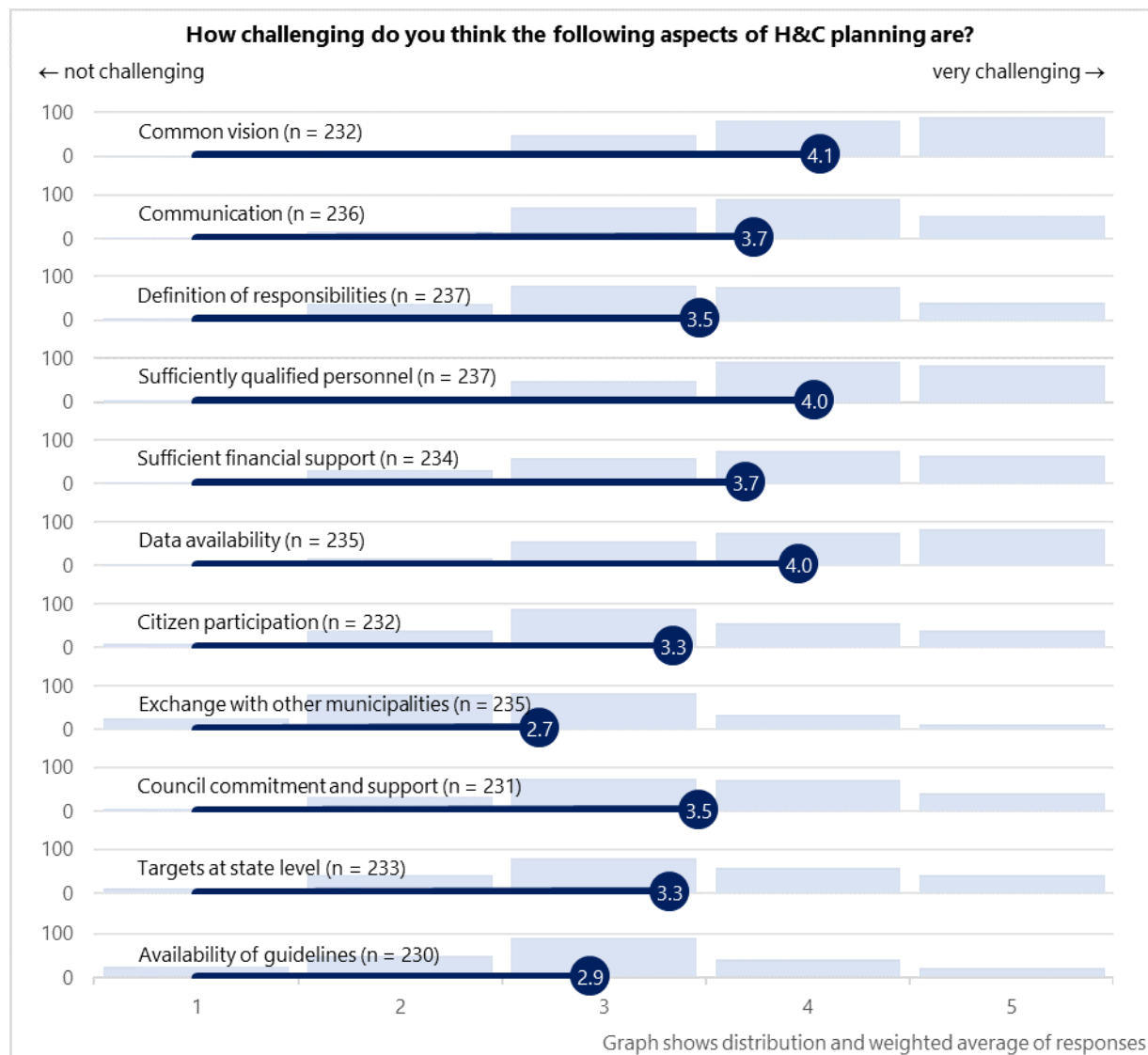


Figure 7. Assessment of challenging factors for H&C planning.

challenging they are perceived, using the weighted average. The higher a point is, the more challenging the factor is rated and the further to the right a point is, the more important the aspect is rated. From this illustration, we learn that data availability, communication as well as staff capacities are seen as the most important and at the same time as the most challenging factors. Also, rather important and challenging are the definition of responsibilities, council commitment, financial support and a common vision. In contrast, exchange with other mu-

nicipalities, availability of guidelines, targets at the state level and citizen participation are perceived as less important and less challenging.

This perception changes significantly when the cities are obligated to draw up a H&C plan, which is illustrated in Figure 9 that shows the ranking of two different groups. Group A includes respondents whose city is obligated to develop a H&C plan in the next years, i.e., mandatory H&C plans. Group B includes all participants whose city is not obligated to develop

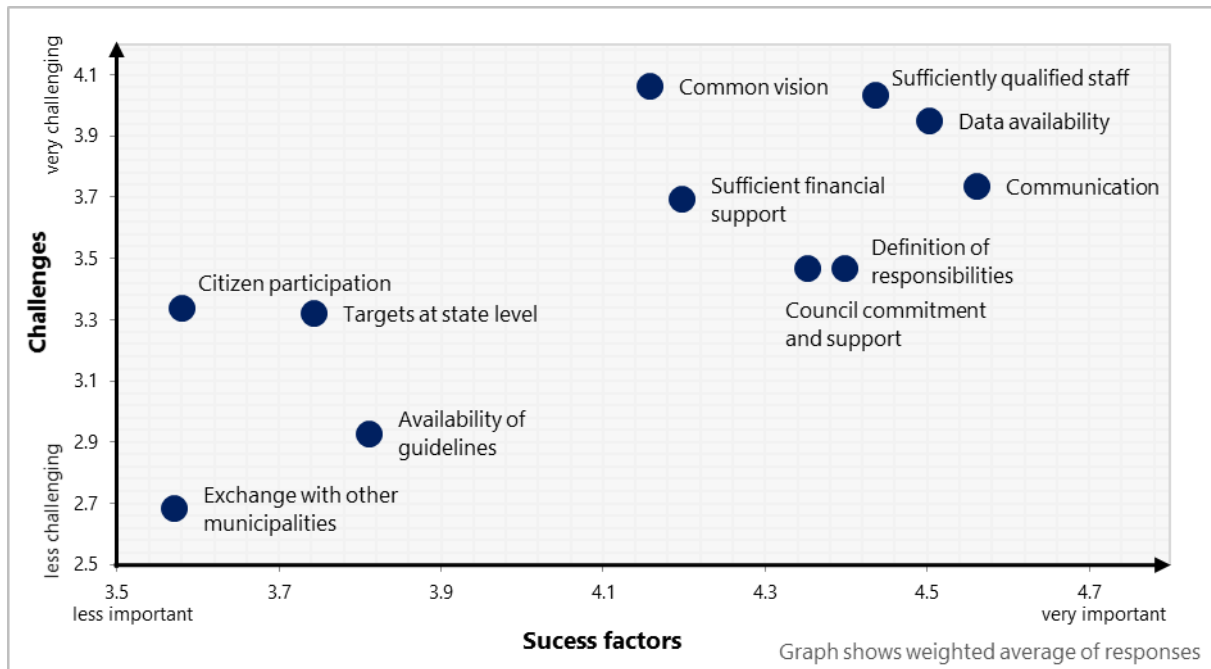


Figure 8. Assessment of success factors and key challenges of strategic H&C planning.

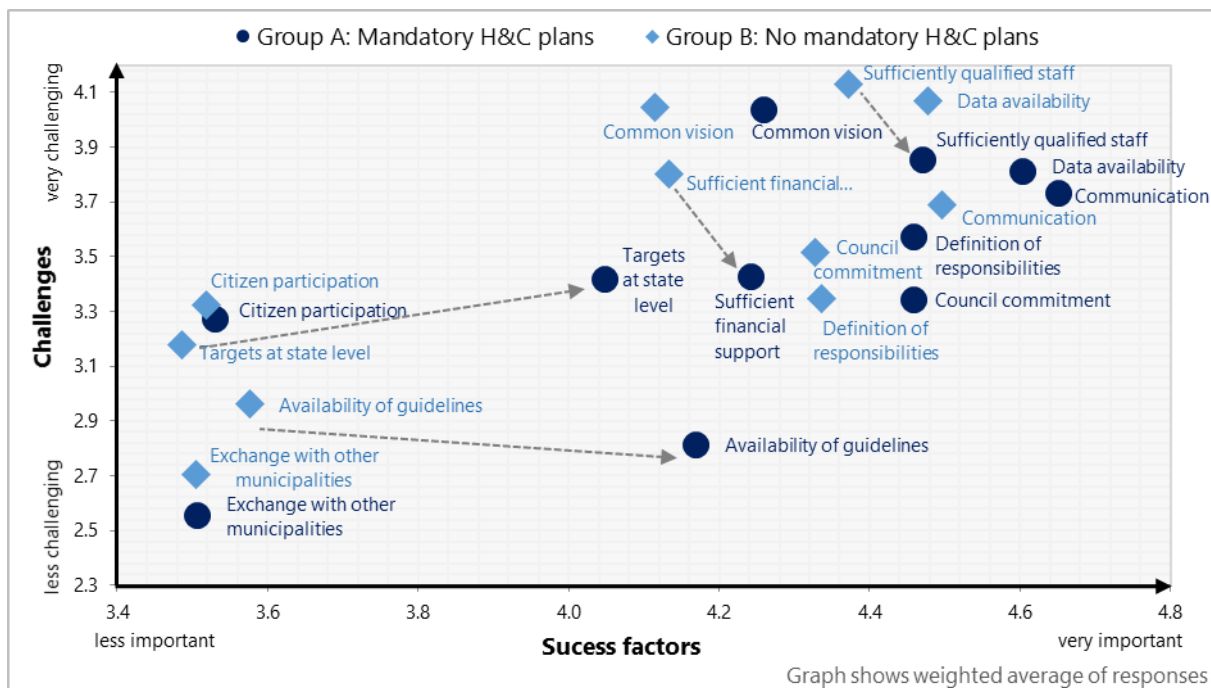


Figure 9. Assessment of success factors and key challenges of strategic H&C planning of different groups.

Note: Group A represents 34 % and group B 47 % of all respondents.



a plan. Group A represents 34 % and group B 47 % of all respondents, whereby 18 % of the respondents are excluded, as they could not provide the needed information. This comparison shows that especially targets at the national level and availability of guidelines are perceived as more important if the city is obligated to develop a H&C plan. Also, data availability and communication are rated as more important. At the same time, enough staff and financial support are seen as less challenging.

Overall, the respondents consider H&C planning to be an effective and suitable instrument. In total 41 % rate the effectiveness and suitability of the instrument as very high, 42 % rate it as rather high and only 2 % see the instrument's effectiveness and its suitability as rather low. This positive rating is a very good starting point for H&C planning in Germany.

## Discussion

This paper analyses strategic H&C planning and presents success factors and key challenges based on semi-structured interviews and an online survey with stakeholders from Germany.

In Germany, strategic H&C planning is still in its infancy. On a voluntary basis, only very few cities have prepared strategic H&C plans so far. Recently, the federal-state Baden-Württemberg has introduced an obligation for large municipalities to develop a strategic H&C plan. This obligation entered into force at the beginning of 2021 and obliges large cities to prepare a plan in the next years. At the present time, actors in Baden-Württemberg are very interested in H&C planning and open for exchange. The new obligation, therefore, explains the high number of responses from Baden-Württemberg in the online survey (70 %).

The very strong participation of actors from Baden-Württemberg may influence the results. However, the sample obtained in the online survey covers over 60 cities from other federal states. For this reason, it can be assumed that the sample represents a large proportion of German municipalities. Furthermore, around half of the respondents (47 %) indicated that their municipality is not obligated to prepare a strategic H&C plan. Against this background, a bias of the results due to the obligation in Baden-Württemberg can also be reasonably excluded.

However, for a successful establishment of strategic H&C planning, more research should be done in the future on how to convince non-obligated municipalities to carry out such planning. In addition, further research on success factors and best practices including data requirements (i.e., which data are particularly relevant) of H&C planning is needed to reduce barriers and to ensure a successful contribution of the instrument to achieving a climate-neutral H&C supply.

## Conclusion

We have carried out an online survey with stakeholders from Germany to present success factors and key challenges of strategic H&C planning. The 241 participants of the online survey see CO<sub>2</sub> neutrality as the main objective of strategic H&C plans. This is followed by security of supply and the implementation of concrete measures. However, all objectives were rated rather high, i.e., the respondents perceived all objectives to be important. In terms of the content of H&C plans, renewable potentials, targets as well as measures for implementation were rated higher in comparison to other topics. These results indicate

that there is a common consensus about the necessity to have targets and information on potentials for successful strategic H&C planning among the respondents. Furthermore, the respondents rated good communication and data availability as the most important success factors. Challenging factors seem to be having a common vision, enough staff as well as data accessibility. Comparing different groups, we see that targets at the state level and guidelines become more important if the city is obligated to develop a strategic H&C plan.

Different actors are involved in H&C planning, which is why good communication is important and why it is a challenge to create a common vision. We, therefore, conclude that successful H&C planning could benefit from (professional) moderation to develop a common vision between all stakeholders and to help with communication. To meet the challenge of enough staff, more personnel, but also better internal structures and interlocking within existing tasks (of the responsible entity), could be envisaged. In addition, the provision of planning tools that reduce the effort required could be helpful.

Data on H&C demand and potentials for renewable energy form the basis of H&C planning, explaining the rating of data availability and accessibility as an important factor for success. At the same time, according to the responses in the online survey, it seems to be a big challenge to get the data needed. In Austria and the Netherlands, initial data for H&C plans is collected or estimated by a central authority and made available for the cities, while in Germany, each city is individually responsible for obtaining the data. Hence, the approaches in Austria and the Netherlands are very different from the H&C planning process in Germany. In view of the fact that data availability was rated as highly challenging in the online survey, the approaches from Austria and the Netherlands and their transferability to Germany should be investigated further in future research.

Furthermore, the majority of respondents indicated that a period between one and two years is required for the development of a H&C plan. Against this background, data should be accessible, preferably right at the beginning of the H&C planning process. This way, no time would be wasted on data collection and the important parts, i.e., concept development of a decarbonised future, can be the main focus. Legislation that requires data to be passed on from energy suppliers or consuming industry to the responsible party for H&C planning might be a suitable measure to ensure data accessibility. At the same time, a legal framework could also address data protection and thus provide more security and structure in the data collection process. This would possibly require the establishment of a standardised data collection by means of uniform templates and also a process for a standardised procedure.

Even though there are obstacles, the respondents see the strategic H&C planning instrument as an effective and suitable instrument to tackle climate change in cities, which is a very good starting point for H&C planning in Germany. Based on the research in this paper, we conclude that for the long-term success of H&C plans it is essential that all relevant actors are involved from the beginning and that the plan is anchored and applied in the municipal structures. We think it is important that all stakeholders jointly support and implement the goal of CO<sub>2</sub> neutrality, which should be facilitated and promoted by a long-term perspective and clarity. Hence, we believe clear targets and objectives, anchored in strategies and roadmaps, are

central to creating a suitable framework. In particular, several interviewees and respondents of the online survey indicated that clarity about the use of natural and synthetic gas as well as biomass in the nearer and long-term future of H&C should be given. Lastly, we conclude that targets at the regional level could accelerate strategic H&C planning, as this factor was rated highly in the online survey.

The preparation of H&C plans will keep the municipalities very occupied in the near future. Currently, only the large municipalities in Baden-Württemberg and the city of Hamburg are obligated to H&C planning. However, due to the relevance of cities for climate protection, an extension of the obligation to the whole of Germany is foreseeable and currently under discussion. Also on the European level, H&C planning is gaining importance and attention in discussions.

In this context, it is important that the focus of H&C planning is not on the creation of a single plan, but on the entire process of achieving a climate-neutral H&C supply. The plan should lead to rapid implementation with concrete policy measures. The results of this paper can help stakeholders to identify and overcome obstacles in advance and so to develop successful H&C plans. Policymakers can use the results to develop support measures for cities that underpin successful strategic H&C planning so that we can live sustainably in cities in the future.

## References

- Büchle, Richard; Kranzl, Lukas; Hummel, Marcus (2019): Integrated strategic heating and cooling planning on regional level for the case of Brasov. In *Energy* 171, pp. 475–484. DOI: 10.1016/j.energy.2019.01.030.
- Chittum, Anna; Østergaard, Poul Alberg (2014): How Danish communal heat planning empowers municipalities and benefits individual consumers. In *Energy Policy* 74, pp. 465–474. DOI: 10.1016/j.enpol.2014.08.001.
- Energie- und Klimaschutzinitiative Schleswig-Holstein (Ed.) (2014): Die kommunale Wärmeplanung. Ministerium für Energiewende, Landwirtschaft, Umwelt und ländliche Räume. Available online at [https://www.schleswig-holstein.de/DE/Landesregierung/V/Service/Broschueren/Broschueren\\_V/Umwelt/pdf/FlyerKommunaleWaermep-lanung.pdf?\\_\\_blob=publicationFile&v=3](https://www.schleswig-holstein.de/DE/Landesregierung/V/Service/Broschueren/Broschueren_V/Umwelt/pdf/FlyerKommunaleWaermep-lanung.pdf?__blob=publicationFile&v=3)
- Energy Agentur NRW (Ed.) (2011): 100 Klimaschutzsiedlungen in Nordrhein-Westfalen. Planungsleitfaden. Available online at <https://www.neuss.de/downloads/2017/11/klimaschutzsiedlung-blausteinsweg/planungsleitfaden-klimaschutzsiedlung-blausteinsweg>.
- European Commission (2021): Directive of the European Parliament and of the Council on energy efficiency (recast). Available online at <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52021PC0558&from=EN>
- Harrestrup, M.; Svendsen, S. (2014): Heat planning for fossil-free district heating areas with extensive end-use heat savings: A case study of the Copenhagen district heating area in Denmark. In *Energy Policy* 68, pp. 294–305. DOI: 10.1016/j.enpol.2014.01.031.
- Heat Roadmap Europe (Ed.) (2017): Heating and Cooling. Facts and figures. Available online at [https://heatroadmap.eu/wp-content/uploads/2019/03/Brochure\\_Heating-and-Cooling\\_web.pdf](https://heatroadmap.eu/wp-content/uploads/2019/03/Brochure_Heating-and-Cooling_web.pdf).
- Johannsen, Rasmus Magni; Østergaard, Poul Alberg; Maya-Drysdale, David; Krog Elmegaard Mouritsen, Louise (2021): Designing Tools for Energy System Scenario Making in Municipal Energy Planning. In *Energies* 14 (5), p. 1442. DOI: 10.3390/en14051442.
- Joshi, Ankur; Kale, Saket; Chandel, Satish; Pal, D. (2015): Likert Scale: Explored and Explained. In *BJAST* 7 (4), pp. 396–403. DOI: 10.9734/BJAST/2015/14975.
- Köhler, Benjamin; Bürger, Veit; Weidinger, Roman; Doderer, Hannes; Schäfer-Stradowsky, Simon; Tänzler, Dennis (2021): Strategische kommunale Wärmeplanung. Ariadne. Available online at <https://ariadneprojekt.de/publikation/analyse-strategische-kommunale-waermep-lanung>.
- Mathiesen, Brian Vad; Bertelsen, Nis (2020): Developing an effective strategic heating/cooling plan: What key success factors? IRENA WEBINAR. April 20th 2020. Aalborg University - Sustainable Energy Planning Research group. Webinar, 2020. Available online at [https://irena.org/-/media/Files/IRENA/Agency/Events/2019/Dec/Strategic-heating-cooling\\_Bertelsen\\_AAU.pdf?la=en&hash=0E9CBF9B0458553116453FC4A4DADF15F769D5CD](https://irena.org/-/media/Files/IRENA/Agency/Events/2019/Dec/Strategic-heating-cooling_Bertelsen_AAU.pdf?la=en&hash=0E9CBF9B0458553116453FC4A4DADF15F769D5CD)
- Nilsson, J. Stenlund; Mårtensson, A. (2003): Municipal energy-planning and development of local energy-systems. In *Applied Energy* 76 (1-3), pp. 179–187. DOI: 10.1016/S0306-2619(03)00062-X.
- Peters, Max; Steidle, Thomas; Böhnisch, Helmut (2020): Leitfaden Kommunale Wärmeplanung. Edited by Ministeriums für Umwelt, Klima und Energiewirtschaft Baden-Württemberg. KEA Klimaschutz- und Energieagentur Baden-Württemberg GmbH. Available online at [https://um.baden-wuerttemberg.de/fileadmin/redaktion/m-um/intern/Dateien/Dokumente/2\\_Presse\\_und\\_Service/Publikationen/Energie/Leitfaden-Kommunale-Waermep-lanung-barrierefrei.pdf](https://um.baden-wuerttemberg.de/fileadmin/redaktion/m-um/intern/Dateien/Dokumente/2_Presse_und_Service/Publikationen/Energie/Leitfaden-Kommunale-Waermep-lanung-barrierefrei.pdf)
- Rehbogen, Alexander (2019): Räumliche Energieplanung für die Wärmewende. SIR Salzburger Institut für Raumordnung und Wohnen. Karlsruhe, 9/30/2019. Available online at [https://www.kea-bw.de/fileadmin/user\\_upload/Veranstaltungen/eigen/Nahw%C3%A4rme\\_Kompakt\\_2019/Vortr%C3%A4ge/13\\_Rehbogen.pdf](https://www.kea-bw.de/fileadmin/user_upload/Veranstaltungen/eigen/Nahw%C3%A4rme_Kompakt_2019/Vortr%C3%A4ge/13_Rehbogen.pdf)
- Weinand, Jann Michael (2020): Reviewing Municipal Energy System Planning in a Bibliometric Analysis: Evolution of the Research Field between 1991 and 2019. In *Energies* 13 (6), p. 1367. DOI: 10.3390/en13061367.
- Worldbank (2018): Urban population (% of total population) – European Union. Available online at <https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=EU>

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## Annex

A1: Obligations, guidelines and financial support schemes for H&amp;C planning in Germany.

Federal state	Obligation for H&C planning (Yes/No)	Guidelines (Yes/ No)	Name and link of guideline	Financial support (Yes/No)	Source/ link to financial support
Baden-Württemberg	Yes	Yes	Handlungsleitfaden: Kommunale Wärmeplanung, <a href="https://um.baden-wuerttemberg.de/de/service/publikation/did/handlungsleitfaden-kommunale-waermeplanung/">https://um.baden-wuerttemberg.de/de/service/publikation/did/handlungsleitfaden-kommunale-waermeplanung/</a>	Yes (only available for cities that are not obligated to draw up H&C plans)	<a href="https://www.kea-bw.de/foerderdatenbank/detail/kommunale-waermeplanung-in-landkreisen-und-gemeinden">https://www.kea-bw.de/foerderdatenbank/detail/kommunale-waermeplanung-in-landkreisen-und-gemeinden</a>
Bavaria	No	Yes	Leitfaden: Energienutzungsplan, <a href="https://www.bestellen.bayern.de/application/">https://www.bestellen.bayern.de/application/</a>	Yes	<a href="https://www.verkuendung-bayern.de/baymb/2019-88/">https://www.verkuendung-bayern.de/baymb/2019-88/</a>
Berlin	No	No		No	
Brandenburg	No	No		No	
Bremen	No	No		No	
Hamburg	Yes	No		No	
Hesse	No	Yes	Konzept: Die Wärmewende voranbringen, <a href="https://redaktion.hessen-agentur.de/publication/2021/3443_LEA_Broschuere_Kommunale_Waermeplanung_212018.pdf">https://redaktion.hessen-agentur.de/publication/2021/3443_LEA_Broschuere_Kommunale_Waermeplanung_212018.pdf</a>	No	
Mecklenburg-Western Pomerania	No	No		No	
Lower Saxony	No	Yes	Leitfaden: Kommunale Wärmeplanung, <a href="https://www.schleswig-holstein.de/DE/Landesregierung/V/Service/Broschueren/Broschueren_V/Umwelt/pdf/FlyerKommunaleWaermeplanung.pdf?__blob=publicationFile&amp;v=3">https://www.schleswig-holstein.de/DE/Landesregierung/V/Service/Broschueren/Broschueren_V/Umwelt/pdf/FlyerKommunaleWaermeplanung.pdf?__blob=publicationFile&amp;v=3</a>	No	
North Rhine-Westphalia	No	Yes	Planungsleitfaden: 100 Klimaschutzsiedlungen in NRW, <a href="https://www.neuss.de/downloads/2017/11/klimaschutzsiedlung-blausteinsweg/planungs-leitfaden-klimaschutzsiedlung-blausteinsweg">https://www.neuss.de/downloads/2017/11/klimaschutzsiedlung-blausteinsweg/planungs-leitfaden-klimaschutzsiedlung-blausteinsweg</a>	No	
Rhineland-Palatinate	No	No		No	
Saarland	No	No		No	
Saxony	No	No		No	
Saxony-Anhalt	No	No		No	
Schleswig-Holstein	No	Yes	Leitfaden: Die kommunale Wärmeplanung, <a href="https://www.schleswig-holstein.de/DE/Landesregierung/V/Service/Broschueren/Broschueren_V/Umwelt/pdf/FlyerKommunaleWaermeplanung.pdf?__blob=publicationFile&amp;v=3">https://www.schleswig-holstein.de/DE/Landesregierung/V/Service/Broschueren/Broschueren_V/Umwelt/pdf/FlyerKommunaleWaermeplanung.pdf?__blob=publicationFile&amp;v=3</a>	Yes	<a href="https://www.schleswig-holstein.de/DE/Fachinhalte/E/energieKlimaschutz_kt/Downloads/richtlinieFoerderung.pdf?__blob=publicationFile&amp;v=1">https://www.schleswig-holstein.de/DE/Fachinhalte/E/energieKlimaschutz_kt/Downloads/richtlinieFoerderung.pdf?__blob=publicationFile&amp;v=1</a>
Thuringia	No	Yes	Integrierter Energie- und Klimaschutzstrategie, <a href="https://umwelt.thueringen.de/fileadmin/Publikationen/Publikationen_TMU/EN/Klimaschutzstrategie_Endfassung.pdf">https://umwelt.thueringen.de/fileadmin/Publikationen/Publikationen_TMU/EN/Klimaschutzstrategie_Endfassung.pdf</a>	No	

