European Commission

# OVERVIEW OF HEATING AND COOLING

PERCEPTIONS, MARKETS AND REGULATORY FRAMEWORKS FOR DECARBONISATION

Deliverable 1.2: Report on results of the meta-study (Task 1): Factors governing decisions in H&C

N° ENER/C3/2019-487


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Cover page: -

## Published

Karlsruhe, June 2021

## Notes

# Content

# 1 Executive summary

The objective of this study is to provide an overview of the elements that govern the decision-making and implementation of the decarbonisation of H&C in the residential, industrial and public sector. Decisions regarding renewable energy or energy efficiency H&C technologies are made by actors, who have different attitudes, perceptions and preferences, and are influenced by different drivers, such as regulatory, economic, environmental, social or cultural factors. Therefore, the aim is to collect all these aspects that govern the decisions on decarbonisation of H&C. To gain an overview, a meta-study was conducted. We primarily selected studies that discuss questions surrounding actors and their behaviour (perceptions, preferences), drivers and decision factors regarding energy behaviour (consumption and generation) and energy technologies with a focus on DHC and HP. We identified 130 studies.

According to the literature reviewed, perceived challenges and concerns regarding the further deployment of DHC are more complex than for HP. This is reflected by the issues discussed in the literature such as market power, free market entry and switching of suppliers, competition issues as well as appropriate and transparent pricing schemes and billing services for DHC services. In contrast, no study linked the use of HP to helplessness and dependency on energy suppliers. Concerning HP, understanding the technologies seems to be more of an issue. The majority of studies focuses on individuals' (residential sector) decision-making factors and less on companies or public authorities. Main findings are:

- Long-term commitment and planning security is key when deciding to implement DHC, but less crucial for the adoption of HP systems.
- Institutional frameworks ensuring clarity of and compliance with pricing rules, access to information, restriction of market power and transparency of markets are preconditions for DHC and are less important for HP adoption.
- Social and ecological (energy) values, attitudes, trust in institutions, culture and practices of peers, citizens, community members and customers are major and undisputed factors affecting ES decisions in all sectors and across all technologies.
- Local environment and conditions such as availability of local natural resources, building stock, financial capacities and socio-demographic aspects are preconditions for using certain H&C technologies.
- Energy literacy and technical and managerial expertise, are considered important drivers, especially for HP and RES-H&C technologies.
- In the industrial sector the increasing awareness and preferences of consumers for socially fair and environmentally clean production has added new product characteristics,
- The decision process of individuals is not triggered by profit orientation alone but by striving for well-being that is contingent on self-centred interests (desires) and altruistic aspects, on both monetary and non-monetary effects. The factors are grouped into contextual factors at the macro and meso level, and individual factors at the micro level. While the macro level comprises the overarching framework (social order, rules and economic system) under which actions take place, the meso level relates to the energy system and the community or peers with respect to their energy behaviour or culture. Both levels together represent the contextual, external factors that have an influence on individuals at the micro level. The micro level comprises different factors governing decisions: values, personal disposition and well-being as well as the energy-related, socio-economic-demographic situation of individuals, and building features.

# 2 Meta-study on factors governing decisions in H&C (Task 1)

## 2.1 Background and objective

This report is part of a study focussing on the perceptions, frameworks and markets concerning heating and cooling (H&C). The overarching goal of the study is to contribute to the decarbonisation of heating and cooling. This means fostering the expansion of **renewable energy and energy efficient H&C technologies** (RE- and EE-H&C), with a focus on heat pumps (HP) and district heating and cooling (DHC), at the system, technology and instrument levels.


Figure 1: Word cloud of elements governing the decarbonisation of H&C

This report sets out the objective, the approach (Section 1.2) and the results of task 1 (Section 1.3) outlined in the technical specifications of the tender and elaborated on in the inception report.

The objective of task 1 is to provide an overview of the **elements that govern the decision-making and implementation of the decarbonisation of H&C**. Decisions regarding renewable energy or energy efficiency H&C technologies are made by actors, who have different attitudes, perceptions and preferences, and are influenced by different drivers, such as regulatory, economic, environmental, social or cultural factors. Therefore, the aim is to collect all these aspects that govern the decisions on decarbonisation of H&C.

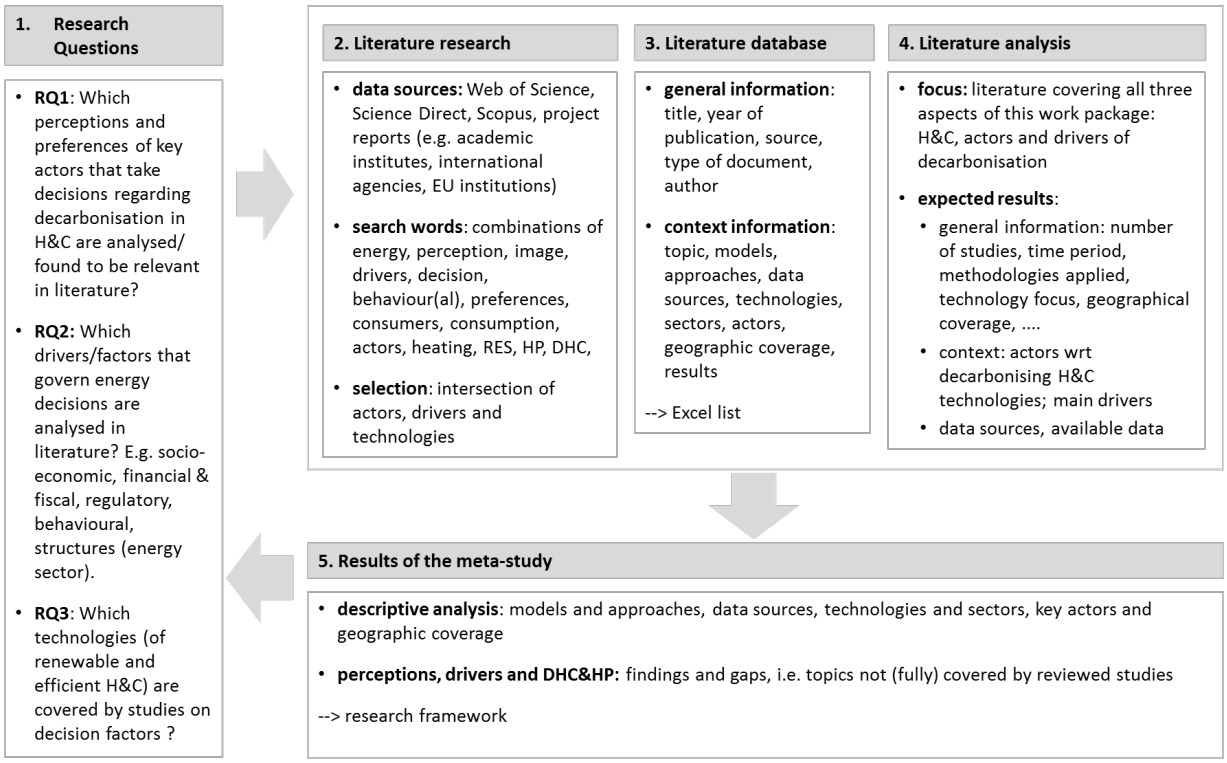
## 2.2 Approach

To expand upon this overview, a **meta-study** of relevant academic and policy-related studies was conducted in five steps.[1] The steps are outlined in the following text and illustrated in **Figure 2**.

In the **first step**, the research questions and therefore the topic of interest were defined. In this study the focus lies on critical elements for decarbonising H&C, which represent the object of research. Subordinated research questions are derived, which place the actors' perceptions on, drivers to and barriers to adopting relevant technologies at the centre of this research with a special focus on decarbonisation of H&C (see **Figure 2** and **Figure 3**). The three sub-research questions (RQ) are:

- **RQ1**: Which perceptions and preferences of key actors that make decisions regarding decarbonisation in H&C are analysed/found to be relevant in literature?
- **RQ2:** Which drivers/factors that govern energy decisions are analysed in literature, e.g. socio-economic, financial & fiscal, regulatory, behavioural, structures (energy sector)?
- **RQ3**: Which technologies (of renewable and efficient H&C) are covered by studies regarding decision factors?

[1] Literature for method: https://journals.sagepub.com/doi/pdf/10.3102/0013189X005010003; https://www.sciencedirect.com/topics/neuroscience/meta-analysis and http://www.stat-help.com/meta.pdf

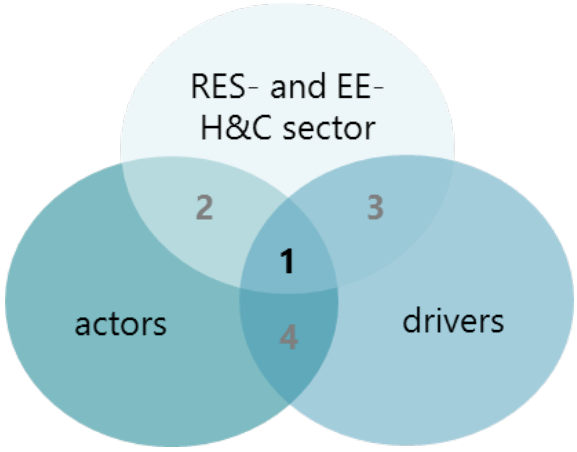



Note: HP stands for heat pumps, RES for renewable energy sources, DHC for district heating and cooling; wrt: with respect to

Figure 2: Methodology of the meta-study

In the **second step**, a comprehensive literature search took place, which covered different types of publications, such as studies, reports and scientific publications on an international level. A set of key words (see Figure 3) was applied and different sources were screened. Example sources for literature are:

- EU-Projects e.g. ECHOS, ENABLE.EU, ENTRANZE, progRESsHEAT, Hotmaps etc.,
- scientific publications e.g. Web of Science, Scopus, Researchgate,
- additional studies and reports e.g. from agencies and associations, e.g. IEA, IRENA.




For the selection of relevant literature, i.e. the inclusion and exclusion of studies, we primarily selected studies that discuss or analyse questions surrounding actors and their behaviour (perceptions, preferences), drivers and decision factors regarding energy behaviour (consumption and generation) and energy technologies with a focus on DHC and HP (see Figure 3). Our main focus lies on studies which cover all three relevant topics, i.e. studies regarding the renewable and energy efficient H&C sector (RES-H&C sector) which also focus on actors and drivers. Nevertheless, we also looked for studies with fewer intersections, e.g. studies on RES-H&C or EE-H&C and actors.

Figure 3: Approach for the selection of literature

In the **third step**, we identified the key information available in the published materials, detected the characteristics, categorised the studies by their characteristics and analysed the collected literature from step two. The output is a literature list (Excel file) with a detailed description of the available studies, such

as general information on title, year of publication, source including a link (in case of studies published online), author, etc., and context-related information on e.g. topic, models and applied approaches, analysed sectors, actors, technologies, geographic coverage, data source, and results (see structure in Annex A.4). The aim was to include high quality studies as far as content and methodological standards are concerned, in this database.. If the methodology seemed poor or the content of the paper was not close enough to the focus of this study, contributions from such literature were discarded.

In the **fourth step**, the selected studies were analysed in detail and the potential use of available data was examined. The focus lay on the intersection of actors, the RES-H&C sector and drivers. In this step we provided a general and content-related description of the literature database, including the number of studies, time period covered, methodologies employed and technological focus, actors etc. Research on factors governing energy decisions is very heterogeneous in various regards. Empirical studies on the same topics might report different findings due to differing data, methodologies, target groups, time when the study was conducted, etc. Thus, it is challenging to get a clear conclusion from the overview of these findings. We approached this challenge by analysing the methodologies and frameworks of the studies selected.

The **fifth step** summarises our findings, which includes an overview of the main approaches and models applied, available data sources and geographic coverage as well as the identified drivers of energy decisions and actors' perceptions regarding renewable and energy efficient H&C technologies. Further, we compared the findings from literature to our research questions and highlighted open issues, i.e. topics not addressed in the studies reviewed or answering other research questions as this study. Based on these results, we elaborated a research framework that should provide an orientation for the work in task 2.

## 2.3 Results

The result section is divided into two parts. In the **first part** a descriptive analysis is provided, outlining the type of studies found regarding the factors governing the use of H&C technologies with a focus on HP and DHC, methods applied, actors analysed in this context and geographical coverage (see Section 1.3.1). The **second part** presents the factors found in literature and points out potential knowledge gaps or further needs in research to better understand the observed decisions in H&C (see Section 1.3.2).

### 2.3.1 Descriptive results

In the following section, we present the **descriptive results of the meta-study**. General data such as the number of studies and timeline, the applied methods, the technological focus, the actor or target group and the illustrated geography in the considered studies are outlined. The studies considered are listed in the annex of this report (see list in Annex A.3 and structure of database in Annex A.4).

In our meta-study, **130 studies** were reviewed (see Table 1). The majority of which are scientific publications. In addition, 36 reports (including annual reports from authorities) and seven other literature sources (e.g. market studies or publications from energy providers) were analysed. The studies cover the **time period of 2008 to 2021**, although only one study from 2008 was included. As there have been extensive literature reviews in the framework of at least two EU projects Enable.EU[2] and Echoes[3] in 2016, we focused our further literature search on studies from 2015/16 or more recent, but the results of the reviews (from Enable.EU and Echoes) were included. The studies obtained were ranked by their relevance according to the approach described in Section 1.2 (see especially Figure 3).

[2] http://www.enable-eu.com/
[3] https://echoes-project.eu/

**Table 1: Type of publication and relevance for this project**

| Feature | # |
|---|---|
| Number of studies | 130 |
| Type of literature | |
| Scientific publication (i.e. research paper) | 86 |
| Report (i.e. project reports, annual reports or other study reports) | 36 |
| Other (e.g. brochures, conference paper) | 7 |
| Time frame | |
| 2008 - 2012 | 19 |
| 2013 - 2016 | 33 |
| 2017 - 2020 | 78 |
| Relevance | |
| 0: One topic (e.g. RES-H&C or actors or drivers) | 17 |
| 1: RES-H&C and actors and drivers | 37 |
| 2: RES-H&C and actors | 17 |
| 3: RES-H&C and drivers | 14 |
| 4: Actors and drivers | 37 |

An overview of the **methods** used in the selected studies is given in Table 2. The majority of the studies conducted surveys combined with quantitative analysis (e.g. Burlinson et al. 2018; Decker and Menrad 2015; Gerganov and Galev 2018; Karytsas et al. 2019; Karytsas and Theodoropoulou 2014). Besides the combination of survey and quantitative analysis, interviews with a qualitative analysis are quite common (e.g. Hodges et al. 2018; Lowes and Woodman 2020; Ariztia et al. 2019). Furthermore, in several studies, the authors analyse case studies (e.g. Büchele et al. 2018 or Lettmayer et al. 2018) or base their analysis on existing literature reviews and conduct for example a meta-analysis (e.g. Selvakkumaran and Ahlgren 2019, Biresselioglu et al. 2018 or Wang et al. 2009). Only a few studies used other methods, e.g. modelling, or did not specify a method at all.

**Table 2: Methods used in the selected studies**

| **Methods** | | **#** |
|---|---|---|
| *Category* | *Specifications* | |
| Publications | literature analysis (as part of the paper), literature reviews (meta-studies), document analysis, screening of media, etc. | 62 |
| Modelling | agent-based, optimisation, simulation, etc. | 8 |
| Experiments | choice experiment, user experiment, framing experiment, field experiments, conjoint analysis, other experiments, etc. | 22 |
| Surveys | survey, interviews, focus groups, questionnaire, etc. | 77 |
| Cases | case studies, energy audits, etc. | 22 |
| Qualitative | qualitative analysis, principal component analysis, conceptual, etc. | 9 |
| Quantitative | quantitative analysis, statistical analysis, comparisons, clustering, sampling, econometric/regressions, etc. | 50 |
| Other | theoretical approaches, path analysis, no information, etc. | 6 |

An overview of the **technologies** covered in the studies considered is presented in Table 3. Several studies looked at different technologies at the same time, e.g. comparing fossil with renewable heating systems or looking at barriers hindering the adoption of different technologies (e.g. in Echoes and Enable.EU). The two main focus technologies **DHC** and **HP** are subject of **71 studies** (DHC e.g. in Hansen et al. 2019, Büchele et al. 2018 or Burlinson et al. 2018 and HP in e.g. Hafner et al. 2019, Karytsas and

Theodoropoulou 2014 or Bjørnstad 2012). Additionally, a significant number of studies examine renewable heating and cooling systems, i.e. geothermal, solar thermal or (wood) pellet heating (e.g. Bjørnstad 2012; Mills and Schleich 2009; Woersdorfer and Kaus 2011). Furthermore, several studies focus on heating technologies in general or on technologies improving energy efficiency. The category "Other" includes energy efficiency technologies (e.g. thermal insulations) as well as (RES) electricity, storage technologies or so-called "green" technologies.

**Table 3: Technology focus in studies**

| Technology | # |
|---|---|
| DHC | 44 |
| HP | 27 |
| RES-H&C | 43 |
| H&C | 30 |
| Other | 64 |

An overview of the **actors,** which the studies address, is shown in Table 4. We grouped the actor types or target groups into (1) individuals, (2) associations and companies, (3) policy-makers, authorities and communities. Individuals (i.e. households or consumers representing the residential sector) mainly have a self-interest motive when deciding on energy consumption and their perspective is characterised by a broad array of different motivations such as environmental concerns, financial interests and social aspects or values. The group associations and companies stands for actors with a strong economic interest, focused on expected returns. It stands for the industrial and service sectors. The last group, policy-makers, authorities and communities, represents actors that look at the issues from a public interest view point (public sector). The **majority of studies focuses on individuals**, such as **households or consumers** (e.g. Ortega-Izquierdo et al. 2019, Skjevrak and Sopha 2012 or Mills and Schleich 2009). Moreover, several studies focus in particular on **homeowners** (e.g. Burlinson et al. 2018, Dharshing and Hille 2017, Achtnicht 2011 or Decker and Menrad 2015). There are over 20 **studies that examine associations and companies** (e.g. Gerganov and Galev 2018 or Magdalinski et al. 2018) and almost 30 **studies analyse public authorities or communities** with a public interest (e.g. Lowes and Woodman 2020, Linnerud et al. 2019).

**Table 4: Actor or target groups of the studies**

| Actor or target group focus | # |
|---|---|
| Individuals (self-interest) | 102 |
| Associations and companies (economic interest) | 26 |
| Policy-makers, authorities and communities (public interest) | 28 |

The studies considered cover a large part of the **geography** relevant for this project. Table 5 gives an overview of the geography encompassed. Many studies look at Germany, the UK, Norway, Sweden, Spain, Italy, Austria, Denmark or Europe/EU (e.g. Streimikiene et al. 2019 or Correia et al. 2019). Countries not within the scope of the project (e.g. USA, Chile or China) are analysed in 21 studies. As Table 5 reveals, we found no studies covering **Cyprus, Ireland, Luxembourg, Malta or Slovenia**. Beside the geographical scope the number of studies per **country in combination with the technology focus** are presented in Table 5. For some countries we found no studies that looked at DHC or HP, i.e. **Belgium, the Netherlands and Switzerland**. The only study we found for Belgium focuses on urban adaption and mitigation plans and not on one of these technologies.

**Table 5: Geographical coverage of the studies by technology focus**

| Country | # all studies | Technology | | | |
|---|---|---|---|---|---|
| | | # DHC | # HP | # RES-H&C | # H&C |
| Europe/EU | 17 | 5 | 3 | 3 | 4 |
| Austria | 10 | 4 | 3 | 2 | 3 |
| Belgium | 1 | - | - | - | - |
| Bulgaria | 7 | 1 | - | - | 1 |
| Croatia | 1 | 1 | - | - | 1 |
| Cyprus | - | - | - | - | - |
| Czech Republic | 1 | 1 | 1 | 1 | 1 |
| Denmark | 10 | 8 | 2 | 4 | 2 |
| Estonia | 1 | 1 | - | 1 | - |
| Finland | 5 | 4 | 2 | 3 | 2 |
| France | 9 | 4 | 1 | 4 | 1 |
| Germany | 25 | 9 | 5 | 14 | 6 |
| Greece | 2 | - | 2 | 1 | 1 |
| Hungary | 2 | 1 | - | - | - |
| Ireland | - | - | - | - | - |
| Italy | 13 | 4 | 2 | 4 | 2 |
| Latvia | 1 | 1 | - | - | 1 |
| Lithuania | 1 | 1 | - | - | - |
| Luxembourg | - | - | - | - | - |
| Malta | - | - | - | - | - |
| Netherlands | 1 | - | - | - | - |
| Poland | 3 | 1 | - | - | - |
| Portugal | 2 | 1 | 2 | 2 | 2 |
| Romania | 4 | 3 | 1 | 1 | 2 |
| Slovenia | - | - | - | - | - |
| Slovakia | 1 | 1 | - | - | - |
| Spain | 12 | 3 | 3 | 5 | 3 |
| Sweden | 15 | 10 | 2 | 5 | 4 |
| UK | 21 | 5 | 2 | 4 | 4 |
| Norway | 14 | 1 | 5 | 8 | 2 |
| Iceland | 1 | 1 | - | - | - |
| Switzerland | 2 | - | - | - | - |

Note: Table shows number of studies per country and number of studies with corresponding countries and technology; the numbers per country are biased by the size of the country

Table 6 shows the data collection and analysis **methods** used **in combination with the technology** focus of the studies. Not surprisingly (see also Table 2 and Table 3), most studies include a survey with a quantitative analysis for all technologies. Additionally, we found **11 case studies for DHC**. For RES-H&C there are also more than 20 studies, using the method publications, i.e. literature analysis/meta-study. Table 6 also discloses that we did not find any qualitative analysis for **HP**.

**Table 6: Coverage of methods and technologies in studies**

| Method | Technology | | | |
|---|---|---|---|---|
| | # DHC | # HP | # RES-H&C | # H&C |
| Publications (i.e. literature analysis, meta-study) | 19 | 11 | 21 | 12 |
| Modelling | 1 | 3 | 4 | 3 |
| Experiments | 5 | 6 | 7 | 6 |
| Surveys | 26 | 22 | 33 | 25 |
| Cases | 11 | 2 | 5 | 1 |
| Qualitative analysis | 4 | - | 2 | 2 |
| Quantitative analysis | 13 | 14 | 21 | 13 |

Note: Table shows number of studies with corresponding method and technology

Table 7 depicts studies by **actor group and technology**. There are **over 30,** respectively **over 20** studies focusing on **individuals** and **DHC and HP**. On the other hand, only **nine,** respectively **five studies** look at **DHC and HP in the industrial sector.** Only a few studies analyse factors governing decision-making of associations and companies with regard to DHC and/or HP. Similarly, there are only a small number of studies focusing on the public sector and the technologies DHC and HP. There are **18 DHC and only four HP studies** available that analyse the perspective and factors governing decisions of **policy-makers, authorities and communities**. Finally, there are no studies for companies or the public sector that focus solely on HP, i.e. without any other technology (e.g. include a comparison).

**Table 7: Coverage of actor groups and technologies**

| Actor group | Technology | | | |
|---|---|---|---|---|
| | # DHC | # HP | # RES-H&C | # H&C |
| Individuals | 35 (16 only DHC without other technologies) | 24 (3 only HP without other technologies) | 38 | 29 |
| Associations and companies | 9 (3 only DHC without other technologies) | 5 (0 only HP without other technologies) | 7 | 4 |
| Policy-makers, authorities and communities | 18 (11 only DHC without other technologies) | 4 (0 only HP without other technologies) | 8 | 3 |

Note: Table shows number of studies with corresponding actor groups and technology

Table 8 further zooms into the collection and analysis methods (i.e. survey and experiments) by actor groups for DHC and HP. It shows that most studies focus on the residential sector: **23 respectively 22 studies including surveys**, but only **five respectively six** studies including **experiments** are found for **individuals**. For the **industrial** as well as the **public sector only a few studies (five in total) including a survey** could be found. Overall, the findings of these studies serve as basis for the works in task 2.

**Table 8: Coverage of relevant methods by actors and technologies**

| Actor group & method | | Technology | |
|---|---|---|---|
| | | # DHC | # HP |
| **Individuals** | Survey | 23 | 22 |
| | Experiments | 5 | 6 |
| **Associations, companies** | Survey | 4 | 1 |
| | Experiments | - | - |
| **Policy-makers etc.** | Survey | 5 | - |
| | Experiments | - | - |

Note: Table shows number of studies with corresponding methods, actor groups and technology

The descriptive results of the meta-study show that:

- **Surveys in combination with quantitative analysis** are the dominating data collection and analysis methods, followed by publications, i.e. literature analysis, meta-studies, document analysis, etc.
- The two focus technologies **DHC and HP are the subjects of 71 studies**, while more studies are available for DHC than for HP.
- The **majority of studies focuses on individuals (residential sector)** and less on companies or public authorities, which is in line with the findings of the previous projects (Enable.EU, Echoes).
- No studies at all were found for **Cyprus, Ireland, Luxembourg, Malta or Slovenia,** and for **Belgium, the Netherlands or Switzerland,** no studies were found that look into DHC and/or HP.
- For **DHC several case studies** are available.
- The **majority** of studies that look at **DHC and/or HP** focus on **individuals** and only a **few studies** look at DHC and HP in the **industrial and public sectors**.

### 2.3.2 Factors governing decisions

The aim of the second part of this study is first, to elaborate the **factors governing decision-making** in **energy investments and services (ES)** in H&C with a special focus on DHC and HP, and second, to identify potential **knowledge gaps** or further needs in research to better understand the observed decisions in H&C. We apply an analytical framework to obtain a structured overview of factors affecting decisions with regard to energy investments and services (ES) in H&C. Based on this framework we elaborate the factors governing decisions concerning ES in H&C and with a focus on DHC and HP.

#### 2.3.2.1 Analytical framework for the literature review

This meta-study builds on previous work and the results of thorough literature reviews conducted in the framework of the Horizon 2020 projects ECHOES and Enable.EU (e.g. Biresselioglu et al. 2017; Biresselioglu et al. 2018) and, thus, focuses on literature published after 2016. However, older references were also included, if deemed useful.

In their review, Biresselioglu et al. (2017) conclude that there is a rich literature discussing and identifying **factors governing energy decisions in households**, but there is a **lack of a comprehensive analytical concept integrating different perspectives**. They classified the factors by their level; the macro level includes motivators and barriers at formal, collective and individual levels; the meso level accounts for socio-cultural aspects of energy use and taps energy use behaviour that is unnoticed at the individual or societal level; the micro level encompasses a comprehensive review of individual-centred approaches outlining how different concepts used contribute to explaining ES decisions, e.g. how values, societal norms, attitudes etc. interact in decision-making processes. The analysis of ES decisions is of interest for many different research disciplines, including psychology, economics, behavioural economics, political science, economic geography, sociology and sustainability transition. Coming from the field of psychology, Burger et al. (2015) refer to **different value bases that shift energy savings behaviour** away from a self-centred to a societal or ecosystem focus: self-interest values focussing on one's own well-being, social altruistic values referring to the well-being of a larger circle of individuals and biospheric altruism values including concerns about all living species. Selvakkumaran and Ahlgren (2019) consider the energy transition as a socio-technical transition. They conduct a content ananylsis and identify 31 explanatory variables governing behaviour of households. These they order into six categories (i.e. demography, housing and location of residence, decision-maker disposition, beliefs about consequences for the household, beliefs about consequences beyond household, social influences and policy measures). Their conceptional framework builds on sustainability transition (resource availability and coordination) and encompasses two factors transforming regimes, i.e. origin of factors (external or internal) and change (transformation) under external influence. On the other hand, Steg et al. (2018), researching environmental psychology, identify two dimensions, individual factors and contextual factors that are key for ES

decisions. In the field of behavioural economics, e.g. Schlüter et al. (2017) focus on individuals and their perceptions. Krikser et al. (2020) look into preferences of households that encompass environmental and economic concerns only. Karytsas et al. (2019), and Correia et al. (2019) use a classification based on empirics and distinguish socio-economic, spatial characteristics, residence characteristics, environmental and technical aspects, socio-demographic factors, energy system-related aspects and personal characteristics such as preferences, attitude and well-being while others do not classify the factor but differentiate between actors, e.g. Iturriza et al. (2019), Hafner et al. (2019), and Lowes and Woodman (2020). Continuing with this overview would not result in a narrowing down of factors rather in the opposite.

To summarise: the literature review reveals that i) there are many factors affecting ES decisions, ii) which can be grouped into different categories, iii) that are based on several theories or models stemming from different disciplines, and iv) which factors are analysed and how they are grouped depends on the purpose of the paper/publication.

For our review we start with a pragmatic approach and differentiate between levels and actors. We identified three actor types that are focused on or targeted in the studies examined (see also Section 1.3.1):

(1) individuals in the residential sector (residential sector), whose behaviour is assumed to be driven by **maximising their well-being**, which could, but does not have to, also include altruistic aspects;
(2) associations and companies (industrial sector), whose main purpose is to use their limited means in an efficient way and **maximise their profits**. Thus, they reveal a market-driven behaviour that could account for environmental concerns, if the market values those concerns;
(3) policy-makers, authorities and communities in the public sector that are supposed to act in **society's best interests**.

In line with Steg et al. (2018), we distinguish individual and contextual factors but we go beyond this, and subdivide the contextual factors into overall factors and factors that relate to the energy system. At both levels they influence opportunities, constraints, costs and benefits of ES decisions and encourage to make decisions or not. Individual factors include individual values and norms, practices and habits, attitudes and preferences and cover many aspects, such as environmental, economic and social issues. Also this classification is similar to Biresselioglu et al. (2017), in that it represents a clear delineation used in many studies even beyond ES decision issues (Breitschopf et al. 2016):

(1) the **macro level** encompasses contextual factors at an aggregated level, concerning society and the economy as a whole. These factors are not specifically energy related, e.g. societal norms, overarching objective, physical and non-physical infrastructures not directly related to energy such as institutional arrangements, access to information and education, communication channels, etc.;
(2) while at the **meso leve**l the factors governing ES decisions are either part of the energy system context or closely related to it, such as energy security issues, energy infrastructure, access to energy services and information; or persons', peers' and communities', energy culture encompassing behaviour and attitudes of the closer environment e.g. with respect to energy consumption;
(3) the **micro level** reflects the individual aspects such as preferences for the individual or societal well-being, individual habits and values. Within this level, we face a complex structure driving ES decisions, governed by very specific preference sets that are in turn shaped by external (values of society, culture, factors related to the energy system, etc.) and internal factors (individual capabilities, capacities and altruistic orientation, etc.).

As a summary, Table 9 visualises our approach and explains the different categories.

**Table 9: Matrix for clustering the factors governing ES decisions**

| | | Actor types/sectors | | |
|---|---|---|---|---|
| | | Individuals | Associations and companies | Policy-makers, authorities and communities |
| **Levels** | Macro | Aspects not directly related to the energy system, i.e. overarching societal, social, economic, environmental, technical and institutional aspects | Global (market) structures, institutions, developments and institutions, e.g. possible "greening" of products | Overarching short-term needs (crisis) and long-term values, structures and cultures |
| | Meso | (i) Energy system-related factors<br>(ii) Energy behaviour-related factors of the individuals' close/local environment | (i) Energy system characteristics (technical, economic, etc.)<br>(ii) Energy consumption values and interests of consumers and other actors | (i) Aspects of demand and supply of energy<br>(ii) Energy literacy and culture of population and policy-makers |
| | Micro | Individual constraints, opportunities, preferences with respect to individual well-being | Company-specific constraints, opportunities and strategies | (i) Public actors' characteristics<br>(ii) Enabling factors in community |

Constraints and opportunities represent the combined results of different infrastructural, technical, institutional economic, societal, socio-demographic and financial factors. Preferences are shaped by different value sets and affect ES decisions, which realisation habits and routines either support or oppose. Individual preferences at the micro level might include altruistic values as well.

Furthermore, energy policies and regulations established to remove barriers and constraints to demand changes, to motivate and apply drivers for a move of society towards sustainable energy use, are considered formal measures. They are per definition factors that are supposed to affect ES decisions. Subsequently, we do not include these policies in our overview, but strive to focus on the factors lying behind policies, that is, on the factors that energy policies are supposed to target. Finally, regulations concerning land use and laws governing use of resources and assets as well as market rules and governance are classified as institutional aspects.

Our meta-analysis includes over 130 studies analysing perceptions of, preferences for as well as barriers to and drivers of decisions and satisfaction of different actors in H&C as well as putting a special focus on DHC and HP. Of these, 102 studies were found which focus on individuals, 26 on companies and 28 on the public sector (see also Section 1.3.1). We present our results sorted by actor groups, i.e. sectors – residential, industrial, public – and apply the analytical framework presented above. In doing so, we apply a **two stage approach**. First we have a closer look at factors governing ES decisions with respect to the application of **DHC** and **HP**, respectively (see Section 1.3.2.2 and 1.3.2.3). Then we outline the factors driving the decision for and application of **renewable and energy efficient H&C technologies** and compare these factors with those of DHC and HP (see Section 1.3.2.4).

### 2.3.2.2 Factors governing decisions with a focus on DHC

Over 40 studies analyse perceptions, preferences, barriers and drivers concerning energy decisions and satisfaction with a focus on DHC (see Section 1.3.1). Table 10 presents the most relevant factors for individuals and Table 11 includes the relevant factors governing decisions of companies and the public sector. In addition to these overview tables, we go into more detail by highlighting specific studies and their results to further expand the analysis and thus provide a more comprehensive picture of the decisions observed regarding DHC.

### Individuals

More than 30 studies and therefore the majority of the DHC studies considered look at individuals. Regarding the **macro level**, i.e. overarching societal aspects, there are several studies presenting a variety of **institutional factors** such as policies and measures or rules affecting individuals (e.g. Skytte and Olsen 2016 or Mahapatra and Gustavsson 2009). Skytte and Olsen (2016) reveal that the choice of technologies for heat generation in Denmark is mainly driven by (outdated) policies and tax conditions that create barriers hindering additional flexibility in the overall energy system. Similarly, to show the influence of policy measures, Mahapatra and Gustavsson (2009) carried out a survey of about 700 homeowners who lived in the city of Östersund, Sweden, in houses with resistance heaters. About 84% of the respondents did not intend to install a new heating system. In the time since the survey was conducted these homeowners have been influenced by (a) an investment subsidy provided by the Swedish government to replace resistance heaters with district heating, a heat pump, or a biomass-based heating system and (b) a marketing campaign launched by the municipality-owned district heating company. The results show that these two measures influenced about 78% of the homeowners to adopt the district heating system. Therefore, **providing information and raising awareness** (marketing campaign) in combination with **financial incentives** (investment subsidy) created an openness among homeowners to adopt a new heating system.

Zaunbrecher et al. (2016) focus more on the **meso level** by analysing the influences of the network design, security of supply, and type of energy source. Technically feasible options of local district heating are weighted against each other from an acceptance point of view, also considering costs and environmental impacts. Results of their analysis show that the energy source and its corresponding primary energy factor was the most important attribute for preferences, followed by network design. The preference for environmentally friendly energy sources changed dramatically when introducing different prices for energy sources. Subsequently, **institutional and technical factors (network design)** and **environmental/climate concerns** (clean energy source) are important but are compensated for by **economic factors** if prices reach a certain level. The results further indicate that it is necessary to integrate **users' requirements** into local DHC network planning processes and to improve communication about local DHC.

The studies from Hodges et al. (2018) or Krikser et al. (2020) focus more on the **micro level**, i.e. characteristics of actors or technologies. Hodges et al. (2018) show that **reliability** of the technology, **control of heating and water**, as well as **speed and effectiveness of repair services are the most relevant factors,** having a large impact on consumer satisfaction. They conducted a survey on the experiences of district heating consumers (and operators, see section below) in the UK. Questions on heat delivery and their effects on consumer satisfaction and consumer protection were asked. According to their results, periodic planned interruptions were accepted by consumers as a necessary part of network maintenance. Some consumers were frustrated with the experiences of unplanned outages, especially when they felt their provider had not acted promptly and/or had not kept them updated. Additionally, some consumers felt being **locked in** when buying their heat from the district heating operator. At the same time, most consumers had only a limited awareness of their consumer rights. The ones that had tried to complain felt they had very limited rights and mostly felt that operators were unhelpful. These incidents could cause a feeling of **helplessness**. In many cases, consumers are unclear on **divisions of responsibility**, particularly between property manager and district heating provider. Krikser et al. (2020) analysed private household preferences and willingness-to-pay for district heating and especially district heat from renewables compared to gas condensing boilers and heat pumps in Germany. For the study they applied a discrete choice experiment and collected data on attitudes towards sustainability, economic aspects and demands towards providers of heat supply as dimensions for a factor and cluster analysis in order to apply market segmentation. The results show that **district heating fuelled by renewables is the most preferred** heating option for households (environmental factors) followed by district heating from fossil fuels, heat pumps and gas boilers. Additionally, Rouvinen and Matero (2013) examined how different attributes of residential heating systems affect private homeowners' choice of heating system

following renovations. The choice modelling results emphasised the role of **investment expenditures** as the main attribute affecting the decisions, but nonfinancial attributes also had a considerable effect.

Summarising, Table 10 provides an overview of the most relevant factors governing the decisions of individuals concerning DHC, using the categorisations into macro, meso and micro level, i.e. characteristics of society, systems and actors/technologies explained above.

**Table 10: Factors governing ES decisions with a focus on DHC for individuals**

| | Actor type individuals |
|---|---|
| **Macro level** | Aspects not directly related to the energy system, i.e. overarching societal, social, economic, environmental, technical and institutional aspects:<br>• Institutional: measures and rules, like building codes etc., co-ordination of national and municipal measures, security, governance and accountability of energy institutions<br>• Social: norms, practices and social acceptance, desirability of change, change to low-carbon technology, most valued attributes of low-carbon heating systems<br>• Long-term planning and commitment (of municipality or government)<br>• Flexibility to account for innovation and market changes; need of flexibility in DHC market |
| **Meso level** | (i) Energy system-related factors:<br>• Public interest<br>• Market and investments structure<br>• DHC network design (construction work, restoration of land)<br>• Building density and existing system (e.g. gas or DHC)<br>• Energy source of network (primary energy factor)<br>• Negative experience of others (image)<br>(ii) Energy behaviour-related factors of the individuals' close environment:<br>• Attitude towards the neighbourhood becoming natural gas free<br>• Trust in DHC provider/DHC systems |
| **Micro level** | Individual constraints, opportunities and preferences with regard to individual well-being:<br>(i) Satisfaction: comfort, usability, system convenience, environmental friendliness, safety of DHC<br>(ii) Decisions:<br>• Economic: prices, market value of building, energy expenditure savings, fee for DHC connection, burden of a high initial investment, lower the entry-cost barrier<br>• Environmental concerns: environmental attitude<br>• Technical: quality of service (i.e. too short heating period, lack of maintenance)<br>• Behavioural: heating habits, heating preferences (temperature level)<br>• Socio-economic-demographic: monthly average income of household, education, academic achievement, kids' age, educational level of the decision-maker, average winter heating cost per household, income level, number of household members, household demographic structure<br>• Building: price per floor size of apartment in residence, age of building, household location (i.e. DHC in area)<br>• Social values of individuals and social needs<br>• Effort-related: heating service satisfaction with current heating system<br>• Energy literacy: heating knowledge, awareness, use of current heating system, control, knowledge concerning the change, environmental awareness<br>• Individual features: attitudes and preferences |

### Companies and public sector

In contrast to the number of studies focusing on individuals, there are only a limited number of studies that analyse factors governing decisions concerning DHC in the industrial sector, i.e. for companies and associations (see Table 7 in Section 1.3.1). The same applies to the public sector, where about 18 studies analyse DHC from the perspective of policy-makers, authorities and communities. Despite the lower number of studies, several factors were found.

Regarding the **macro level and meso level**, there are several studies addressing specific barriers to and drivers towards the use, adoption and the implementation of DHC with the intention to formulate appropriate policy recommendations (see e.g. Chassein et al. 2017, Rao et al. 2017). The comprehensive report from Chassein et al. (2017) provides an overview of barriers, driver and stakeholders in the field of district heating. The analysis is based on a literature review and quite a number of empirical results from local case studies in Austria, the Czech Republic, Denmark, Germany, Portugal and Romania. Apart from district heating, they also looked at HP (see Section 1.3.2.2) and RES-H&C technologies, such as solar thermal energy. One of the main results regarding district heating is that drivers and barriers depend on the country and stakeholder, showing that the **surrounding conditions (environment) are the most important**. Similar results are arrived at in the research of Rao et al. (2017). They draw on best practices, experiences and enabling policies to focus on the challenges to and benefits of the various governance and financing models for district heating and identify major drivers for project development or reinvestment. According to Rao et al. (2017) district heating systems are driven by **local considerations and specific objectives** which address a variety of local needs and challenges and often contribute to national resource efficiency and the meeting of environmental targets. They define **economic, environmental, social and political drivers** as far as district heating is concerned, such as local considerations and specific objectives, revenue generation, strategic restructuring, increasing local economic competitiveness, boosting the value of existing resources, increased efficiency and the integration of renewable energy technologies, resilience in the face of natural and other disasters and mitigating fuel poverty. Key factors for the success of DHC are (1) identifying, allocating and managing **risks**, (2) gathering and disseminating **information** needed for decision-making, (3) managing funds to align with the needs of the system lifecycle stage, (4) **including appropriate people and experts** as needed in decision-making and (5) using available **evaluation tools** to improve decision-making. With the same focus on key factors, Galindo Fernangez et al. (2016) analysed eight efficient district heating systems in different Member States of the EU, i.e. Denmark, Estonia, France, Germany, Italy, Spain and Sweden. They identified key factors enabling the development of high quality, efficient and low-carbon district heating system. These are: **adequate national policy and regulatory environment, direct/indirect financial support, focused local policy and coherence with urban planning, alignment of interests and/or cooperation maturity**, especially between district heating operators, local authorities and consumers, availability and relevance of local resources, comprehensive project development, price competitiveness compared to alternative energy solutions, flexible heating and cooling and the combination of technical and non-technical innovations.

On the other hand , Santos et al. (2016) analysed barriers which form obstacles for the adoption of district heating. The main barriers identified included: **distinctive competence**, fuel **price volatility** as well as the current financial and regulatory **framework**. Sayegh et al. (2017) also investigated trends and developments of district heating in Europe with related results. The key conclusion is that the district heating development requires more **flexible energy systems**, more **significant contribution of RES**, more dynamic **prosumers' participation** and therefore suitable framework conditions.

Additionally, Cornelis (2020) focused on companies and analysed barriers to investments by industrial companies in the areas of energy efficiency and renewable energy, including district heating. Strong relationships seem to exist between behavioural, organisational and competence-related barriers. The results indicate that small companies tend to view a larger number of barriers as important to them, as compared to medium-sized companies. Relevant barriers for small and medium companies are a lack of **competences** to implement the interventions, a lack of **time to investigate** the energy efficiency options as well as divergent interests within the companies. On the other hand, the following barriers are more prevalent in larger companies: other **priorities than energy efficiency** investments, a lack of joint **objectives** and **awareness.**

There are more authors providing recommendations for heat suppliers, policy-makers and governments. The research from Rebosio et al. (2015), for example, highlights the need for governments and energy providers to ensure **wider acceptance** of reforms by (i) improving citizens' **awareness** of the rationale for reforms; (ii) committing to high degrees of **transparency**; and (iii) improving the way they

**communicate** about improvements in sector governance. The findings highlight the importance of increasing clarity regarding **consumer rights and obligations, introducing accessible and effective customer services**, and enforcing strong **grievance redress mechanisms**. Named factors are energy payment, household vulnerability to energy tariff increases, energy affordability and income security, energy efficiency and energy-saving behaviour, social assistance and protecting energy affordability, the governance and accountability of energy institutions.

Furthermore, the report from ClimateXChange[4] (Donnellan et al. 2018) provides lessons from European examples (i.e. Norway, Netherland, Sweden, Hungary, Denmark, Germany and Poland) of district heating regulation aiming to help policy-makers considering whether and how regulation should be introduced in Scotland. Their results show that **pricing, long-term planning and commitment, stimulation of markets and investments** via specific tools, **coordination of national and municipal measures**, **scope of industry to have a say** and the flexibility to account for innovation and market changes are relevant aspects for the successful regulation of district heating.

Moreover there are some studies available which focus more on the **micro level**, often for one specific country. The report from e.g. Bouw (2016) provides an exploration of customers' attitude towards district heating in the Netherlands and possible solutions for increasing the attractiveness of district heating. In the report customers are not divided into separate sectors. Also, the report specifically addresses cities and policy-makers. According to Bouw (2016) customer satisfaction depends on **price, comfort, transparency of pricing, sustainability in terms of CO2 reduction, flexibility, possibilities for consumer choices, consumer protection, as well as service products**. District heating systems in the Netherlands seem to have a bad image and seem to be seen as old block heating systems. This impression arose because several complaints on the technical performance of the district heating system were recorded. Factors supporting this bad image are a lack of trust towards a **monopolistic** district heating company, a **lack of consumer choice**, high district heating **prices and long-term contracts** for district heating systems. Bouw (2016) argues that third party access (TPA) could be a good measure to stimulate the use of small-scale waste heat and renewable heat. However, positive effects on district heating prices are expected to be low and consumer choice will not increase much. He argues that alternative price models could be a more effective measure to increase consumer choice. Apart from that, an important aspect are the legal possibilities for product differentiation. Similarly, Ericsson (2009) addresses policy-makers and identifies factors that have shaped the development of district heating in Sweden. The high DHC customer satisfaction in Sweden seems to depend on: **low prices, reliable supplies and convenience**. The acceptance of **collective solutions depends on the cultural and political heritage** of the country.

Hodges et al. (2018) on the other hand provide (inter alia) a more detailed picture of the **provider side** and show that roles and **responsibilities of district heating operators** in ensuring consumer protection differ across heat networks. None of the providers in their study recalled passing on the additional costs of inefficient performance to customers. Some public district heating providers mentioned their preference for using noticeboards and door drops rather than emails or mail outs to provide advance notice to consumers of any planned outages. Additionally, several providers expressed a **preference for smart metering**, as it enables automated meter readings to be used to produce accurate bills; and smart meter displays offer a more engaging way for customers to view their consumption.

In addition, for some countries there are reports from energy providers available. For example, the discussion paper of the energy provider Finnish Energy (Kohopää 2019) describes how Finland organises an efficient heating market and how the heating market is developed on market terms, presented from the viewpoint of a district heating operator. Relevant factors influencing the perception of DHC are **competition and free access and exit and selection/choice, price and environmentally friendly energy sources**. Overall, the customer satisfaction is very high in Finland, according to Finnish Energy. Besides reports from energy providers, there are also studies from energy authorities providing insights from their regulatory perspective.

[4] ClimateXChange is Scotland's centre of expertise on climate change, providing independent advice to support the Scottish Government.

The Italian Competition Authority published a presentation about district heating in Italy (Esposito 2014), addressing policy-makers and public authorities. According to the analysis of the Competition Authority, elements influencing the perception are: **market power** of district heating operators, **lack of retail competition, and cost of switching** to another system affecting the actual exploitation of monopoly power. Similarly for Slovakia a report from the Antimonopoly Office was found. According to this report, district heating systems are the main sources of heat supply for municipality inhabitants and for the public and commercial sector, but increasing costs of heating and hot water and the efforts of unsatisfied customers to disconnect from the existing systems have negative impacts on the situation and the functioning of the whole heating sector in Slovakia (Antimonopoly Office of the Slovak Republic 2013).

Concluding, Table 11 provides an overview of the most relevant factors governing decisions of companies as well as public authorities regarding DHC, using the classification defined.

**Table 11: Factors governing ES decisions with a focus on DHC for companies and the public sector**

| | Actor types | |
|---|---|---|
| | **Associations and companies** | **Policy-makers, authorities and communities** |
| **Macro level** | Global (market) structures, institutions, development perspectives and institutions:<br>• Institutional: regulations and processes, such as building codes, price regulations or standards for technologies or buildings<br>• Societal: social acceptance of DHC<br>• Long-term perspectives and certainty | Overarching short-term needs (crisis) and long-term values, structures and cultures:<br>• Institutional framework as well as cultural and political heritage<br>• Regulations regarding consumer protection<br>• Social costs and benefits, such as energy affordability and income security<br>• Long-term planning and commitment |
| **Meso level** | (i) Energy system characteristics (technical, economic, institutional)<br>• Infrastructure<br>• Stimulation of markets and investments via specific tools<br>(ii) Energy consumption values and interests of consumers and other actors<br>• Flexibility to account for innovation and market changes<br>• Transparency of pricing, accurate billing and right amount of information | (i) Aspects of demand and supply of energy:<br>• Roles and responsibilities of DHC network operators<br>• Comfort and security of supply, e.g. resilience in the face of natural and other disasters<br>• Availability and potential of local resources, like use of excess heat or/and electricity<br>(ii) Energy literacy and culture of population and policy-makers<br>• Local considerations and specific objectives<br>• Overarching strategies for DHC<br>• Capabilities and willingness to interact and co-operate, cooperation maturity/experience<br>• Transparency of pricing, accurate billing and right amount of information |
| **Micro level** | Company-specific constraints, opportunities and strategies:<br>• Economic: heating costs and revenue generation<br>• Technical performance: energy intensity<br>• External/Market: locked-in effect (buying heat from one supplier)<br>• Internal factors: commitment of the top management to climate action, uncertainties, preference for smart metering (from DHC provider) | (i) Public actors' characteristics<br>• Leadership, opinion of key stakeholders<br>• Negative experience of others (image)<br>(ii) Enabling factors in community<br>• Increasing local economic competitiveness and boosting value of existing resources<br>• Sustainability in terms of CO2 reduction<br>• Uncertainty |

Table 10 and Table 11 as well as the described studies show that there are a variety of factors governing the decisions concerning DHC as seen from different perspectives, including the view of DHC operators as well as regulatory authorities. Moreover, factors governing the decisions regarding DHC could be identified on all levels (i.e. macro, meso and micro) and for all groups of actors.

### 2.3.2.3 Factors governing decisions with focus on HP

The examined studies on perceptions of, preferences for, barriers to and drivers of energy decisions and satisfactions with a focus on HP are diverse and include many different aspects. In this meta-study we identified 27 studies focusing on HP, of which 20 studies focus on individuals. Table 12 presents the most relevant factors governing decisions in HP for individuals and Table 13 shows the relevant factors for companies and the public sector.

**Individuals**

Regarding the **macro level**, some authors (e.g. Chassein et al. 2017) list policy framework as an institutional-structural factor, which can also be considered as a measure to address barriers and drivers. Hafner et al. (2019) outline the significance of normative information in combination with feedback on environmental and economic effects for decisions with regard to investment decisions. In this respect, communication of norms and feedback as a way of framing are a measure to address perceptions and increase **awareness of sustainable energy** use, while **economics and environmental aspects** are seen as governing factors of decisions. In addition, Jansma et al. (2020) consider further aspects such as **guidance from governments** and **financial support** as drivers, which, however address economic and value aspects at the micro level.

Jansma et al. (2020) also identified factors on the **meso level** such as **cohesion and trust in community members and civil neighbourhood and a high commitment of community members** as supportive factors for the energy transition as contextual or community factors. Michelsen and Madlener (2016) also stress the significance of the **social acceptance** for adopting a new technology such as HP. Moreover, they identified **habits** as key factor with independence from fossil fuels as a crucial element for switching to renewable energies. The latter factor could be considered as an "security of supply issue". Likewise, Sovacool et al. (2021b) found **practices and resistance to change** (of a society) as factors hindering investments in renewables – also at the micro level. Sovacool et al. (2021a) stress that decisions made extend beyond economic and environmental interest, logic and rationality. In addition to these factors, Krikser et al. (2020) found that direct contact to the **service or technology provider** as well as the attribute "local provider" favour the adoption of HP.

On the **micro level**, a distinction between factors governing decisions and factors affecting satisfaction with an existing heat system has been made by Bjørnstad (2012). He found that values and attitudes such as **economic and environmental** issues are listed among the most important factors driving decisions. Regarding the satisfaction, Bjørnstad (2012) found that when HP were already in use, the **indoor climate and comfort**, the **quality of the heating technology** as well as the **service of the supplier** are the most important factors influencing user satisfaction.

Chassein et al. (2017), Ruokamo (2016) and Lillemo et al. (2013) mainly consider **economic factors** such as prices of electricity and gas (as an alternative) as well as investment expenditures as key factors, but also **behavioural aspects** such as security aspects and risk aversion and individual issues such as comfort and efforts to adopt a new technology. **Socio-economic and-demographic** factors as well as **building features and technology** form another group of factors that are also found to affect decisions (Karytsas et al. 2019; Karytsas and Theodoropoulou 2014; Lillemo et al. 2013; Ruokamo 2016). Hecher et al. (2017) had a deeper look into building features and their impact on heating investments: homeowners refurbishing their house strongly focus on operational convenience, while financial support is an effective incentive for homeowners with a lower income, while for new buildings, fuel security and availability of fossil fuels play a role. Jingchao et al. (2018) identified global environmental concerns as a weak, but local environmental concerns as a strong factor governing decisions. In addition, literacy with respect to energy as a socio-demographic factor seems to matter as well.

According to a study of the Bundesverband der Energie- und Wasserwirtschaft e. V. (2019) (Federal Association of the German Energy and Water Industries) additional features such as a **high safety standard and progressive simple and convenient technology** are further highly appreciated features of HP ensuring a high satisfaction in Germany. Regarding heat consumption e.g. fed by HP, Cui et al. (2017)

found that socio-economic and demographic aspects as well as building features, comfort and environmental aspects were dominating factors.

To sum up, Table 12 provides an overview of the most relevant factors governing the decisions of individuals regarding HP, using the categorisation into macro, meso and micro level introduced earlier.

**Table 12: Factors governing ES decisions with focus on HP for individuals**

| | Actor type individuals |
|---|---|
| **Macro level** | Aspects not directly related to the energy system, i.e. overarching societal, social, economic, environmental, technical and institutional aspects:<br>• Institutional: regulations and frameworks, communication of norms, economic and environmental aspects<br>• Societal: norms, practices, social acceptance, extent of materialism/post-materialism |
| **Meso level** | (i) Energy system system-related factors:<br>• Proximity and access to technology and service providers<br>• Market structure, supplier issues<br>(ii) Energy behaviour-related factors of the individuals' close environment:<br>• Community factors: cohesion, trust in community members, civil neighbourhood, commitment of members, practices and resistance of peers, recommendations |
| **Micro level** | Individual constraints, opportunities and preferences with respect to individual well-being:<br>(i) Satisfaction: indoor climate/comfort, quality of heating, service of supplier<br>(ii) Decisions:<br>• Economic: prices, investment, expenditures<br>• Environmental: local pollution concerns, awareness of climate change<br>• Technical: progressive, simple, high safety, convenient<br>• Behavioural: reliability/security of heat provision, risk aversion, comfort and efforts to adopt or refurbish, convenience, openness to changes, innovation orientation, want to try out new heating technology, technical interest<br>• Socio-economic-demographic: income, age, ownership, education<br>• Building: type, location<br>• Individual features: openness, experiences with technology, awareness, ease of use of heating system |

### Companies and public sector

Few authors analyse the constraints, opportunities and drivers affecting energy investments of companies and the public sector; none focus on HP only. Subsequently for these two actor groups, we could not identify specific factors for HP, but instead give an outline based on a broader coverage of H&C technologies.

On the **macro level**, Chassein et al. (2017) outline drivers and motivations of authorities to making energy decisions. Public actors' focus is society and therefore factors such as **social equity** and **environmental benefits** influence actions and measures implemented. Formal measures such as regulations, minimum standards and different support instruments address certain market and system failures. They are either classified as measures or institutional factors. On the other hand, the business sector focusses primarily on **market aspects** such as competitiveness and market shares. Furthermore, due to their market orientation, they care for the perceived features of their product, i.e. **environmental and social aspect of their product(ion)** gain in importance if this is a general market trend.

Regarding the **meso level,** the surrounding and the existing **infrastructures and markets** (designs) are relevant factors for both actor groups, while **security of supply** (beyond infrastructures) regarding the energy system is a decisive factor in public decisions. Apart from this administrative and regulatory aspects (institutional) represent potential drivers or barriers (Chassein et al. 2017). In the building business sector, an additional product feature is **comfort as one service-element** for their clients (inhabitants). Awareness of the sector regarding their product features has changed, as the **awareness of customers** regarding social and environmental aspects has increased, such that they have become increasingly more important product features in addition to initial features such secure heat and comfort. Therefore,

the perception of customers (and hence customers' value systems) becomes a new driver regarding energy decisions in the industry.

Koponen and Le Net (2021) elaborate a decision model which encompasses a limited set of factors that are decisive for investments in heating technologies, mainly on the **meso** and **microlevel**. These factors include performance regarding economic factors such as costs, investments, environment and climate such as CO2 emissions, technical performance and **social contributions**. **Uncertainty** regarding these performance indicators comes on top of these factors. Aside from that, findings show that companies base their decisions on individual factors (**microlevel**) such as **economic and technical performance** and the potential impact on competitiveness and **attractiveness for customers.** The importance of technical factors is underpinned by the statement that the **type of technology** that will be used for process heating, is strongly dependent on the process utilised (Fleiter et al. 2016). One study analysed drivers of urban climate mitigation plans (Reckien et al. 2015). It found that factors similar to those influencing households drive city administrations' climate ambitions, such as per **capita income, population size, capacity to adopt and adapt, memberships in networks**.

Decision-making in the **public sector** with respect to energy services has not yet been thoroughly investigated. In short decisions on energy investments or services account for **societal objectives and targets** such as equity, environmental and energy security at the **macro level**, while at the **micro level** each actor strives to meet his or her individual value system with regard to economic, environmental and technical performance and social concerns. At both levels, these characteristics could be ensured by formal measures such as support policies (incentives), and regulations and standards (**macro level**).

Table 13 provides an overview of the most relevant factors governing decisions of companies as well as public authorities regarding HP (identified in combination with other technologies as there is only limited literature available), using the classification defined.

**Table 13: Factors governing ES decisions with focus on HP for companies and the public sector**

| | Actor types | |
|---|---|---|
| | **Associations and companies** | **Policy-makers, authorities and communities** |
| **Macro level** | Global (market) structures, institutions, developments, e.g. possible greening of products:<br>• Market shares, (global) competitiveness<br>• Sustainable production as product criteria<br>• Environmental and social standards/compliance | Overarching short-term needs (crisis) and long-term values, structures and cultures:<br>• Social equity<br>• Environmental benefits |
| **Meso level** | (i) Energy system characteristics (technical, economic, institutional):<br>• Technical: infrastructure, available resources<br>• Market design (access)<br>• Institutional: administration, regulation<br>(ii) Energy consumption values of consumers and interests of consumers and other actors<br>• Comfort of people in building business sector<br>• Awareness of customers (social/environmental) | (i) Aspects of demand and supply of energy services:<br>• Energy supply security<br>• Infrastructure, resources<br>• Institutions: regulations<br>(ii) Energy literacy and culture of population and policy-makers:<br>• Institutional: market design, networks |
| **Micro level** | Company-specific constraints, opportunities and strategies:<br>• Economic: energy cost savings, investment volume, financial performance, uncertainty<br>• Technical (and economic) performance or parameters: energy intensity, functionality/reliability<br>• External/Market: customer attractiveness, exposure to competition,<br>• Internal factors: degree of innovation orientation, company size, company policy | (i) Public actors' characteristics:<br>• Expertise in ES, energy literacy<br>• Local networks<br>(i) Enabling factors in community:<br>• Socio-demographic factors<br>• Technical and economic factors and performance<br>• Uncertainty (risk aversion) |

The overview-tables (see Table 12, Table 13) and the described results of the exemplary studies show that factors governing the decisions concerning HP could be identified on all levels (i.e. macro, meso and micro) and for all actor groups, despite only a few studies being available.

#### 2.3.2.4 Factors governing decisions with a focus on all H&C technologies

With regard to H&C technologies all 130 studies could be included in the analysis. In this final section of the results discussion all relevant factors governing ES decisions in H&C technologies are presented.

**Individuals**

An overview of the factors influencing decisions on ES in the residential sector is given in Table 14. For individuals around 100 studies are available (see Section 1.3.1). Regarding the **macro level**, several studies provide a variety of factors (e.g. Büchele et al. 2018; Kotsch and McCoy 2016; Magdalinski et al. 2017). Most relevant factors on this level are factors of an institutional nature that foster the transition towards sustainable energy use, as well as factors that still promote non-sustainable energy use and thus hinder a transition towards sustainability (policies and measures like funding or support schemes for households as well as regulations and processes, like building codes, subsidies for fossil fuels, etc.). Factors on the **meso level**, i.e. characteristics of the energy system, are described e.g. in Pons-Seres de Brauwer et al. (2019), Steg et al. (2018) or Sovacool et al. (2021b). Factors discussed include (unconscious) energy behaviour and values/attitudes of the environment or community but also energy system-related factors like billing systems and pricing schemes. The **micro level**, i.e. individual factors of technologies and persons, include a variety of factors, such as individual comfort and ease, values, norms and attitudes, energy literacy or specific technical features of the system (and also specific features of buildings such as size or location of the building, insulation, refurbishment, age, etc.). Demographic factors, economic and environmental concerns and interests as well as behavioural aspects such as perceived risks, costs and preferences are investigated by many authors (e.g. Biresselioglu et al. 2017; Carrus et al. 2019; Masson et al. 2017) as well. This level also accounts for altruistic and self-centred interests. That is, an individual's well-being is not only a function of its direct and immediate satisfaction of needs (self-interest) but also includes the well-being of others, i.e. altruistic aspects.

**Companies and public sector**

Factors governing the decision of associations and companies with an economic interest as well as public actors with a public interest differ from the factors for individuals (mostly but not completely). For the two groups of actors 54 studies are available (see Section 1.3.1). Regarding the **macro level**, i.e. characteristics of society factors for companies identified in the literature are policy measures, like obligations or norms (e.g. in Gerganov and Galev 2018). For the public sector the macro level also includes policies addressing public authorities, but a stronger focus lies on public acceptance as well as public opinions and views (see e.g. Gölz and Wedderhoff 2018). Factors on the **meso level**, i.e. characteristics of systems for companies include infrastructures or institutions but also resources like capacities (see e.g. Cornelis 2020). For the public sector the focus lies more on the social environment, culture or responsibilities (see e.g. Magdalinski et al. 2017). On the **micro level**, i.e. characteristics of actors or technologies, factors for companies include among others corporate policy, competitive situation or company size (see e.g. Fleiter et al. 2016). For public actors labels and brands or front-runners and impact of leaders can be defined as relevant factors.

**Table 14: Factors governing ES decisions in H&C**

| | Individuals | Associations and companies | Public authorities |
|---|---|---|---|
| **Macro level** | Aspects not directly related to the energy system, i.e. overarching societal, social, economic, environmental, technical and institutional aspects:<br>• Institutional: e.g. price regulations, building codes, technology standards, regional planning, education and qualification standards, policy frameworks<br>• Communication of norms, economic and environmental aspects<br>• Societal: norms, practices, social acceptance, extent of materialism/post-materialism<br>• Coordination: coordination, consistency and coherence between policies, regulations, acts, activities, at national, regional and local level, etc.<br>• Long-term perspective, commitment and planning certainty | Global (market) structures, institutions, developments, perspectives, institutions:<br>• Market shares, (global) competitiveness<br>• Sustainable production as product criteria<br>• Environmental and social standards/compliance<br>• Security of supply<br>• Long-term perspective and commitment | Overarching short-term needs (crisis) and long-term values, structures and cultures:<br>• Social equity<br>• Environmental benefits<br>• Long-term commitment<br>• Public opinion and views<br>• History of political consensus<br>• Coordination of policies/strategy<br>• Acceptance of collective solutions (cultural heritage) |
| **Meso level** | (i) Energy system-related factors:<br>• Institutional: market structure (limited dependency), supplier issues and access, regulators and authorities, governance, clear responsibilities between service provider, owner, resident, grid operator (ascribed responsibilities), accountability and transparency of costs and benefits, pricing information (system)<br>• Technological: Availability and simple use of technology: IT (remote control, flexibility), capability and capacities of the energy system to integrate new technology<br>• Natural resources and local/system environment e.g. integration of (local) RE, population density and building stock, network and design; lending and financial market<br>• Service related: direct (and local) contact to technology and service providers (billing, metering, complaint, supply), transparency of services<br>• Costs and benefits<br>• Trust and rights: trust in markets, regulations etc., ensuring of rights, lock-in<br>(ii) Energy behaviour-related factors of the individuals' close environment:<br>• Community factors: cohesion, trust in community members, civil neighbourhood, commitment of members, practices and resistance of peers, recommendations, social interactions, participation in initiatives/networks<br>• Energy culture and socialisation: practices, routines of peers and neighbours, openness<br>• Communication and influencers: front-runner, leader, motivation of key stakeholders, brands, labels; marketing of DHC, experiences of others, attitudes of others | (i) Energy system characteristics (technical, economic, institutional):<br>• Technical: infrastructure, available resources, flexibility<br>• Market design (access and exit), prices (and control), competition, transparency, market power, switching costs<br>• Institutional: administration, regulation; political and institutional frameworks, rights and obligations, redress mechanisms<br>• Natural conditions and local environment<br>• Policy coherence, consistency and destruction policies for phasing-out, policy coordination and cooperation across all actors, coordinated urban/rural planning<br>• Service related: effective service<br>(ii) Energy consumption values and interests of consumers and other actors:<br>• Comfort of inhabitants for building business sector<br>• social/environmental awareness of customers<br>• Corporate policies<br>• Practice of others (sector/region)<br>• Cooperation maturity of different actors | (i) Aspects of demand and supply of energy services:<br>• Energy supply security<br>• Infrastructure, available local resources<br>• Institutions: regulations with respect to market design/access competition, authorities, rules, lock-in effects, networks<br>• Long-term stable energy policy and planning and commitment<br>• Widely supported local heat planning framework<br>• Legislative framework for municipality participation<br>(ii) Energy literacy and culture of population and policy-makers:<br>• Perceived trust and fairness by citizens<br>• Social conventions |

| | Individuals | Associations and companies | Public authorities |
|---|---|---|---|
| | • Social norms: values, beliefs, openness to changes | • Alignment of interest of different actors; having a say | |
| **Micro level** | Individual constraints, opportunities and preferences with respect to individual well-being:<br>(i) Satisfaction: indoor climate/comfort, quality of heating, service of supplier (repair), transparency of pricing, flexibility, protection, sustainability (CO2)<br>(ii) Decisions:<br>• Economic: prices, investment level, operational and maintenance expenditures, price risks/volatility, market value of building, energy expenditure savings, uncertainty of savings and revenues<br>• Environmental concerns: local pollution concerns, awareness, climate change, clean energy uses (pollutant), connectedness to nature,<br>• Technical: progressive, simple, high safety, convenient, reliable, automatisation degree, quality performance, interruptions,<br>• Behavioural: reliability/security of heat provision, risk aversion, openness to changes, innovation orientation, want to try out new heating technology, presence bias, satisfaction with current system, current practices/habits/routines, one-time behaviour,<br>• Socio-economic-demographic: income, age, ownership, education, size of household, age, gender, whether person is an immigrant, country, time spent inside<br>• Building: type, location, age, efficiency performance, size, occupation level,<br>• Social values of individuals: energy poverty, access to energy, affordability<br>• Social needs: acknowledgement and status symbol, independency and autonomy, control of system, helplessness<br>• Effort-related: effort/work to replace system, effort to understand technology/ease of use and convenience of heating system, comfort and efforts to adopt or refurbish, time to go through administrative processes, access to technology and fuels and services, effort for maintenance, short-term vs long-term changes<br>• Energy literacy: awareness, use of system, management of system, heating knowledge<br>• Individual features: openness, experiences with technology, awareness, interest in technology, knowledge/skills and experience, feedback on energy consumption, decision heuristics and strategies, attachment to location/place, attitudes | Company-specific constraints, opportunities and strategies:<br>• Economic: energy prices, energy cost savings, investment volume, financial performance, uncertainty of energy savings and revenues, return, payback, environmental calculations, financial attractiveness (opportunity costs)<br>• Technical (and economic) performance or parameters: energy intensity, functionality/reliability, flexibility, prosumage, available energy sources, comfort and ease issues<br>• External/Market: customer attractiveness, exposure to competition,<br>• Internal factors: degree of innovation orientation, company size, company policy, business strategy (and objectives) and models, commitment<br>• Capabilities and capacity: long-term decisions, financial capacity, organisational and competence issue, time issues, lack of awareness and other priorities, expertise and information and evaluations<br>• Dependency issues (long-term contracts) in combination with uncertainty regarding costs, prices, energy demand, lock-in and risks | (i) Public actors' characteristics:<br>• Expertise in ES, energy literacy<br>• Local networks<br>• Project development expertise/experience<br>(ii) Enabling factors in community:<br>• Socio-demographic factors: per capita income, vulnerability of households, expected energy saving behaviour, local environment and location<br>• Technical and economic factors and performance<br>• Uncertainty (risk aversion) concerning future prices, costs, etc.<br>• Expected costs and benefits (risks)<br>• Local initiatives/leading group or actor |

As Table 14 shows, there are a variety of factors, which have been investigated in many studies. It should be noted that different methods were used (e.g. meta-studies, surveys, experiments, etc.; see also Section 1.3.1) and therefore no conclusion about the significance of single factors is drawn. Nevertheless, this section provides an overview of the most relevant factors influencing the decision-making process in renewable and energy efficient H&C technologies.

## 2.4 Conclusion and research framework

In this last section of the report, we reflect on the results from the meta-study and provide **final conclusions.** In addition, we point out **knowledge gaps** identified and indicate further needs in research to better understand the decisions in H&C. In doing so we place a special focus on DHC and HP by comparing factors governing decision-making for energy investments and services (ES) with regard to DHC and HP and H&C in general.

Generally speaking, according to the literature reviewed, perceived challenges and concerns regarding the further deployment of **DHC are more complex than for HP**. This is reflected by the issues raised in the literature such as market power, free market entry and switching of suppliers, competition issues as well as appropriate and transparent pricing schemes and billing services for DHC services in several countries. In contrast, no study linked the use of HP to helplessness and dependency on energy suppliers. Concerning HP, understanding the technologies seems to be more of an issue. A special characteristic of DHC is the potential excessive use of market power, which is framed by institutional settings and regulations. These institutional settings were established to ensure market transparency, competition and consumer rights. At the same time, different approaches towards regulations addressing these settings can be observed in various European countries, ranging from more market-oriented regulations to stricter, more obligation or rule-based, requirements. Subsequently, an analysis of the interrelation between institutional settings and the extent of perceived market power and dependency could reveal how well these settings contribute to a positive perception of DHC with respect to exertion of market power. This issue – how DHC is perceived - can be addressed in interviews and surveys within this study, while additional data collected in the framework of other projects[5] completes the information needed to reflect on the link between regulations and perception.

The target sector most focussed on in the literature has been the residential sector although industries are key consumers of heat services. Reasons for this could be i) the difficulties of researchers **gaining access to information in industries** on decisions and strategies and, thus, collect the respective information and ii) the low willingness of industrial actors to spend time sharing information without receiving a benefit from their perspective. Moreover, the decision processes and factors governing ES decisions in the **public sector** are also not well examined. The public sector seems to be of less importance with respect to energy consumption but could take a **leading role or front-runner position in the energy transition of communities** as it is supposed to act primarily in the interest of society. This potential role of the public sector is also addressed in several policy measures indicating that the public sector has a role model function (e.g. specific standards for public buildings in several countries). We suggest delving a bit deeper into these two issues in interviews and case studies.

These are the main messages across all three sectors:

- **Long-term commitment and planning security** is key when deciding to implement DHC, but less crucial for the adoption of HP systems.
- **Institutional frameworks** ensuring clarity of and compliance with pricing rules, access to information, restriction of market power and transparency of markets are preconditions for DHC and are less important for HP adoption.

[5] District Heating and Cooling in the European Union- Overview of Markets and Regulatory Frameworks under the Revised Renewable Energy Directive

- **Social and ecological (energy) values, attitudes, trust in institutions, culture and practices of peers**, citizens, community members and customers are major and undisputed factors affecting ES decisions in all sectors and across all technologies.
- **Local environment and conditions** such as availability of local natural resources, building stock, financial capacities and socio-demographic aspects are preconditions for using certain H&C technologies.
- **Energy literacy and** technical and managerial **expertise,** are considered important drivers, especially for HP and RES-H&C technologies.
- **Coordination of actions, policies across all actors, institutions and levels** as well as willingness to cooperate is mandatory for the successful expansion of DHC.

There are also very sector/actor-specific factors that have a significant impact on ES decisions. In the **industrial sector** the increasing awareness and preferences of consumers for **socially fair and environmentally clean production has added new product and company-specific characteristics**, which companies strive to meet in order to gain or keep market shares. Furthermore, in the industrial sector the competitive use of scarce resources (time, capacities) does not favour environmentally friendly investments if the forgone profit of an alternative investment is not compensated for, and other **investment priorities** exist. This calls for framework conditions that reverse investment priorities, force different industries to account for social and environmental issues (costs and benefits) and promote sustainable production.

In the **public sector** a lot of initiatives and activities are ongoing, mainly through municipal utility providers and climate initiatives at regional levels. However, studies elucidating the **formation process and initial development** phase (interplay of structures, contents and processes) as well as the driving forces and key factors of successful RE deployment in heating and beyond do not exist.

In contrast to the public and industrial sector, many authors have thoroughly investigated the **residential sector** from different perspectives. Various drivers and barriers are listed in Table 14 and they all can take on a significant role in the ES decisions. Furthermore, they are linked to each other. For example, the social needs of an individual (status symbol) depend on the value set of the peers and society, environmental concerns are shaped by access to information, its processing and evaluation, which in turn depends on perceptions and acquired qualifications, etc. As opposed to the case of companies, the decision process of individuals is not triggered by profit orientation alone but by the **search/striving for well-being** that is contingent on self-centred interests (desires) and altruistic aspects, on both monetary and non-monetary effects. Thus, external aspects influence an individual's decision in two ways: 1) through the orientation and adaptation of value sets and attitudes and practices prevailing in society and 2) through the valuation of altruism, i.e. whether the well-being of others makes the individuals feel good and thus increases the individual's well-being as well. This complexity is approached by different models, but not yet completely understood.

In only a few papers, the **additional effort** or work needed to adopt a new heating technology has been mentioned as a potential barrier. Although the additional effort is not specified in detail, the term transaction costs is well known. It covers several aspects such as searching for, collecting and processing information, administrative procedures and networking of actors (e.g. membership in initiatives, associations). Beyond transaction costs, additional costs could arise due to cleaning and rearranging needs after craftsmen/builders have installed the new technologies. This "effort" issue is mentioned in a few papers, but its extent and diversity and complexity is not yet well investigated. This could be further elaborated on in interviews and its extent could be assessed via surveys.

Overall, we collected and classified factors governing ES decisions by levels (macro, meso and micro) and actors (sector), identified sector/actor-specific issues or topics that could be further investigated, but also perceptions and factors that apply across all sectors at different levels. Further we learnt, that the factors at the different levels interact, just as the sectors do (role model function, B2C's influence). Given this variety and multitude of factors and perceptions, the challenge is to understand which factors

are more relevant than others, and under which conditions. This is a challenging question which we will not be able to fully answer. We will start approaching it in task 2.

Table 15 summarises the research gaps and how they could be approached, which actor is addressed and under which tasks of the project.

**Table 15: Identified research gaps**

| **Identified research gaps** | | **Actor** | **Task** |
|---|---|---|---|
| ***Topic*** | ***Potential approach*** | | |
| Type of transaction costs of adoption and extent | Interviews (to identify types of transactions) | Companies | 2.2 |
| | Literature review (types of transactions)<br>Survey (extent of efforts ) | Individuals | 2.1 |
| **Relationship between perceived exposure to market power and institutional settings in DHC** | Survey and econometrics | Individuals | (2.1) |
| | Literature review | Individuals/companies/public | (3) |
| **Decision process in public and industrial sectors (impact of external and internal factors)** | Case study | Companies/public | (2.2) |
| **Information regarding investment priorities in companies** | Interviews | Companies | (2.2) |
| Relevance of factors at the different levels: magnitude and weights | Survey (magnitude the factors take) | Individuals companies/ public | 2.1<br>2.2 |

Note: ( ) means these gaps are not focused on and explicitly addressed in these tasks, but some information could be collected. **Bold:** these topics will be addressed in this study. Magnitude means the size of (each) the factor e.g. high or low additional costs, strong or weak contribution to decarbonisation, etc.. Weight: reflects the priority or ranking of the factor, i.e. how important this factor is compared to other factors.

We have identified **research or knowledge gaps**, i.e. areas or questions that are not yet answered or fully understood. We have suggested how to approach some of the open questions in the further course of the project. A topic we want to address is the question of how to assess the relevance of these factors identified with respect to their influence on ES decisions. To approach this question, we apply an analytical concept explaining the interrelations and interplay between the factors (see Figure 4).

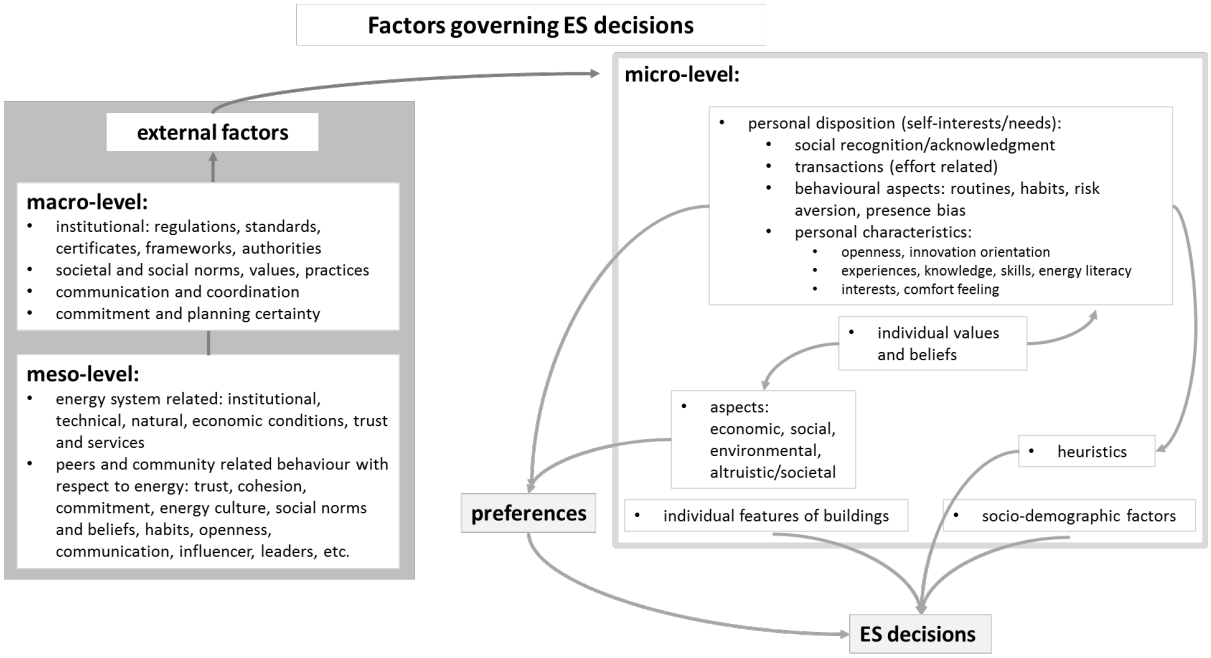
The factors in our meta-study are grouped into contextual factors at the macro and meso level, and individual factors at the micro level. While **the macro level** comprises the overarching framework (social order, rules and economic system) under which actions take place, the **meso level** relates to the energy system and the community or peers with respect to their energy behaviour or culture. Both levels together represent the contextual, **external factors** that have an influence on individuals at the **micro level.** The micro level comprises different factors governing decisions: values, personal disposition and well-being as well as the energy-related, socio-economic-demographic situation of individuals, and building features. How an individual decides regarding ES depends on the weights that these different factors are given, and on their magnitude (extent). This means some factors, for example environmental aspects are assigned a larger weight than the personal disposition for risk aversion. On the other hand, the, magnitude or extent stresses how strong or weak this risk aversion is. Similarly, economic aspects can take different magnitudes e.g. high costs (0.5 Euro/kWh) or low costs (0.01 Euro/kWh). The weight stands for the importance or relevance the person attributes to this factor compared to other aspects such as social or environmental aspects. This means to obtain an idea about the potential relevance of a factor, we have to know the magnitude of the factors and their respective weights (i.e. personal relevance).

In Figure 4 preferences are depicted as the results of the respective weights of personal dispositions, as well as social, economic, societal and environmental aspects. The weights are influenced by individual

values, beliefs and norms[6], which in turn are affected by external factors. In addition to the weights, as illustrated in Figure 4, the magnitude of the factors (e.g. of personal dispositions: risk aversion, building features: insulation, socio-economic: income level, demographic factors: number of persons per household) affect ES decisions.

As a consequence of this analytical concept, three steps are required to identify the main factors governing ES decisions and contributing to a decarbonisation of the H&C sector: i) assess magnitude of the different factors; ii) assess attributed (personal) weights and the relevance of the factors; iii) identify potential measures to address the relevant factors.

In task 2 we conduct a survey among households as well as a non-representative survey combined with interviews in the industrial and public sectors. In this survey, we take up the selected factors identified in this meta-analysis. Assessing the (personal) weights and identifying measures is beyond the scope of this study. However, we will look into the different types of efforts or transactions (costs) and assess their magnitude. All other knowledge gaps identified (see Table 15) are either beyond the scope of this study, e.g. the interrelation between regulation and perception in DHC, or are addressed less comprehensively in additional approaches that are also beyond the proposed study outline.




Note: Heuristics is highlighted as it plays a key role in many decisions, but it is based on experiences, patterns and different logics and are part of behavioural aspects.

Figure 4: Interplay of the different factors

[6] Can also be the result of bounded rationality and uncertainty.

# 3 List of figures

# 4 List of tables

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Zaunbrecher, Barbara S.; Arning, Katrin; Falke, Tobias; Ziefle, Martina (2016): No pipes in my backyard? Preferences for local district heating network design in Germany. In Energy Research & Social Science 14, pp. 90–101. DOI: 10.1016/j.erss.2016.01.008.

## A.2 Deliverable D1.1: Database of publications

See Excel file H&C-Perception_Task_1_Database_Literature

## A.3 List of literature


| No. | Author | Year | Title |
|---|---|---|---|
| 1 | Achtnicht | 2011 | Do environmental benefits matter? Evidence from a choice experiment among house owners in Germany |
| 2 | Biresselioglu et al. | 2017 | Social Science Perspectives on Electric Mobility, Smart Energy Technologies, and Energy Use in Buildings – A comprehensive Literature Review. Report No ECHOES 3.1 |
| 3 | Biresselioglu et al. | 2018 | Examining the barriers and motivators affecting European decision-makers in the development of smart and green energy technologies |
| 4 | Bjørnstad | 2012 | Diffusion of renewable heating technologies in households. Experiences from the Norwegian Household Subsidy Programme |
| 5 | Boeri, Longo | 2017 | The importance of regret minimization in the choice for renewable energy programmes: Evidence from a discrete choice experiment |
| 6 | Braun | 2010 | Determinants of households' space heating type: A discrete choice analysis for German households |
| 7 | Büchele et al. | 2018 | What is the impact of the policy framework on the future of district heating in Eastern European countries? The case of Brasov |
| 8 | Burlinson et al. | 2018 | Technology adoption, consumer inattention and heuristic decision-making: Evidence from a UK district heating scheme |
| 9 | Carrus et al. | 2019 | Psychological factors in Energy Decisions - results from experimental studies and a multinational survey. Report No ECHOES D4.2 |
| 10 | Carrus et al. | 2019 | Analysis of Enabling Factors for Consumer Action. Report No ECHOES 5.3 |
| 11 | Chassein et al. | 2017 | Using Renewable Energy for Heating and Cooling: Barriers and Drivers at Local Level. An analysis based on a literature review and empirical results from local case studies |
| 12 | Collier | 2018 | Renewable heat policies. Delivering clean heat solutions for the energy transition |
| 13 | Correia et al. | 2019 | Proposal for SSH oriented indicators to support policy-making for clean energy transition in EU. Report No ECHOES 2.3 |
| 14 | Decker et al. | 2015 | House owners' perceptions and factors influencing their choice of specific heating systems in Germany |
| 15 | Dharshing et al. | 2017 | The Energy Paradox Revisited: Analysing the Role of Individual Differences and Framing Effects in Information Perception |
| 16 | Gerganov, Galev | 2018 | Final report on comparative sociological analysis of the business enterprises' survey. Report D3.1 |
| 17 | Gerganov et al. | 2019 | Report on economic factors impacting individual short-term energy choices. Report D3.4 |
| 18 | Hafner et al. | 2019 | Exploring the role of normative, financial and environmental information in promoting uptake of energy efficient technologies |
| 19 | Hansen et al. | 2019 | Cost efficiency of district heating for low energy buildings of the future |
| 20 | Hodges et al. | 2018 | Qualitative Research with consumers and operators of heat networks |
| 21 | Iturriza et al. | 2019 | Collective energy practices in Europe. Report No ECHOES 5.4 |
| 22 | Karytsas et al. | 2019 | Factors affecting willingness to adopt and willingness to pay for a residential hybrid system that provides heating/cooling and domestic hot water |
| 23 | Karytsas, Theodoropoulou, | 2014 | Public awareness and willingness to adopt ground source heat pumps for domestic heating and cooling |
| 24 | Kotsch, McCoy | 2018 | Report on the drivers of household adoption of energy-saving technologies using the English Housing Survey. Report D3.2 |
| 25 | Lettmayer et al. | 2018 | The impact of "Energy memories" on Energy Cultures and energy consumption patterns. Report No ECHOES D5.2 |
| 26 | Lillemo et al. | 2013 | Households' heating investments: The effect of motives and attitudes on choice of equipment |
| 27 | Lillemo, Halvorsen, | 2013 | The impact of lifestyle and attitudes on residential firewood demand in Norway |

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| 28 | Lowes, Woodman | 2020 | Disruptive and uncertain: Policy makers' perceptions on UK heat decarbonisation |
| 29 | Magdalinski et al. | 2017 | Final comprehensive literature review setting the scene for the entire study. Report D2.2. |
| 30 | Magdalinski et al. | 2018 | Report on the impact of energy prices and other policies on energy-saving innovation and technology adoption in the manufacturing sector based on French company data. Report D3.3 |
| 31 | Mahapatra, Gustavsson | 2010 | Adoption of innovative heating systems—needs and attitudes of Swedish homeowners |
| 32 | Mahapatra, Gustavsson, | 2009 | Influencing Swedish homeowners to adopt district heating system |
| 33 | Masson et al. | 2017 | Identity processes and individual factors in Energy Decisions: Two comprehensive Meta-Analyses. Report No ECHOES 4.1 |
| 34 | Michelsen, Madlener, | 2012 | Homeowners' preferences for adopting innovative residential heating systems: A discrete choice analysis for Germany |
| 35 | Michelsen, Madlener | 2013 | Motivational factors influencing the homeowners' decisions between residential heating systems: An empirical analysis for Germany |
| 36 | Mills, Schleich | 2009 | Profits or preferences? Assessing the adoption of residential solar thermal technologies |
| 37 | Noblet et al. | 2015 | Public preferences for investments in renewable energy production and energy efficiency |
| 38 | Ortega-Izquierdo et al. | 2019 | Analysis of the decision making factors for heating and cooling systems in Spanish households |
| 39 | Pons-Seres de Brauwer et al. | 2019 | Building consensus for a citizen-driven Energy Union: understanding energy choice dynamics and their impact on energy governance in the EU. Report No ECHOES 7.1 – D7.1 Knowledge Consolidation. |
| 40 | Rao et al. | 2017 | Governance Models and Strategic Decision-Making Processes for Deploying Thermal Grids |
| 41 | Rochefort, Hanaé Chauvaud de | 2018 | Market Report: Heat Networks in the UK |
| 42 | Rogge, Dütschke | 2018 | What makes them believe in the low-carbon energy transition? |
| 43 | Rouvinen, Matero | 2013 | Stated preferences of Finnish private homeowners for residential heating systems: A discrete choice experiment |
| 44 | Salm, Sarah | 2018 | The investor-specific price of renewable energy project risk – A choice experiment with incumbent utilities and institutional investors |
| 45 | Scarpa, Willis | 2010 | Willingness-to-pay for renewable energy: Primary and discretionary choice of British households' for micro-generation technologies |
| 46 | Schwarzinger et al. | 2019 | Comparative Assessment of European Energy Lifestyles. Report No ECHOES 5.1 |
| 47 | Selvakkumaran et al. | 2019 | Determining the factors of household energy transitions: A multi-domain study |
| 48 | Semikolenova et al. | 2012 | Modernization of the District Heating Systems in Ukraine: Heat Metering and Consumption-Based Billing |
| 49 | Skjevrak et al. | 2012 | Wood-Pellet Heating in Norway: Early Adopters' Satisfaction and Problems That Have Been Experienced |
| 50 | Sopha, Klöckner | 2011 | Psychological factors in the diffusion of sustainable technology: A study of Norwegian households' adoption of wood pellet heating |
| 51 | Sopha et al. | 2011 | Adopters and non-adopters of wood pellet heating in Norwegian households |
| 52 | Sopha et al. | 2013 | Adoption and diffusion of heating systems in Norway: Coupling agent-based modelling with empirical research |
| 53 | Sopha et al. | 2010 | Norwegian households' perception of wood pellet stove compared to air-to-air heat pump and electric heating |
| 54 | Streimikiene et al. | 2019 | A Review of Willingness to Pay Studies for Climate Change Mitigation in the Energy Sector |
| 55 | Thornton et al. | 2017 | Heat networks consumer survey |

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| 56 | Wang et al. | 2009 | Review on multi-criteria decision analysis aid in sustainable energy decision-making |
| 57 | Wilson, et al. | 2015 | Why do homeowners renovate energy efficiently? Contrasting perspectives and implications for policy |
| 58 | Woersdorfer et al. | 2011 | Will nonowners follow pioneer consumers in the adoption of solar thermal systems? Empirical evidence for north-western Germany |
| 59 | Yoon et al. | 2015 | Individual Heating systems vs. District Heating systems: What will consumers pay for convenience? |
| 60 | Ambrosio-Albalá et al. | 2019 | Purely ornamental? Public perceptions of distributed energy storage |
| 61 | Ariztia et al. | 2019 | Heating ecologies: Resituating stocking and maintenance in domestic heating |
| 62 | Azizi et al. | 2019 | Analysing the house-owners' perceptions on benefits and barriers of energy renovation in Swedish single-family houses |
| 63 | Balta-Ozkan, Le Gallo | 2018 | Spatial variation in energy attitudes and perceptions: Evidence from Europe |
| 64 | Brange et al. | 2016 | Prosumers in district heating networks – A Swedish case study |
| 65 | Cui et al. | 2017 | Exploring the factors and motivations influencing heating behavioral patterns and future energy use intentions in the hot summer and cold winter climate zone of China |
| 66 | Ediger et al. | 2018 | Turkish public preferences for energy |
| 67 | Graff et al. | 2018 | Stakeholder perceptions of the United States energy transition: Local-level dynamics and community |
| 68 | Selvakkumaran, Ahlgren | 2018 | Determining the factors of household energy transitions: A multi-domain study |
| 69 | Schlüter et al. | 2017 | A framework for mapping and comparing behavioural theories in models of social-ecological systems |
| 70 | Venkatachalam, L. | 2008 | Behavioral economics for environmental policy |
| 71 | Steg et al. | 2018 | What Drives Energy Consumers?: Engaging People in a Sustainable Energy Transition |
| 72 | Grimm et al. | 2020 | Green innovations: The organizational setup of pilot projects and its influence on consumer perceptions |
| 73 | Hille et al. | 2019 | Consumers' preferences for electricity-saving programs: Evidence from a choice-based conjoint study |
| 74 | Jansma et al. | 2020 | Kissing natural gas goodbye? Homeowner versus tenant perceptions of the transition towards sustainable heat in the Netherlands |
| 75 | Jingchao et al. | 2018 | Public acceptance of environmentally friendly heating in Beijing: A case of a low temperature air source heat pump |
| 76 | Jones et al. | 2016 | Space heating preferences in UK social housing: A socio-technical household survey combined with building audits |
| 77 | Gölz et al. | 2018 | Explaining regional acceptance of the German energy transition by including trust in stakeholders and perception of fairness as socio-institutional factors |
| 78 | Hecher et al. | 2017 | The Trigger Matters: The Decision-Making Process for Heating Systems in the Residential Building Sector |
| 79 | Ruokamo, Enni | 2016 | Household Preference of Hybrid Home Heating Systems - A Choice Experiment Application |
| 80 | Zheng et al. | 2020 | A literature review of energy flexibility in district heating with a survey of the stakeholders participation |
| 81 | Ford et al. | 2016 | Evaluating Energy Culture: Identify and validating measures for behaviour-based energy interventions |
| 82 | Karlin et al. | 2013 | Beyond kWh: A New Tool for Assessing Behaviour-Based Energy Interventions |
| 83 | Zaunbrecher et al. | 2016 | No pipes in my backyard? Preferences for local district heating network design in Germany |
| 84 | van den Broek, et al. | 2019 | Exploring the perceptions of drivers of energy behaviour |

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| 85 | Michelsen et al. | 2016 | Switching from fossil fuel to renewables in residential heating systems: An empirical study of homeowners' decisions in Germany |
| 86 | Reckien et al. | 2015 | The Influence of Drivers and Barriers on Urban Adaption on Mitigation Plans - An Empirical Analysis of European Cities |
| 87 | Karytsas et al. | 2017 | Barriers against and actions towards renewable energy technologies diffusion: A Principal Component Analysis for residential ground source heat pump (GSHP) systems |
| 88 | Fleiter et al. | 2017 | Mapping and analyses of current and future (2020-2030) heating/cooling fuel deployment (fossil/renewables) |
| 89 | Antimononpoly Office of the Slovak Republic | 2013 | Functioning of heat energy sector in Slovakia focusing on DH systems from the AMO point of view |
| 90 | Bouw | 2016 | Increasing the attractiveness of district heating networks to consumers |
| 91 | Donnellan et al. | 2018 | Lessons from European regulation and practice for Scottish district heating regulation |
| 92 | Ericsson | 2009 | Introduction and development of the Swedish district heating systems |
| 93 | Kohopää | 2019 | Opportunities and challenges of opening the district heating networks – How to heat the future home? |
| 94 | Esposito | 2014 | The Italian Competition Authority and District Heating Sector |
| 95 | Galindo et al. | 2016 | Efficient district heating and cooling systems in the EU |
| 96 | Public Utilities Commission | 2018 | The Public Utilities Commission's Annual Report 2018 |
| 97 | Greater London Authority | 2018 | Communal Heating Consumer Survey |
| 98 | Marketmind | 2019 | Fernwärme Imagestudie 2019 |
| 99 | Reykjavík Energy | 2020 | Annual Report 2019 - Society |
| 100 | BDEW | 2019 | Wie heizt Deutschland 2019? |
| 101 | Aronsson, Hellmer | 2009 | An International Comparison of District Heating Markets |
| 102 | Valeri et al. | 2016 | Modelling individual preferences for environmental policy drivers: Empirical evidence of Italian lifestyle changes using a latent class approach |
| 103 | Werner | 2017 | District heating and cooling in Sweden |
| 104 | Rebosio et al. | 2015 | Adapting to higher energy cost: Findings from qualitative studies in Europe and Central Asia |
| 105 | Lund, Henrik et al. | 2018 | The status of 4th generation district heating: Research and results |
| 106 | Cardoso et al. | 2020 | Making demand side response happen: A review of barriers in commercial and public organisations |
| 107 | Skytte et al. | 2016 | Regulatory barriers for flexible coupling of the Nordic power and district heating markets |
| 108 | Sayegh et al. | 2017 | Trends of European research and development in district heating technologies |
| 109 | Santos et al. | 2016 | Cogeneration and district heating networks: Measures to remove institutional and financial barriers that restrict their joint use in the EU-28 |
| 110 | Chittum et al. | 2014 | How Danish communal heat planning empowers municipalities and benefits individual consumers |
| 111 | Meyer et al. | 2014 | Barriers and Potential Solutions for Energy Renovation of Buildings in Denmark |
| 112 | Krikser et al. | 2020 | Willingness-to-Pay for District Heating from Renewables of Private Households in Germany |
| 113 | Cornelis | 2020 | Shaping a Sustainable Industry. Guidance for Best Practice & Policy Recommendations |
| 114 | Tu et al. | 2021 | The heat is off! The role of technology attributes and individual attitudes in the diffusion of Smart thermostats - findings from a multi-country survey |
| 115 | Sovacoo et al. | 2021 | Beyond climate, culture and comfort in European preferences for sustainable heat |
| 116 | Sovacool et al. | 2021 | Decarbonizing household heating: Reviewing demographics, geography and low-carbon practices and preferences in five European countries |

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| 117 | Chen | 2021 | District or distributed space heating in rural residential sector? Empirical evidence from a discrete choice experiment in South China |
| 118 | Koponen, Le Net | 2021 | Towards robust renewable energy investment decisions at the territorial level |
| 119 | Franceschinis et al. | 2017 | Adoption of renewable heating systems: An empirical test of the diffusion of innovation theory |
| 120 | Geels, Johnson | 2018 | Towards a modular and temporal understanding of system diffusion: Adoption models and socio-technical theories applied to Austrian bio-mass-district-heating (1979–2013) |
| 121 | Department of Energy & Climate Change | 2015 | Research to Assess the Barriers and Drivers to Energy Efficiency in Small and Medium Sized Enterprises |
| 122 | Wolf et al. | 2012 | Industrial heat pumps in Germany: Potentials, technological development and market barriers |
| 123 | Trianni et al. | 2016 | Barriers, drivers and decision-making process for industrial energy efficiency: A broad study among manufacturing small and medium-sized enterprises. |
| 124 | Cagno et al. | 2013 | A novel approach for barriers to industrial energy efficiency. |
| 125 | Cagno et al.A. | 2014 | Evaluating the barriers to specific industrial energy efficiency measures: an exploratory study in small and medium-sized enterprises. |
| 126 | Seetharaman et al. | 2019 | Breaking barriers in deployment of renewable energy. |
| 127 | Engelken et al. | 2016 | Comparing drivers, barriers, and opportunities of business models for renewable energies: A review. |
| 128 | Abeelen | 2019 | Implementation of energy efficiency projects by Dutch industry |
| 129 | Iten et al. | 2017 | Management as a Key Driver of Energy Performance |
| 130 | Ipsos | 2019 | Baromètre de notorieté du chauffage par reseaux de chaleur vague 3 2019 - Ad-Hoc Online |

# A.4 Table used for the literature review

| No. | Relevance | Author | Year | Title | Type | Project | Publisher | Journal | Main topic | Data sources | Type of data | Link or info to data | Model | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | Discussed models of analysis or behaviour | Derived model |
| | 0: one topic (e.g. RES-H&C)<br>1: RES-H&C + Actors + Drivers<br>2: RES-H&C + Actors<br>3: RES-H&C + Drivers<br>4: Actors + Drivers | Free Text | Free Text | Free Text | List | Free text | Free text | Free text | Free text, short | List:<br>primary<br>secondary<br>mixed | List:<br>qualitative<br>quantitative<br>mixe | Free text | Free text, best selection:<br>SIA: Social Identity Approach<br>TPB: Theory of planned behaviour<br>NAT: Norm activation theory<br>VBN: Value belief norm theory | Free text, best selection:<br>CADM: Compreshensive Action Determination Model<br>SIMPEA: Social Identity model of pro environmental action |

| Method | | | | | | | | Technologies | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Publications | Modelling | Experiments | Surveys | Cases | Analytical-qualitative | Analytical - quantitative | Other | HP | DHC | RES-H&C | H&C | Other |
| Free text, best selection:<br>literature analysis (as part of the paper),<br>literature review / meta-study,<br>document analysis, | Free text, best selection:<br>agent-based,<br>optimisation,<br>simulation,<br>other modelling | Free text, best selection:<br>choice experiment,<br>user experiment,<br>framing experiment, | Free text, best selection:<br>interviews,<br>focus groups,<br>survey, | Free text, best selection:<br>case studies,<br>energy audits | Free text, best selection:<br>qualitative analysis,<br>principal component analysis, | Free text, best selection:<br>quantitative analysis,<br>statistical analysis,<br>comparisons,<br>clustering, | Free text | Free text, best selection:<br>HP | Free text, best selection:<br>DH, DHC | Free text, best selection:<br>RES-H&C,<br>solar thermal,<br>biomass | Free text, best selection:<br>H&C,<br>heating technologies,<br>hybrid system offering H&C,<br>innovative heating systems, | Free text |

| Actors or target group | | | | Sector | | | | | | Geography | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Individuals (self-interest) | Associations and companies (economic interest) | Policy-makers, authorities and communities (public interest) | Other or additional info | Residential | Services | Industrial | Transport | Public | Other | Country 1 | Country 2 | Country 3 | Country 4 | Country 5 | Country 6 | Country 7 | Country 8 | Country 9 | Country 10 | Country 11 | Countries not within the scope (not EU, UK, Norway, | State, federal state or city |
| Free text, best selection:<br>homeowners,<br>households,<br>DHC residents,<br>tenant, | Free text, best selection:<br>companies,<br>operators,<br>services,<br>investors | Free text, best selection:<br>policy makers,<br>public authorities,<br>communities,<br>countries, | Free text | x | x | x | x | x | Free text | Free text | Free text | Free text | Free text | Free text | Free text | Free text | Free text | Free text | Free text | Free text | Free text | Free text |

| Brief description | Results | Factors or elements governing energy decisions | Preferences | Perception (percieved characteristics) | Drivers | Barriers | Link or DOI | Comments or other apects |
|---|---|---|---|---|---|---|---|---|
| Free text | Free text | Free text, list elements | Free text, list elements | Free text, list elements | Free text, list elements | Free text, list elements | Free text | Free text |