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OVERVIEW OF HEATING AND COOLING

PERCEPTIONS, MARKETS AND REGULATORY FRAMEWORKS FOR DECARBONISATION

Deliverable 4: European end user costs for providing heating and cooling with heat pumps and district heating (Task 4)

Evaluation of the total cost of ownership for providing space heating and cooling as well as domestic hot water using different heat pump technologies and district heating for typical residential end users in EU27, UK, Iceland, Switzerland, and Norway

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Content

1 Executive Summary

This report was created within the project "*Overview of Heating and Cooling: Perceptions, Markets and Regulatory Frameworks for Decarbonisation.*" The focus of this report is on the evaluation of the final cost for owning and operating district heating (DH) connections and heat pumps (HPs) for preparing space heating and space cooling as well as domestic hot water (DHW) from an end user's perspective. This analysis was conducted for different typical residential consumers in the individual Member States of EU27, UK, Norway, Switzerland, and Iceland.

Due to the fact, that not all the necessary data is available for all countries, clusters of similar countries were selected to fill in missing data (North, West, South, Central and East). Further on, since the cost for heating and cooling is influenced by the characteristics of the building and the behaviour of the consumer (end user), "typical customers" have been developed for each cluster as well as an "European typical customer". Each typical customer is described by seven properties (building density, dwelling type, construction period, renovation status, household size and tenure status). The methodology in principle considers following technologies and technology combinations for providing space heating, domestic hot water (DHW) and space cooling:

<table>
<tr><td colspan="3">Main heat supply technology:
Heat pump (HP)</td><td colspan="3">Main heat supply technology:
District heating (DH)</td></tr>
<tr><td>Heating</td><td>Domestic hot water (DHW)</td><td>Cooling</td><td>Heating</td><td>Domestic hot water (DHW)</td><td>Cooling</td></tr>
<tr><td colspan="3">**Air/Air**
Air/Water
Ground/ Water</td><td colspan="2">**Direct substation**
Indirect substation</td><td>**Air/Air Heat pump**</td></tr>
</table>

Here,

- Air/Air HPs can be used for heating and cooling, but they cannot be used to supply DHW. In turn, an electric boiler for the supply with DHW is considered.
- Ground/Water HPs can be used for free cooling by circulating the fluid through the collectors.
- For DH, cooling is always produced using Air/Air HPs, since district cooling is normally not available to end users. Also, in some cities, DH is turned off during summer times. In turn, an optional electric boiler for the supply with DHW can be considered.

Within this report, the **annualised total cost of ownership** is considered as the main indicator for estimating the end users' costs for H&C services (excluding recycling and subsidies), since it allows the fairest comparison between the different technologies. It considers the total annualised capex and the total opex together with the value added tax. Possible subsidies are not included in the investigation, since a country-specific investigation was beyond the resources of the underlying project.

For HPs, DH substations and electric boilers, the **total annualised capex** is based on the cost of the equipment and the installation costs. For DH, the costs for connecting the building to the DH network are included. Those costs depend on the installed capacity, that is calculated based on the heating and/or cooling load of the individual buildings. In all cases, the lifetime of the device, the country-specific interest rate as well as a labour factor is considered.

The **total opex** consist of the fixed operation and maintenance expenses and the opex of the HP, DH substation, or electric boiler. The latter depends mainly on the heating and / or cooling demand as well as the demand for domestic hot water. Further on, the HP efficiency is taken into account as well as the country-specific electricity and DH tariff.

The required data for the calculations is gathered from various literature sources, including Eurostat, the TABULA/ Episcope building data, the Hotmaps Building Stock Analysis; the Database Energinet, EHPA statistics and data, Sven Werner's European district heating price series, District heating and cooling – country-by-country survey and others. Regarding data availability, countries that are not part of the EU (Norway, Iceland, Switzerland and the UK) have the least data availability, whereby the UK has the best availability out of the four because of their recent exit from the EU. For a validation of the methodology and data, the results and assumptions of the calculations are compared with those of established online heating cost calculators. As one of the key results, an *Excel sheet for calculating typical cost* is attached to this report and is referenced since important data and references are included.

The following results can be summarised:

Comparison of the main influencing factors

- The heating and cooling demand is one of the main influencing factors on the yearly energy costs. Overall, the heating demand decreases the later the building was constructed. In some countries, the demand of the construction years 1945-1969 are lower than the demand of buildings built before 1945. The northern countries have the highest heating demands in general. Even considering the low insulation standards, the southern countries still have the lowest heating demand, due to the warmer climate. On the contrary, the south has the highest cooling demand, followed by the eastern countries due to the wide spectrum of countries included in the cluster.
- The demand for domestic hot water not only depends on the number of people living in the building but also on the country of the consumers. There are large differences in the different European countries. With 1.95 MWh/a Denmark has the highest DHW demand per person, and Lithuania has the lowest with 0.55 MWh/a.
- The electricity price has an influence on the energy cost of the HP or boiler. The highest electricity prices are in Germany with 0.30 €/kWh followed by Denmark and Belgium. In general, the central and southern countries have the highest prices, while the electricity cost in the east and north are the lowest. The prices in Bulgaria are only one third of the ones in Germany.
- The labour cost has also a wider variation. As well as the electricity price, the labour cost is lower in the eastern countries. The highest costs are in the centre and the north of Europe, with Switzerland having over eight times higher costs than Bulgaria.
- The floor space per person influences the heating and cooling demand of a building as well as the size of the installed H&C equipment. Generally, the floor space per person in a single-family house (SFH) is higher than in an apartment building (AB). In both, SFH and AB, the least floor space is used in the eastern countries. In the central and northern countries, the floor space is equal for each building type. The southern countries need the most space per person in SFH, while the central and northern countries use the most floor space in AB.
- The interest rate has an impact on the annualised capex. The data considered in the tool is only for the countries of the eurozone, which leads to the assignment of cluster values for over one third of the countries.

Cost comparison by country

For comparing the annual costs for DH, Air/Air HPs, Air/Water HPs and Ground/Water HPs, the calculations are based on an average EU consumer. This customer lives in a multifamily house, built between 1990 and 1999, with a usual refurbishment, in a suburban area. The average EU consumer owns his flat, lives in a household of three persons and is not of low social status.

- District heating: Generally northern countries like Denmark, Norway and Sweden as well as Germany are the most expensive when it comes to DH Systems. This can be related to the fact of generally lower temperatures and higher heating demand. In high income countries, maintenance influences the total costs more due to higher labour costs. For the annualised capex, the interest rate is a major factor. Therefore, Estonia, which has the highest interest rate, has a high annualised capex, while labour costs are quite low. Croatia has the lowest costs, due to generally warmer climate and low labour costs. While in western and northern Europe DH prices are high, they are lower in eastern Europe. Denmark is the most expensive country with an annual cost of 2117.95 € per year and Croatia has the lowest cost with 578.78 per year. In most cases Croatia has the lowest overall costs due to low labour costs and warm temperatures, while Denmark is among the highest labour costs with generally colder temperatures.
- Air/Air heat pump: As the Air/Air HP cannot produce hot water, an electric boiler was considered in the calculation. This added cost of the boiler makes the Air/Air HP one of the most expensive systems. Denmark and Germany are the most expensive countries and Croatia has the lowest overall costs. Due to low electricity prices and low warm water demands Malta and Croatia are among the lowest costs. Especially, central Europe ranges among the most expensive areas for Air/Air HPs and eastern and southern Europe is less expensive. Air/Air HPs also have the greatest difference between highest and lowest price. Countries with lower electricity prices have lower overall costs for the Air/Air HP because of assumed electric boiler.
- Air/Water heat pump: High energy costs for heating play a major role in the cost structure. Denmark, Germany and Belgium are the most expensive countries, while Croatia again is the cheapest. This can be related to low demands in Croatia, while the capex in Belgium is high compared to other countries. Germany and the surrounding countries show the highest costs for the Air/Water HP, while mainly southern and south-eastern countries show lower costs, due to low demands and lower labour costs.
- Ground/Water heat pump: Germany and its surrounding countries rank also among the most expensive countries, with Croatia as the cheapest due to low costs and low demands. On average, the Ground/Water HP ranges as the cheapest system compared to the three other systems above. A great cost factor is once again the high energy costs for heating, while also the capex in Belgium is quite high. Germany and the surrounding countries show the highest costs for the Ground/Water HP, while mainly southern and south-eastern countries show lower costs, due to low demands and lower labour costs. In Belgium, the high capex cost plays a major role.

Summary: In Belgium, Denmark and Germany, the cost for Air/Air HPs is significantly higher compared to the other technologies, which can be related to the highest electricity costs in Europe. Croatia, Hungary and Spain are the cheapest countries, due to low heating demand, low labour costs and low electricity prices. In general, central Europe with moderate temperatures, higher labour costs and higher electricity costs is the most expensive cluster, followed by the North, with colder, darker winters and generally higher labour costs. The western European countries resemble the north and the central cluster. The fact that all systems are slightly cheaper could be related to the milder temperatures. The southern cluster is among the cheapest, due to low labour costs and generally milder temperatures. For the eastern cluster, the lower labour and energy costs play a more significant role, while also milder temperatures for more southern countries of the eastern cluster come into play. While for DH mainly the central European countries and the Scandinavian countries are among the most expensive ones, for HPs Germany and its surrounding countries face the highest costs.

The **overall conclusions and data gaps** can be summarised as follows:

- One of the key challenges for calculating the end-user costs was to identify and collect the required data for all countries considered

- For calculating realistic and fair costs, a set of complex technical combinations and conditions had to be considered
- There is very little data on cooling and especially district cooling

2 Introduction

2.1 Background

This report is was created within Task 4 of the project 'Overview of Heating and Cooling: Perceptions, Markets and Regulatory Frameworks for Decarbonisation '(Breitschopf et al. 2022), coordinated by the Fraunhofer Institute for Systems and Innovation Research (F-ISI), and in partnership with the Austrian Institute of Technology GmbH (AIT) and the European Heat Pump Association (EHPA), funded by the European Commission (the Project).

Main aim of task 4 of the project is to analyse the final cost for owning and operating district heating (DH) connections and heat pumps (HPs) for preparing space heating and space cooling as well as domestic hot water (DHW) from an end user's perspective. This analysis was done for different types of consumers in individual Member States of EU27, in the UK, Norway, Switzerland, and Iceland. Figure 2-1 shows the structure of the subtasks of task 4.

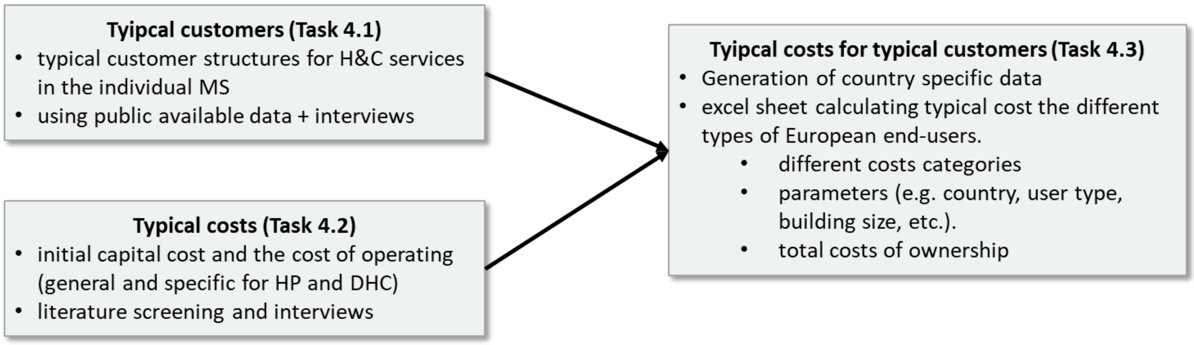

Figure 2-1: Overview of Task 4: structure for analysing the cost for investing and operating appliances for H&C, focusing on HP and DH installations and influencing factors

This report describes the bottom-up approach used in task 4 for calculating the final capital cost and final operating cost for preparing space heating and space cooling as well as domestic hot water (DHW). It considers different properties of the end user for calculating the annualised total cost of ownership. Here, typical customers from task 4.1 (see D4.1, attached to the report) are considered, but also customised customers can be created. It summarises the following deliverables:

- D4.1: Report on typical customer structures and selection of end user types
- D4.2 Report on costs structure and influencing factors
- D4.3 Report on typical costs for different types of European end users

Further on, as one of the key results, "D4.4: Excel sheet for calculating typical cost" is attached to this report and is referenced, since important data and references are included.

2.2 Structure of the report

- Section 3 introduced the typical customers chosen for the assessment as well as the technologies and technology combinations considered for providing heating and cooling services to end users.
- In section 4, the general methodology and data used for calculating the end-user costs for providing heating and cooling with HPs and DH is described, including the details for calculation the capex and opex.
- In section 5, the main influencing factors for the costs are compared.

- Section 6 shows the results of the calculation for different countries and clusters.
- Finally, section 7 gives some conclusions and shows some data gabs discovered during the development of the methodology.

In the appendix to this report, an introduction into the excel tool is given and the excel tool itself can be found.

3 Consumers and technologies

3.1 Country clusters

The methodology developed requires a large amount of data for each country. Due to the fact, that not all the necessary data is available for all countries, clusters of similar countries were selected to fill in missing data. Table 1 shows the countries, which belong to the five selected clusters, each cluster conjoining countries with similar climate and economic characteristics. The average value of the available data from the countries of one cluster is built and used if data for an individual county is not available.

Table 1: Clusters and countries within the cluster

Region	Countries
North	Sweden, Norway, Finland, Denmark, Iceland
West	France, United Kingdom, Ireland, Netherlands, Luxembourg, Belgium
South	Spain, Portugal, Italy, Malta, Cyprus, Greece
Central	Germany, Austria, Switzerland
East	Poland, Slovakia, Czech Republic, Hungary, Croatia, Slovenia, Romania, Bulgaria, Lithuania, Latvia, Estonia

Figure 3-1: Clusters and countries within the cluster

3.2 Consumer data

The characteristics of the building and the consumer (end user) behaviour are strongly influencing the individual heating and cooling demand and thus the cost for heating and cooling. Thus, "typical customers" have been developed for calculating characteristic costs.

In this report, the most important information is summarised for a better understanding of the methodology. The consumer is described by seven properties, which are perpetuating for the whole calculation, see Figure 3-2.

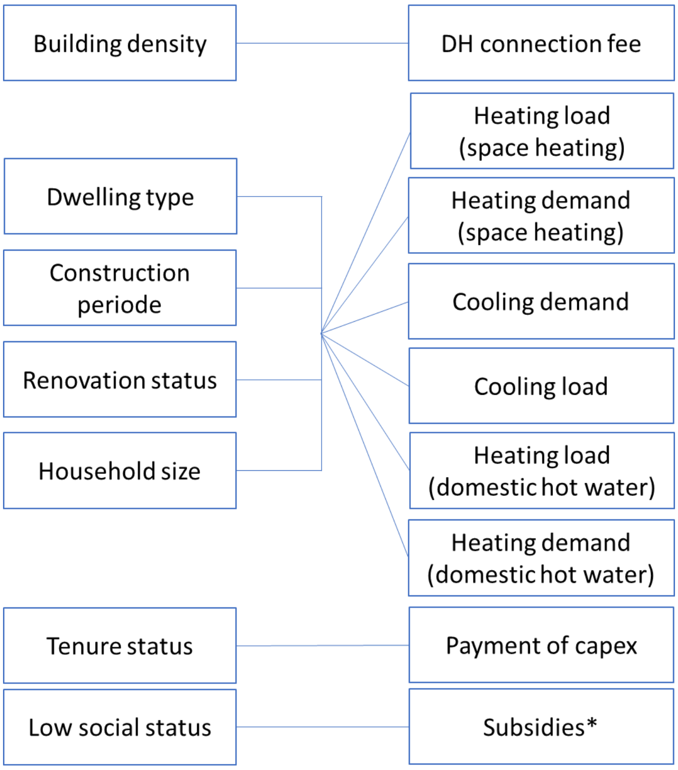

Figure 3-2: Customer properties (left) influencing calculation parameters (right)

Each property has the following variants based on the available data:

• Building density: ○ Urban ○ Suburban ○ Rural • Dwelling type: ○ Single-family house ○ Terraced house ○ Multifamily house ○ Apartment block	• Construction period: ○ <1945 ○ 1945-1969 ○ 1970-1979 ○ 1980-1989 ○ 1990-1999 ○ 2000-2010 ○ >2010 • Renovation status: ○ No refurbishment ○ Usual refurbishment ○ Advanced refurbishment	• Household size: ○ 1 person ○ ... ○ 5 persons ○ 6+ persons • Tenure status: ○ Owner ○ Tenant • Low social status: ○ Yes ○ No

3.3 Typical customers

Table 2 lists the characteristics of the four chosen typical consumers per country cluster. The selection of the typical consumers as well as of the country clusters is explained in detail in the deliverable D4.1 in the appendix.

Table 2: Typical Consumers per cluster

Cluster	Consumer Charasteristics	Typical Consumer 1	Typical Consumer 2	Typical Consumer 3	Typical Consumer 4
Central	Building Density	Urban	Suburban	Suburban	Rural
	Dwelling Type	Apartment Block	Multi Family House	Single Family House	Single Family House
	Construction Period	1945-1969	<1945	1990-1999	1945-1969
	Renovation Status	No Refurbishment	Usual Refurbishment	Advanced Refurbishment	Usual Refurbishment
	Household Size	1 Person	2 Persons	3 Persons	4 Persons
	Tenure Status	Owner	Tenant	Tenant	Owner
	Low Social Status	No	No	No	No
East	Building Density	Urban	Suburban	Rural	Rural
	Dwelling Type	Apartment Block	Single Family House	Single Family House	Apartment Block
	Construction Period	1970-1979	1945-1969	1980-1989	1970-1979
	Renovation Status	Usual Refurbishment	No Refurbishment	Usual Refurbishment	No Refurbishment
	Household Size	1 Person	3 Persons	2 Persons	4 Persons
	Tenure Status	Owner	Owner	Owner	Tenant
	Low Social Status	No	No	No	Yes
North	Building Density	Urban	Urban	Suburban	Rural
	Dwelling Type	Apartment Block	Terraced House	Single Family House	Single Family House
	Construction Period	1970-1979	<1945	1945-1969	1945-1969
	Renovation Status	Usual Refurbishment	Usual Refurbishment	Usual Refurbishment	Advanced Refurbishment
	Household Size	1 Person	2 Persons	1 Person	4 Persons
	Tenure Status	Tenant	Tenant	Owner	Owner
	Low Social Status	No	No	No	No
South	Building Density	Urban	Urban	Suburban	Rural
	Dwelling Type	Multi Family House	Apartment Block	Terraced House	Single Family House
	Construction Period	1990-1999	1945-1969	2000-2010	1970-1979
	Renovation Status	No Refurbishment	No Refurbishment	No Refurbishment	Usual Refurbishment
	Household Size	3 Persons	2 Persons	4 Persons	4 Persons
	Tenure Status	Owner	Tenant	Owner	Owner
	Low Social Status	No	Yes	No	No
West	Building Density	Urban	Urban	Suburban	Rural
	Dwelling Type	Terraced House	Apartment Block	Terraced House	Single Family House
	Construction Period	1990-1999	<1945	2000-2010	1945-1969
	Renovation Status	Usual Refurbishment	No Refurbishment	Usual Refurbishment	Advanced Refurbishment
	Household Size	2 Persons	1 Person	3 Persons	4 Persons
	Tenure Status	Tenant	Owner	Owner	Owner
	Low Social Status	No	No	No	No

3.4 Technologies considered

The methodology in principle considers following technologies and technology combinations for providing space heating, domestic hot water (DHW) and space cooling, as described in Table 3.

Table 3: Applied technologies and technology combinations;

Main heat supply technology: Heat pump (HP)			Main heat supply technology: District heating (DH)		
Heating	Domestic hot water (DHW)*	Cooling**	Heating	Domestic hot water (DHW)*	Cooling**
• Air/Air** • Air/Water • Ground/Water			• Direct substation • Indirect substation		• Air/Air HP**

* In some cases, the heating system is not capable to supply DHW. This is the case for Air/Air HPs and in some cities, where DH is turned off during summer times. In turn, an optional electric boiler for the supply with DHW (in summer/ all year) is considered; ** in case of DH, cooling is always produced using Air/Air HPs, since district cooling is normally not available to end users.

For HPs, the following technologies can be selected (EHPA 2022a):

- **Air/Air HPs** use air as source and as sink and can be reversible, which means they can be used for heating and cooling. They are either optimised for air-conditioning and extended for heating purpose, or are optimised for heating, and are additionally able to cool.
- **Air/Water HPs** are mainly used for DHW and can use outdoor or indoor-air as energy source.
- **Ground/Water HPs** use the consistent temperature level of the ground. The ground can be used with vertical drills or with horizontal collectors.

Furthermore, exhaust air HPs are using the exhausted air of the ventilation system of a building as source (Fehrm et al. 2002). Since their share is relatively low, they will not be considered further.

Most modern **heat pumps**

- can be used for providing heating, domestic hot water (DHW) and cooling.
- In the case of cooling using ground/ water HPs only operation & maintenance cost applies since free cooling is possible by circulating the fluid through the collectors.
- Air/Air HPs cannot provide domestic hot water, in turn an electric boiler[1] for the supply of DHW can be considered.

For **district heating**,

- direct or indirect substations can be used, referring to the use of a heat exchanger for separating the DH water and the water in the building heating system, or not.
- Furthermore, it needs to be considered that in some countries, DH is turned off during summer times for reducing heat losses. In turn, an optional electric boiler for the supply of DHW during this time can be considered.
- Within the methodology, cooling is always produced using Air/Air HPs, since district cooling is normally not available to end users. I.e. there are rarely examples for residential buildings connected to a district cooling network. To the authors' knowledge, only one exists[2], thus very little data would be available for calculating reliable prices.

[1] In many countries, this is also done via oil or gas boilers. However, since the use of such fossil sources should be minimized, an electric boiler is considered to be the relevant choice.

[2] https://annual.wienenergie.at/en/2019/LdRBWHJe/increasing-cold-to-fight-the-heat/

4 Methodology and data

4.1 Overview

Within this report, the annualised total cost of ownership is considered as the main indicator for estimating the end users' costs for H&C services, since it allows the fairest comparison between the different technologies (heat pumps (HP) or district heating (DH) connections). The data used is indicated in D4.4: Excel sheet for calculating typical cost, linking both documents.

The factors in Figure 4-1 apply to the calculation of the end users' costs for heating only, or the cost for a combination of heating and cooling. In both cases, the preparation of domestic hot water (DHW) is considered.

For the calculations, the following aspects should be noted:

- The calculation of the total cost of ownership does not include the cost of recycling.
- Possible subsidies for each country are investigated, but do not effectively reduce the resulting costs; since a country-specific implementation of subsidies would require a detailed assessment of the subsidies and this was beyond the resources of the current project. Also, subsidies may change over time, depending on available budgets, political situation etc., which represents the risk that data would not be up to date.

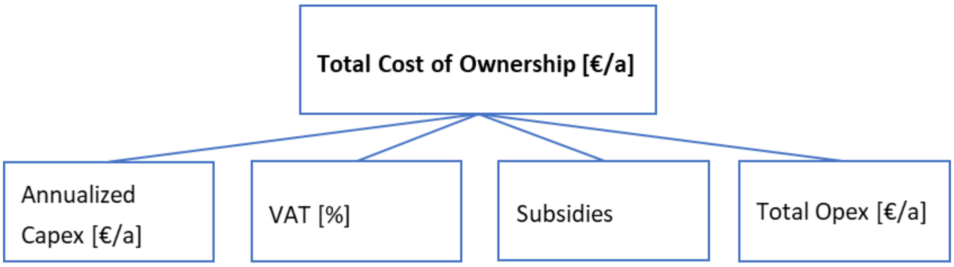

Figure 4-1: Calculation schemata for the total cost of ownership for HPs and DH, excluding the cost of recycling (the VAT might differ in VAT standard and VAT electricity)

Calculation of the capex: Capital expenditure or capital expense (capex) is the money that the end user spends to buy and install all required devices for the required service (heating only or a combination of heating and cooling, and in both cases, the preparation of domestic hot water).

The schemata of Figure 4-2 describes the main factors for the calculation of the capex of either HPs or a DH connection, and for electric boilers (in case additionally required for DHW preparation).

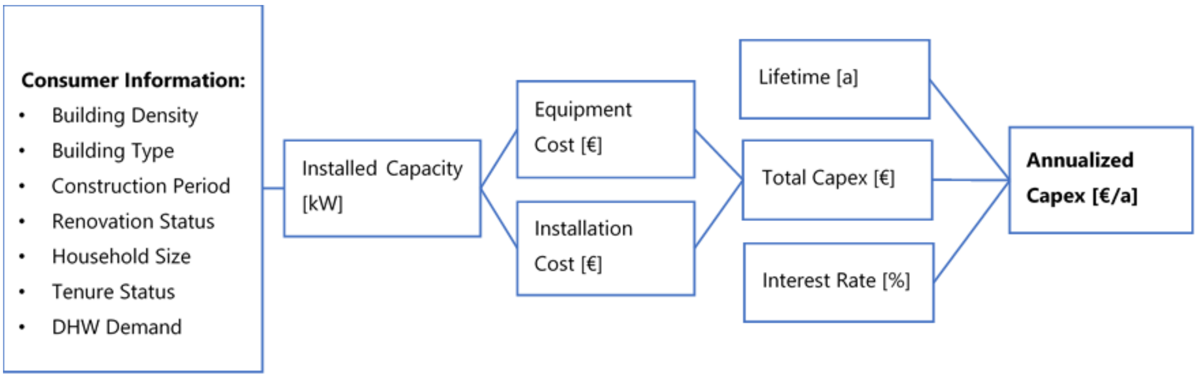

Figure 4-2: Calculation schemata for the capital expenditure (capex) for HPs, DH and electric boilers

In this report, especially the **annualised capex** is calculated. This refers to the cost, that is incurred each year during the lifetime of the device. To calculate the annualised capex for each technology (Substation for DH, HP, and electric boiler), the interest rate (i), the total capex, as well as the lifetime of the device are needed. It is calculated as shown in equation 1 (CFI 2022).

$$\textbf{Annualized Capex} = \frac{i}{1-(1+i)^{-lifetime}} * \textbf{Capex} \qquad (1)$$

Calculation of the opex: The operating expenses (opex) are ongoing expenses that are inherent to the operation of the HP, DH connection (and electric boiler, if required).

The schemata of Figure 4-3 describe the main factors for the calculation of the opex for a **DH** connection.

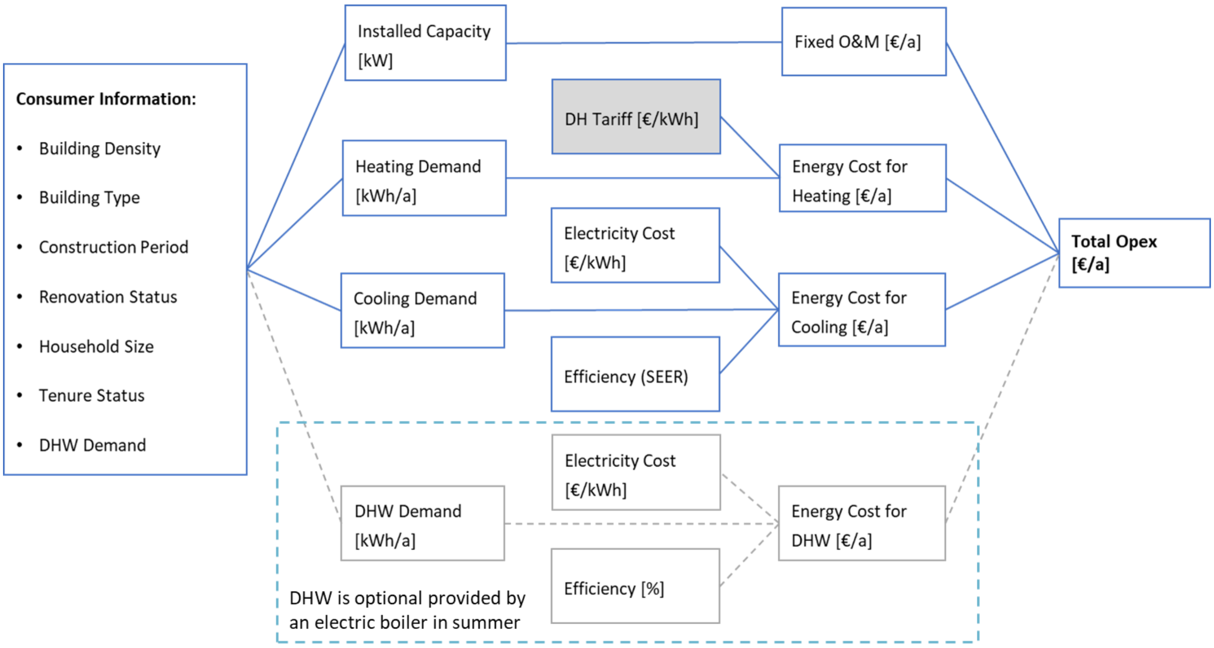

Figure 4-3: Calculation schemata for the operational expenditure for DH

For calculating the opex for DH connections, the following aspects needs to be considered:

- In case of space heating and cooling, the capex and opex of an Air/Air HP are included for the space cooling.
- The heating demand includes the demand for space heating and DHW.

\- - - Optional: an electric boiler is considered for DHW preparation, if DH is turned off during summer times.

The schemata of Figure 4-4 describe the main factors for the calculation of the opex for a **HP:**

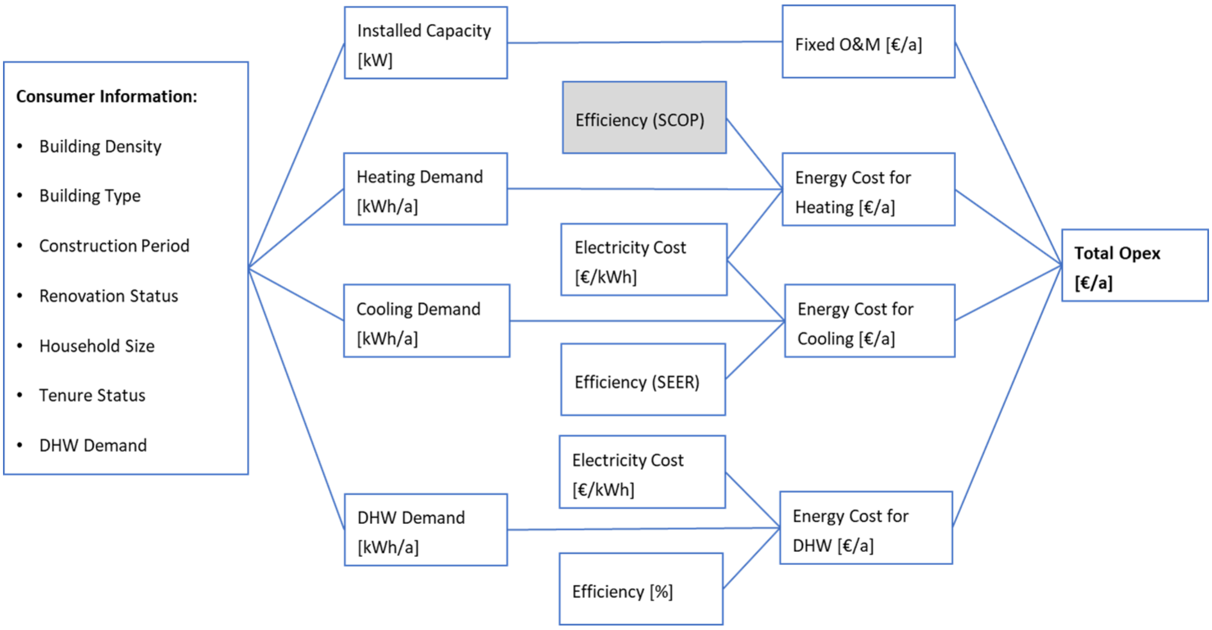

Figure 4-4: Calculation schemata for the operational expenditure for HP

For calculating the opex for HPs, following aspects needs to be considered:

- The heating demand includes the demand for space heating and DHW.
- In case of an Air/Air HP the capex and opex of an electric boiler are included and the heating demand excludes the DHW demand.

A detailed description of the calculation steps and data used can be found in the following sections.

The data used for the calculation is mostly not shown directly in the report due to its size. The data is rather shown in the "*Excel sheet for calculating typical cost*" attached to the report (each of the following section is related to the respective data sheets with "→ Data used in the excel tool")

4.2 Total annualised capex

4.2.1 Installed capacity

The installed capacity of the system refers to the thermal power needed to reach and remain the required indoor temperature/ DHW temperature. The capacity has a direct influence on the size of the equipment and thereby also on the capex.

The installed capacity equals:

- the heat load in case of heating use only
- the higher load in case of heating *and* cooling with the same technology
- the DHW load in case of an electric boiler

4.2.1.1 Heating load

The installed heating capacity of the HP or the DH substation depends on the heating load needed to supply the building with enough energy. The space heating load is influenced by different building structures and climate conditions. U-values of building types and construction periods were collected for all construction elements of all EU27 countries + UK from the building stock analysis of the project Hotmaps (Hotmaps 2022). To calculate an average U-value for the building, the envelope was considered to consist of 30% wall, 20% window, 25% floor and 25% roof (European Commission 2016). The outdoor temperature for defining the heating capacity is following the definition for the design outdoor temperature of the DIN EN 1283 (Oertel 2022).

For the analysis, daily climate data for the past 20 years in all considered countries, except Iceland, are collected from the AGRI4CAST project (Agri4Cast 2021). The data is prepared to show the lowest temperature, which remains for at least 2 days in a row for 10 times in the past 20 years. Therefore, the maximum daily temperatures are used for this calculation. Due to the general availability, practical values for the specific heating load in Germany for different dwelling types and construction years (Heizungsratgeber 2021) (Bund der Energieverbraucher 2021) were used. Figure 4-5 and Figure 4-6 show the used data, which was adjusted to the construction periods in the tool by calculating the average between two values. With the U-vales (U) of the countries and the climate data of the countries (T_{OUT}), the heating load of Germany (HL(G)) is varied for all countries (HL) by dividing the factors of the country through the factors of Germany (U(G)), T_{OUT}(G)) (see equation 2).

$$HL = HL(G) * \frac{U*(T_{IN}-T_{OUT})}{U(G)*(T_{IN}-T_{OUT}(G))} \qquad (2)$$

The design indoor temperature (T_{IN}) is estimated with 20 °C in the calculation. To be able to consider the renovation state of the buildings, a renovation factor has been implemented using the data of the heating demand. The renovation factor is given by the ratio of the heating demand of the not refurbished building and the heating demand of the usual or advanced refurbished building for the respective chosen renovation status.

Construction Period	specific heating load [W/m²]
< 1959	180
≥ 1959	177
≥ 1969	163
≥ 1978	115
≥ 1984	99
≥ 1995	67
≥ 2002	45
≥ 2009	38
≥ 2020	10

Figure 4-5: Specific heating load for different construction periods (Heizungsratgeber 2021)

Construction Period	Single Family House	Terraced House	Multifamily House	Apartment Block
< 1958	180	150	130	120
1959-68	170	140	120	110
1969-73	150	125	110	100
1974-77	115	105	75	70
1978-83	95	88	65	60
1984-94	75	68	60	55
≥ 1995	60	53	45	40

Figure 4-6: Specific heating load in W/m² for different construction periods and building types (Bund der Energieverbraucher 2021)

In case of a domestic hot water (DHW) supply, a separate capacity needs to be considered. Within the present tool, a value of 0.25 kW per person has been added to the space heating load (Natiesta 2021).

➢ Data used in the excel tool

In the sheet d. Heating Load of the tool,

- Table d-1 holds the calculated heating load for all countries, building types and construction periods.
- Table d-2 holds the U-Values (Hotmaps 2022) and the indoor and outdoor temperatures (Agri4Cast 2021).
- Table d-3 and d-4 contain the heating load of Germany (Heizungsratgeber 2021) (Bund der Energieverbraucher 2021).
- Table d-5 provides the calculation to fit the data from d-3 and d-4 to the building conditions of the tool.
- Table d-6 contains the shares wall, window, floor, and roof area of the building envelope (European Commission 2016).

4.2.1.2 Cooling load

The installed capacity for cooling depends on the cooling load of the building. The data is gathered from the project Heat Roadmap Europe (Dittmann et al. 2017) for all EU27 countries +UK. Since only one value is available per country, this value is considered the average value of all buildings of the country. It is assumed that the cooling load is proportional to the cooling demand, considering the building types and construction periods, i.e. by multiplying with the ratio of the respective cooling demand and the average of the cool demands of the country.

➢ Data used in the excel tool

In the sheet e. Cooling load, table e-1 contains the cooling load of all countries, building types and construction periods.

4.2.2 District heating capex

The capex of DH is the cost of the equipment and the installation of DH. It is composed of the costs for the substation as well as of the pipeline connection from the main heat network to the building.

4.2.2.1 Substation costs

To connect a DH network to a building, a substation needs to be installed. It transfers the heat from the DH network to the buildings heating system. The size is depending on the heating demand and the domestic hot water demand.

With substation cost data from (Danish Energy Agency and Energinet 2016), linear cost functions were calculated for the investment costs (installation and equipment), maintenance costs, and fixed yearly electricity costs, whereat the variable is the heating load in kW. Here, two different functions for indirect and direct substations were developed. However, direct substations are only suggested for Denmark and Romania (Sipilä et al. 2015).. The investment costs do not include the connection costs. It is suggested that 70% of the investment costs are for the equipment and 30% for the installation. For the installation share, a country-specific labour work factor is included, see section 4.2.

To match the data, two linear functions were created. Figure 4-7 shows the case of indirect substations where one linear function for heating loads between 5-15 kW and one for heating loads between 150-500 kW is used. The intersection of the two lines is at about 44 kW.

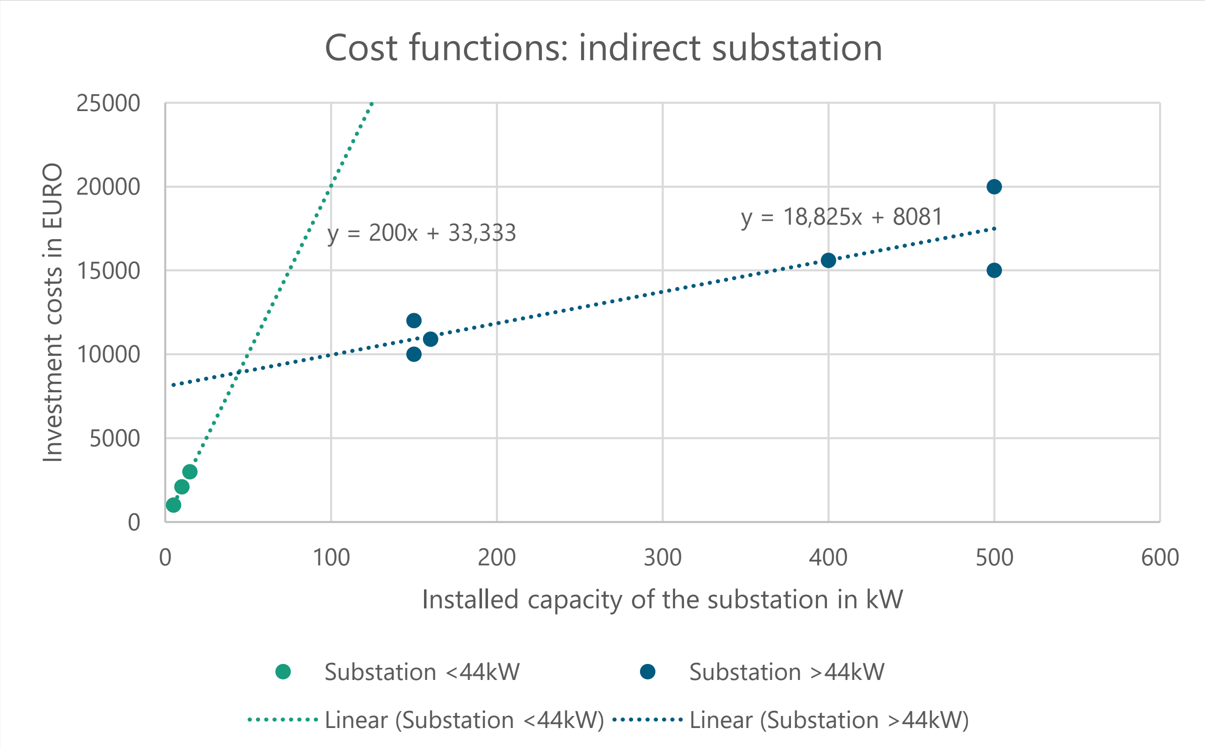

Figure 4-7: Cost functions for indirect substations

➢ Data used in the excel tool

In the sheet g. Substation of the tool,

- table g-1 presents data from Danfoss (Danfoss 2020a) is used as reference and verification.
- table g-3 compares the data from the Danfoss price list with the one from technology data for heating installations.
- table g-4 assigns a substation technology to every considered country – direct or indirect (Sipilä et al. 2015).
- table g-5 shows values from technology data, which is used to create the cost functions.
- the following tables present the resulting parameters from the cost functions as well as equipment/installation share and the values for the uncertainties.

4.2.2.2 Connection costs

To connect a building to a DH network, a pipe must be built from the main network to the substation of the building. The required length of this connection is an important variable. It depends on the geography of the DH network and the distance to the building as well on the distance from the border of the property to the actual substation[3].

Here, an average value for the connection length is suggested based on a discussion with DH experts, since no data is available in the literature. The related connection costs are calculated with data from the *project heat_portfolio* (Geyer 2018). Depending on the categories urban, suburban and rural, a specific linear cost function is suggested, assuming different construction efforts for the different categories. As the values are from 2011, an inflation factor 2011-2020 from *Eurostat* (Eurostat 2022b) is considered.

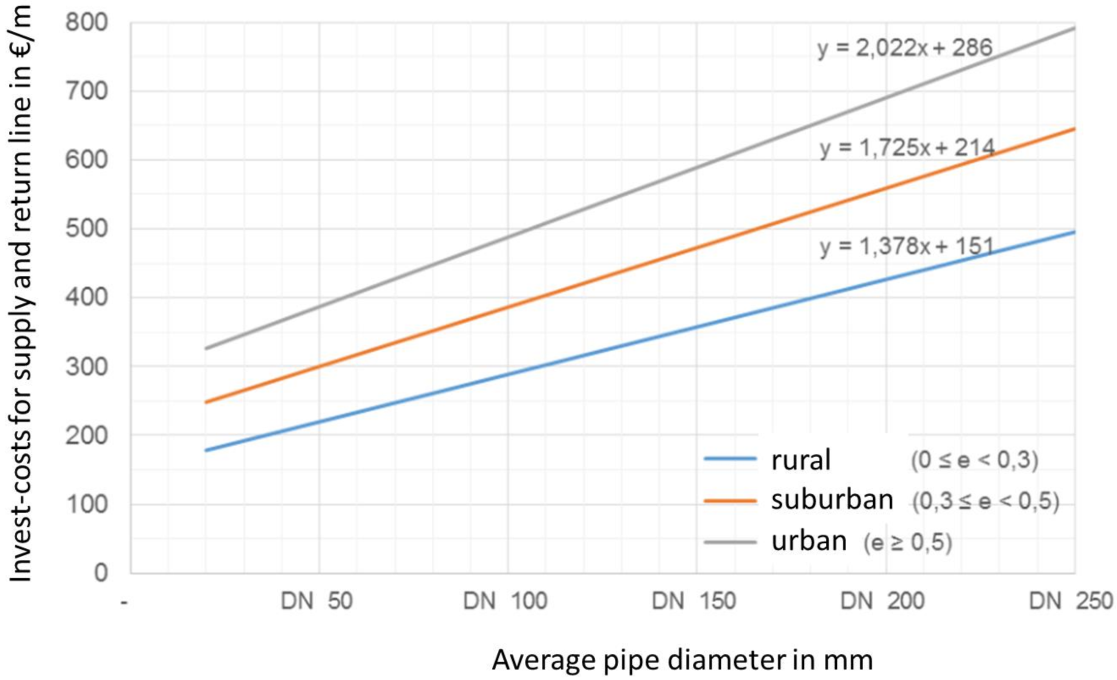

Figure 4-8: Investment costs for DH pipes in different underground conditions.

Additionally, a share of 70% for equipment and 30% for installation is proposed. The latter is considered with a labour factor (see section 4.2.7).

➢ Data used in the excel tool

In the sheet h. DH connection,

- table h-1 displays all information that was gathered from the project heat_portfolio (Geyer 2018). In the end, only the column "Investment cost per pipeline length" was used for the calculation. The last column of the table is the inflation factor, as mentioned above.
- Table h-2 shows data from the Gemeindewerke Holzkirchen (Gemeindewerke Holzkirchen 2022c), which is only used as a reference and verification of the data from heat_portfolio.
- Table h-3 shows data from GIS-based assessment of the DH potential in the USA (Gils et al. 2013), which also used only as verification. Since it provides data about the total length of a heat network

[3] Please note, that in report D3-2, the DH network costs relate to the overall costs of the DH network from the investors or utility point of view, including all piping, central substations and supply units. This report considers only the costs for the connection of a building to an existing DH network to properly represent the costs for the end user. DH utilities normally allocate the costs of the overall DH network in the DH tariff (base price) that is considered separately in this report.

in different building densities, it is used as a reference to conclude the average distance from a house to an existing heat network in rural, suburban and urban regions.
- Table h-4 presents the data that is finally used for the calculation, which is the pipe length per building and the average connection cost per building. Anyway, the tool uses the values from the first table for the connection cost to react dynamically to a change of the pipe length as input. Last, equipment to installation share of 0.7 to 0.3 was assumed to integrate a labour work factor for the installation.

4.2.3 Heat pump capex

The HP capex are the costs for the equipment and the installation of a HP. They are calculated for all four considered HP types and include a domestic hot water storage tank (except for air/air HP) and the auxiliary equipment.

With *technology data for heating installations* from Energinet (Danish Energy Agency and Energinet 2016), linear cost functions were calculated for the investment costs (installation and equipment), maintenance costs and fixed yearly electricity costs, whereas the variable is the heating load in kW. For Air/water and ground source HPs, there are each two different cost functions for devices below 100 kW heating load and the ones above 100 kW. This is to match the given data with a linear function.

Depending on the type of HP, 60-80% of the investment costs are for the equipment and 20-40% for the installation of the HP. For the installation costs, the labour factor (see chapter 4.2) has been applied. To display lower and upper uncertainties regarding the calculated costs, an estimated value of 20% of the investment costs are subtracted and added.

No data is available for air/air HPs for apartment blocks built before anno 2000, supposedly because there were no air/air HPs of this size, respectively the needed ventilation technologies. To incorporate this detail in the calculation, for apartment blocks and multifamily houses older than building year 2000, no air/air HPs are adopted for the whole building but for each dwelling.

In case of a ground/water HP, a vertical heat collector would cause additional cost of around 6000€ per borehole (hardware and installation). This cost is not considered in the calculation.

At the end of the calculation, the equipment and installation cost are summed up, and the annualised capex are calculated considering the lifetime and rate of interest (i).

➢ Data used in the excel tool

In the sheet j. Heat Pump of the tool,

- table j-1 contains the lifetime for the four HP types.
- table j-2 shows values from technology data, which is used to create the cost functions.
- the further tables j-3 to j-5 present the resulting parameters from the cost functions as well as equipment/installation share and the values for the uncertainties.

4.2.4 Electric boiler capex

Electric boilers are considered as supplementing technologies for DHW preparation for air/air HPs (all year round) and if DH is turned off during the summer months (optional).

Data for the investment and maintenance costs is taken from *Technology data for heating installations* (Danish Energy Agency and Energinet 2016). Furthermore, linear cost functions are calculated in a similar way as for substations and HPs (see chapters 4.2.2.1 and 4.2.3).

➢ Data used in the excel tool

In the sheet k. Heat Pump of the tool,

- table k-1 shows values from Technology data, which is used to create the cost functions.
- the following tables k-2 to k-5 present the resulting parameters from the cost functions as well as equipment/installation share and the values for the uncertainties.

4.2.5 Lifetime

The lifetime of the technologies describes how long the technology can be used until it has to be replaced and is relevant for calculating the annualised capex.

The lifetimes of DH substations, HPs and an electric boiler were assessed from *Technology Data for heating installations* (Danish Energy Agency and Energinet 2016) and is used to calculate the annualised investment and furthermore the annualised total costs of ownership.

For ground source HPs, it is considered, that the heat collector has a longer lifetime than the HP as such. Therefore, for the calculation of annualised costs, the lifetime was doubled (from 25 to 50), while the replacement only is considered with 30% of the initial investment cost (Danish Energy Agency and Energinet 2016).

Device	Lifetime [years]
DH substation (direct and indirect)	25
Air/air HP	15
Air/water HP	20
Ground source HP (since the borehole lasts longer than 25 years, the lifetime is doubled in the calculation as well as the equipment cost but with steady installation cost)	25 (50)
Electric boiler	30

➢ Data used in the excel tool

In the excel tool, the lifetimes are each listed in the sheet of the respective device:

- table g-11 in sheet g. Substation,
- table j-1 in sheet j. Heat pump
- and table k-1 in sheet k. Electric Boiler.

4.2.6 Interest rate

These values are used to consider an interest rate on the annualised capex.

If a loan should be considered to cover the investment costs, a country-specific interest rate is suggested from the Austrian National Bank (Oenb 2022).

➢ Data used in the excel tool

The values are contained in the sheet b. Additional Data in table b-1 of the tool.

The distribution of the interest rate for the different countries is shown in section 5.5.

4.2.7 Labour factor

The labour cost has an influence on the installation cost of the equipment.

The data for the capex of all three technologies (DH, HP and electric boilers) is gathered from the *Technology data for heating installations* from Energinet and the Danish Energy Agency (Danish Energy Agency and Energinet 2016). To adapt the costs for all countries, a labour factor was implemented, which is applied to the installation cost part of the capex. The labour factor is determined by dividing the hourly labour cost (Statista 2020) of the country by the labour cost of the reference country Denmark. Figure 4-9 shows the labour factors of the countries. Denmark, as reference country, has the value 1, only Norway and Switzerland have a higher factor, while Bulgaria with a factor of 0.1, has the lowest labour costs.

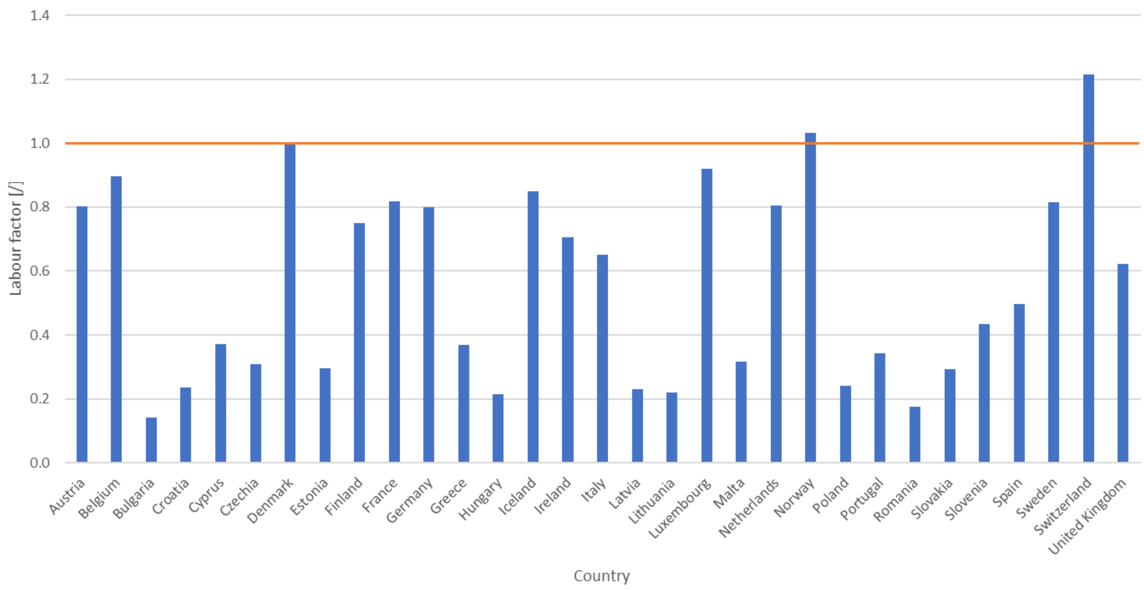

Figure 4-9: Labour factor with reference Denmark (=1)

➢ **Data used in the excel tool**

In sheet b. Additional Data, table b-1 contains the labour cost of all countries.

4.3 Total opex

The total opex consist of the fixed O&M (Operation and Maintenance Expenses) and the opex of the HP, DH, or electric boiler. Table 4 gives an overview of the technologies used for providing heating, cooling and DHW. In case of heating and cooling, the opex are added up.

Table 4: Overview of the calculation of the opex

	Heat Pump			District Heating		
Function	**Heating**	**DHW**	**Cooling**	**Heating**	**DHW**	**Cooling**
Technology	HP	HP, Electric Boiler (in case of Air/Air HP)	HP (Ground/Water HP only O&M because of free cooling)	DH	DH, Electric Boiler (in case of DHW is not provided by DH in summer)	Air/Air HP
OPEX	$= \frac{p_{electricity}}{SCOP} * h_{demand}$	$= \frac{p_{electricity}}{Efficiency} * DHW_{demand}$	$= \frac{p_{electricity}}{SEER} * c_{demand}$	$= DH_{tariff} * h_{demand}$	$= DH_{tariff} * DHW_{demand}$ $= \frac{p_{electricity}}{Efficiency} * DHW_{demand}$	$= \frac{p_{electricity}}{SEER} * c_{demand}$
	+ fixed O&M					

4.3.1 Heating demand

The heating demand is defined as the energy needed per year to heat a building.

The specific heating demand in kWh/(m²a) of each building type was gathered from Episcope's TABULA (TABULA 2016d). The database considers four different building types, several construction periods and three insulation standards for 13 European countries. The construction periods in TABULA are not consistent between the countries. For the tool, the periods that appeared most were taken. If the data from TABULA was not consistent with the data of the excel tool, e.g., the construction period in TABULA is from 1985-1995, and from 1996-2005, and the period in the excel tool is from 1990-1999, the average of the two values from TABULA is calculated. If this option is not possible because no data is available for a certain period, the respective cells were left blank, and the cluster average was taken for the calculation. For the countries and buildings that are not covered by TABULA, the average heating demand of the respective cluster is taken.

To determine the annual heating demand in kWh/a, the specific heating demand has to be multiplied with the floor space in m². The tool suggests a value based on the selected building type and household size. For this purpose, data of the floor space per capita in m² for all countries, and two building types is used (Rapf and Economidou 2011). Regarding the building types, the values for single family houses are also used for terraced houses and the values for apartment blocks are also used for multifamily houses.

➢ **Data used in the excel tool**

In sheet c. Heating Demand of the tool

- Table c-1 shows the specific values of the heating demand of different construction years, building types, insulation standards and countries.

- Table c-2 reflects the data for the selected consumer.

In sheet b. Additional Data of the tool, table b-1 contains the data of the floor space per capita.

- Table a-2 and a-3 provide the data for the charts shown in the sheet "Consumer Information for the selected country."
- Table a-4 holds the parameters for the typical consumers for each country as well as the EU, which were calculated in a separate Excel tool using shares and correlation factors.
- Table a-5 provides the information about the clustering of the countries.

4.3.2 Cooling demand

The cooling demand describes the energy needed per year to cool a building.

The source for the specific cooling demand in kWh/(m²a) is the building stock analysis from the project Hotmaps (Hotmaps 2022). It gives data for all EU27 countries + United Kingdom (UK) and the four different building types and all needed construction periods. Due to a lack of experience with cooling, especially in the residential sector of Europe, there is a lack of precise data. As a result, most of the data regarding the cool demand, the installed capacity of cooling systems as well as the consumer behaviour is estimated.

Unlike as in the case of heating, not all of the floor space of a building needs to be cooled. Therefore, for the calculation of the annual cooling demand in kWh/a, the suggested floor space (see 4.3.1) is multiplied with the share of the floor space that has to be cooled in per cent, and the specific cooling demand. The tool suggests 50% for the cooled floor space.

➢ **Data used in the excel tool**

In sheet e. Cooling Demand of the tool table e-1 shows the specific values of the cooling demand of different construction years, building types and countries.

4.3.3 Domestic hot water (DHW) demand

The DHW demand is defined as the energy needed per year to supply the residents with hot water.

The DHW demand is calculated by relating the DHW consumption of the countries (Eurostat 2019a) to the population of the respective countries (Eurostat 2019b). In general, the DHW demand is added to the heat demand.

The DHW is provided by the DH network or the HP, except in the case of an Air/Air HP and in cases where the DH network is turned off in summer times and does not provide DHW. In these cases, the DHW demand is provided by an electric boiler. For the electric boiler, an efficiency of 1 is estimated.

In sheet b. Additional Data of the tool, table b-1 contains the DHW consumption of the countries in GJ and their population, as well as the calculated DHW energy demand in MWh per year and capita.

The distribution of the DHW demand for the different countries is shown in section 5.2.

4.3.4 Heat pump efficiency for heating / cooling

The efficiency of heating and cooling systems has a great impact on the opex. For HPs it is expressed with the SCOP (seasonal coefficient of performance) in case of heating, and as SEER (seasonal energy efficiency ratio) in case of cooling. The efficiency is defined as the ratio between the useful heat transfer and the required drive energy (IEA 2022).

Because of the wide variation of this parameter depending on the quality of the HP and the performance of the buildings heating/cooling system, a lower, average and upper value for the SCOP and SEER is considered in the calculation.

- The lower value is the average performance of installed HPs in Europe (EHPA 2019c),
- the average value represents the minimum SCOP, that is needed to receive the EHPA Quality Labe (Wärmepumpe Austria 2022d) and
- the upper value is representing the best technologies available in the certified product directory from Eurovent (Eurovent 2022e).

For the SEER, the lower and upper value are both representing technologies available in the certified product directory from Eurovent (Eurovent 2022e), and the average is built from these two values.

Table 5 gives an overview of the sources used for the SCOP and SEER.

Table 5: Sources for the SCOP and SEER values (EHPA 2019c; Wärmepumpe Austria 2022d; Eurovent 2022e)

	Low	Estimated	High
SCOP	(EHPA 2019c)	(Wärmepumpe Austria 2022d)	(Eurovent 2022e)
SEER	(Eurovent 2022e)	Average value	(Eurovent 2022e)

Due to the option of free cooling in case of ground sourced HPs, the calculation for this case does not consider a SEER.

➢ Data used in the excel tool

In the sheet j. Heat Pump of the tool, table j-8 shows the high, average and low values of the SCOP and SEER of the HP technologies.

4.3.5 Energy costs

The cost for the heating and cooling process is based on the energy cost in €/MWh. In case of DH, the cost depends on a tariff, while in case of a HP, it depends on the electricity price and efficiency. To calculate the annual energy cost, it has to be multiplied with the annual heating demand in MWh/a.

4.3.5.1 District Heating: tariff

The energy cost for DH is calculated by multiplying the DH tariff with the heating demand.

The tariff for DH to be paid by the final customer is varying between countries, cities in the same country and heat provider in the same city. Furthermore, a variety of tariff systems exists, e.g.

- the three-component tariff includes a base price (dependent on heat load or floor space), energy price (dependent on consumed kWh) and measurement price (fixed yearly costs),
- the two-component tariff includes only the base price and the energy price
- the one-component tariff dependents on the consumed kWh.

For considering this variety, the tool uses a mixed price. Please note, that this price does not consider the mentioned factors, since very little data is available, and collecting specific data was out of the scope of this report.

For estimating the mixed price, the following two main sources are considered: Sven Werner's *European district heating price series* (Werner 2016) and the *District heating and cooling – country-by-country* (Voss 2015) survey from Euroheat&Power. While Werner's price series covers (mostly) 1980-2013, the *country-by-country* report provides values for 2017. For the tool, Werner's values from 2000 to 2013 and Euroheat&Power's values for 2017 were collected to create an exponentially smoothed forecast for 2020. A 95% confidence interval is calculated to provide a lower and upper uncertainty.

If the values did not match, a more detailed analysis of the specific country data was conducted, see for example Figure 4-10, in which the linear forecast until 2016/17 (grey line) does not match with the data from Euroheat and power and Tilia. Therefore, the forecast was offset starting from the values with the same trend as the earlier years.

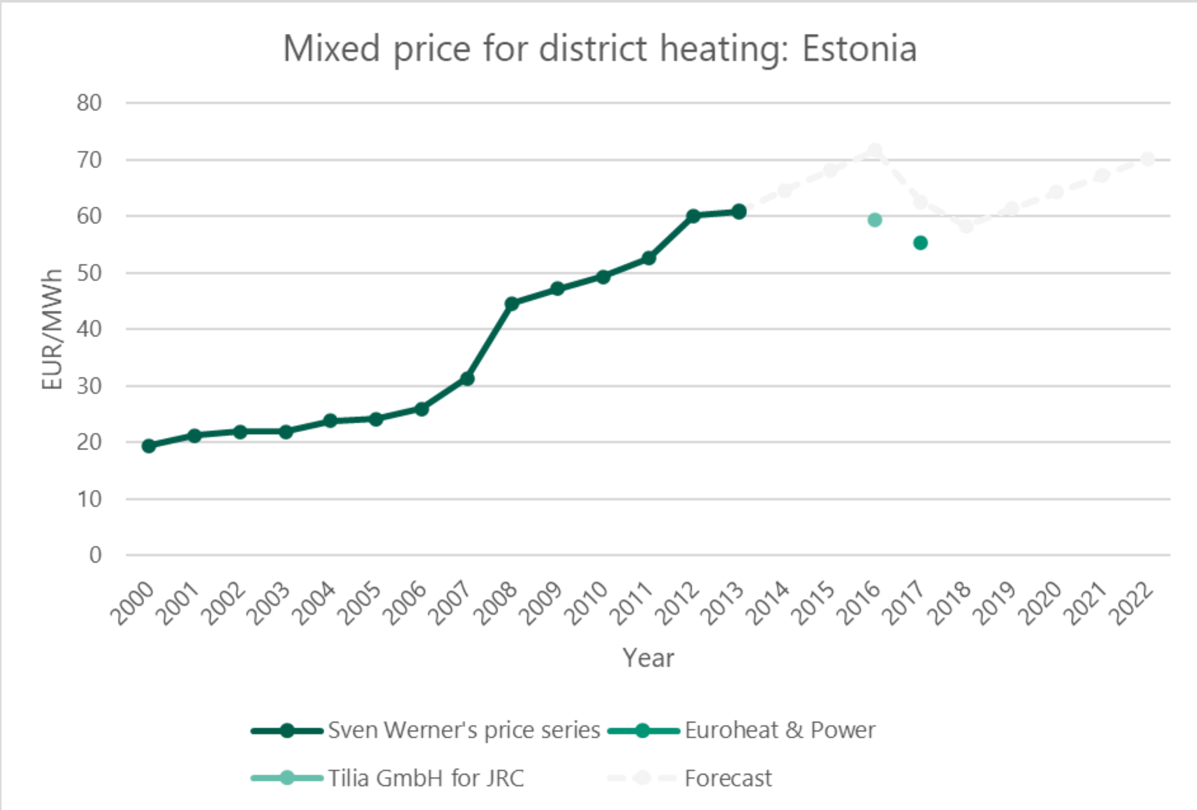

Figure 4-10: Data and forecast of mixed price in Estonia

All additional sources and changes are marked explicitly beside table i-1 of the sheet i. DH tariff in the tool.

➢ Data used in the excel tool

In the sheet i. DH tariff, table i-1 presents all collected data for the mixed price and is used for the forecast.

4.3.5.2 Heat pump energy costs

The energy cost for HPs depends on their efficiency, the electricity price, and the annual heating and cooling demand.

The following equation 3 describes the calculation of the cost of energy ($\boldsymbol{c_{energy}}$) for HPs and electric boilers. The efficiency is described in chapter 4.3.4 and the energy demand ($e_{\boldsymbol{demand}}$) for space heating and cooling, as well as for DHW is described in the chapters 4.3.1, 4.3.1 and 4.3.3. The electricity price for households is taken form Eurostat (Eurostat 2020).

$$\boldsymbol{c_{energy}} = \frac{\boldsymbol{p_{electricity}}}{\boldsymbol{Efficiency}} * \boldsymbol{e_{demand}} \tag{3}$$

➢ **Data used in the excel tool**

In the sheet b. Additional Data of the tool, table b-1 contains the electricity price for household consumers for all countries.

4.3.6 Fixed O&M

Fixed O&M are the annual cost of maintaining and operating an application.

The maintenance and fixed yearly electricity costs were gathered from Technology Data for heating installations (Danish Energy Agency and Energinet 2016) for the devices DH substation, HPs and electric boiler. Like for the equipment and installation costs, linear cost functions were created with the data to achieve precise values in dependency of the installed heat capacity.

➢ **Data used in the excel tool**

The functions and values can be found in the sheets of the respective devices.

4.3.7 Price change over lifetime

The price of electricity and DH tariffs can change over the lifetime of the equipment.

The user of the tool has the option to enter a forecast for the opex of the HP and the DH price. For example, see Figure 4-11: in the lifetime of 25 years, the opex rise from 100% to 120%. The tool calculates the average price change of the opex (in this case 110% of the current) and considers it in the results.

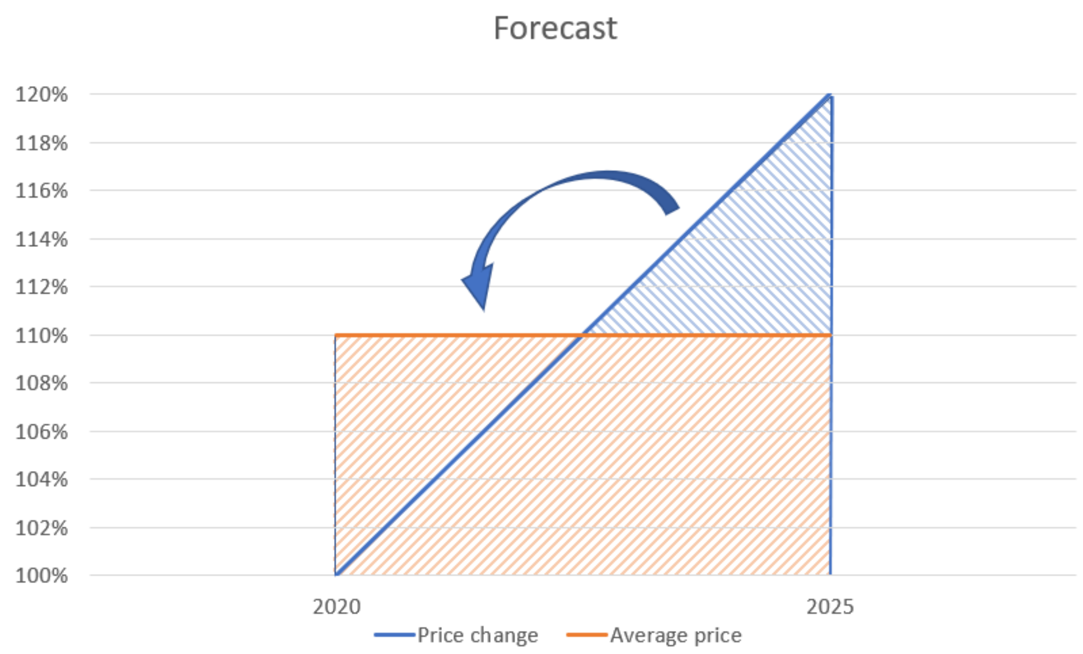

Figure 4-11: Consideration of a price change of the opex over the lifetime of the equipment

➢ Data used in the excel tool

The data can be entered in sheet 4, Other Information of the tool.

4.3.8 Flexibility for HP applications

Due to a flexible operation of the HP together with time-dependent electricity tariffs; or by using specific electricity tariffs for HPs, the electricity cost of HPs can be lower than the normal household electricity price.

Since no reliable and country-specific data for those aspects is available on a European level, the tool provides the option to enter the percentage for the reduction of the electricity price manually. This will be applied on the price and will lead to lower opex. From experience, this value can range between 0% and 5% (R. Hemm, 2022) for flexible HP operation. It is also possible to change the considered electricity price in €/kWh directly.

➢ Data used in the excel tool

The data can be entered in the sheet 3, Technology Information of the tool.

4.4 Further cost factors

4.4.1 VAT

The VAT are the valued added taxes, which may differ depending on the purpose of the cost and the country.

The VAT for DH and electricity as well as the standard value were gathered from the European Commission (European Commission 2020b).

A special case concerning the VAT is France, where a reduced VAT is applied on DH and electricity with at least 50% of renewable energy sources: instead of 20% it would be 5.5% (European Commission 2020b). If France is chosen, this is noted in the sheet *4. Subsidies and Taxes*. The VAT can be manually adjusted if the requirement of minimum 50% renewables is achieved.

➢ **Data used in the excel tool**

In the sheet b. Additional Data of the tool, the table b-1 contains the three different VATs for all countries.

4.4.2 Subsidies

Nearly all the considered countries provide subsidies on some heating installations to enforce sustainable and climate-friendly heating solutions. In most cases, the incentives target the investment costs.

The tool gives information about potential applicable subsidies in the different countries concerning DH and HPs. Up to four different subsidies per country are shortly summarised, also with regard to the requirements. The main sources are an analysis of incentives for the EEB (Sabbadin et al. 2020) and RES legal (RES LEGAL 2022e). However, the subsidies are for information only and they are not included in the calculations since they are very heterogeneous. They are included as information on the calculation sheet *4. Subsidies and taxes* in order to show the existence of the principle options.

If subsidies should be included in the results, the user has to enter them manually in sheet *4. Other Information* of the tool. For DH and HPs, the user can enter a discount in % or an absolute value. If two or more different subsidies apply, both values can be entered. Notice, when both values from one subsidy are known, only one should be entered. Otherwise, the discount will reduce the costs twice.

➢ **Data used in the excel tool**

In the sheet l. Subsidies of the tool, table l-1 shows potential applicable subsidies.

4.5 Validation by comparison with other heating cost calculators

The results and assumptions of the calculator are compared with those of established online heating costs calculators. Of course, there are differences in the level of detail regarding the input and output specifications, so the results should only be compared roughly.

The following table gives an overview.

Online calculator	Relevant input values for comparison	Output values	Comments
Heizkostenrechner | Kelag (Kelag 2022f)	• Refurbish-ment status • floor space • specific heat demand	• heat pump opex	• ground source HP and air HP are covered, but no DH • HP opex 30-60% higher, probably a COP of 2.5 (vs. 4.1 in the present calculation) was assumed
Energieinstitut (Energieinstitut Vorarlberg 2022g)	• region • number of persons • heat load • O&M costs	• energy demand for space heating and DHW • DH mixed price • substation cost • DH connection fee • HP equipment and installation • HP COP • electricity price	• heat demand for consumers in AB and MFH 3-4 times higher, for SFH only 6-19% deviation → probably SFH-specific values • electricity price of 0.12 €/kWh (vs. 0.21 €/kWh from Eurostat 2020) • COP of 3.3 (vs. 4.1) • → HP energy price of 0.04 €/kWh (vs. 0.05 €/kWh) • DH mixed price of 0.095 €/kWh (vs. 0.061 €/kWh) • Substation price can be twice as high, probably VAT already considered. Price change depending on heat load appears similar. • DH connection: 5000€ flat rate • HP (ground water) capex: 25-42% higher • Final opex not comparable because of different heat demand
Heizkostenrechner .com (Heizkostenrechner.com 2022h)	• region • refurbish-ment • number of persons • floor space	• energy demand for space heating and DHW • HP opex	• heat demand deviation between 8% and 100%: double heat demand in Switzerland, probably due to large floor space • Final opex not comparable due to different heat demand
IEA Residential Heat Economics Calculator (IEA 2022i)	• country	• energy demand for space heating and DHW • lifetime, capex and O&M costs for air/air and air/water HP	• O&M costs: deviation between 9% and 34% • no explanation about air/air HP and DHW • air/water HP capex deviation between 6% and 96%

The sheet *Comparison* in the excel tool provides detailed information about all input and output that was gathered, shown in two rows that can be compared. The upper row is the calculation with this tool, beginning with the consumer specifications and going on to heat demand, technology information and the cost results. If changes were applied to the calculation method (e.g., setting the domestic hot water demand to zero because the online calculator does not include it), the cells are marked in yellow. The lower row presents the values from the online heat cost calculator, where input cells are blue and output cells are green.

5 Comparison of influencing factors

5.1 Heating and cooling demand

The heating and cooling demands have an influence on the yearly energy costs. Table 6 shows the available data for the specific heating and cooling demand in kWh/(m²a) for the EU27+4 from TABULA (TABULA 2016d). For the heating demand, the average over the building types and refurbishment statuses has been built for all construction periods. Since only average values are available from the project hotmaps (Hotmaps 2022) for cooling, only one value per country is shown.

Table 6: Average specific heating demand over different building types and refurbishment statuses for different construction periods and average cooling demand, both in kWh/(m²a) for the EU27+4 + average values for each cluster

	heating							cooling
[kWh/(m²a)]	<1945	1945 - 1969	1970 - 1979	1980 - 1989	1990 - 1999	2000 - 2010	>2010	Average
Austria	88.2	89.4	89.6	67.2	78.1	72.6	64.3	30.1
Belgium	86.0	94.7	81.0	81.0	69.2	63.4	49.8	28.2
Bulgaria	116.2	86.2	84.9	84.9	84.9	62.9	55.4	42.9
Croatia								49.8
Cyprus	39.8	40.0	39.6	38.5	38.7	32.5	22.5	52.0
Czech Republic	99.9	96.9	93.5	80.9	75.8	71.5	52.7	31.5
Denmark	94.3	82.5	73.0	57.5	57.3	42.8	28.8	21.0
Estonia								28.0
Finland								26.9
France	73.8	68.9	61.9	43.9	42.5	42.2	28.1	32.6
Germany	83.2	80.1	72.9	65.9	62.6	50.3	44.1	27.1
Greece	68.2	70.8	70.2	63.9	62.9	46.5	33.7	49.9
Hungary	102.4	86.7	85.9	79.8	58.2	53.2	47.3	43.5
Iceland								
Ireland	87.5	81.0	55.9	84.0	78.8	67.4	41.9	11.9
Italy	78.7	76.6	65.3	65.3	63.2	42.7	42.7	45.6
Latvia								28.7
Lithuania								30.4
Luxembourg								27.8
Malta								51.7
Netherlands	75.2	71.3	59.6	55.5	48.0	38.6	24.6	17.4
Norway	131.6	139.1	121.3	125.9	121.7	79.8	49.8	
Poland	113.2	94.0	80.6	78.0	60.3	54.6	59.4	34.6
Portugal								37.5
Romania								46.3
Slovakia								40.5
Slovenia	86.4	71.0	64.9	63.4	63.4	47.5	47.1	44.6
Spain	8.3	7.7	6.8	4.3	4.3	4.3	2.5	48.3
Sweden	111.6	113.0	96.4	87.5	76.5	76.7	82.3	29.9
Switzerland								
United Kingdom	97.1	102.0	99.1	92.0	88.9	69.9	46.2	29.3
Central	85.7	84.7	81.2	64.9	70.3	61.4	54.2	28.6
East	103.6	86.9	82.0	77.4	68.5	56.3	52.4	37.1
North	112.5	111.6	96.9	90.3	85.2	66.4	53.6	25.9
South	48.7	48.8	45.5	43.0	42.3	31.5	25.4	47.8
West	83.9	83.6	71.5	71.3	65.5	56.3	38.1	24.5

Source: (TABULA 2016d; Hotmaps 2022)

Table 7 shows the U-Vales of different construction periods for the EU27+4 in W/(m²K) which are generated with data from the project hotmaps (Hotmaps 2022). The values for each, U-values and heating and cooling demand, are coloured by a scale, whereby dark indicates a relatively high demand/U-value and a lighter colour a relatively low value.

Table 7: U-Values of different construction periods of the EU27+4 (Hotmaps 2022)

[W/(m²K)]	<1945	1945 - 1969	1970 - 1979	1980 - 1989	1990 - 1999	2000 - 2010	>2010
Austria	1.34	1.64	1.26	0.94	0.54	0.43	0.45
Belgium	2.44	2.58	1.59	1.54	1.12	0.69	0.51
Bulgaria	1.81	1.67	1.54	1.25	1.00	0.71	0.49
Croatia	1.70	1.54	1.25	0.81	0.55	0.38	0.33
Cyprus	2.92	2.05	1.62	1.40	1.29	1.24	1.19
Czech Republic	1.52	1.48	1.26	1.02	0.73	0.59	0.47
Denmark	1.32	1.17	0.86	0.71	0.59	0.47	0.34
Estonia	0.74	0.56	0.47	0.42	0.39	0.39	0.38
Finland	0.87	0.77	0.68	0.56	0.48	0.43	0.37
France	2.19	2.47	1.60	0.98	0.83	0.54	0.43
Germany	1.68	1.44	1.14	0.77	0.68	0.49	0.45
Greece	2.89	2.61	2.39	2.22	1.80	1.32	1.01
Hungary	1.42	1.34	1.18	1.07	0.71	0.60	0.49
Iceland							
Ireland	2.19	2.14	1.98	1.31	0.99	0.70	0.45
Italy	2.12	1.93	1.82	1.37	1.07	0.87	0.69
Latvia	1.39	1.29	1.24	1.15	0.99	0.83	0.63
Lithuania	1.19	0.99	0.79	0.66	0.60	0.53	0.95
Luxembourg	2.19	1.67	1.15	0.81	0.67	0.54	0.52
Malta	2.99	2.33	2.00	1.84	1.76	1.71	0.52
Netherlands	2.07	1.83	1.67	1.04	0.69	0.60	0.53
Norway							
Poland	2.12	1.70	1.41	1.21	0.68	0.58	0.51
Portugal	2.76	2.55	2.32	2.20	2.05	1.47	1.01
Romania	1.84	1.69	1.58	1.49	1.42	0.95	0.59
Slovakia	2.19	1.90	1.67	1.38	1.18	0.90	0.59
Slovenia	1.70	1.54	1.25	0.81	0.55	0.38	0.33
Spain	2.99	2.56	2.30	1.51	1.30	1.20	1.09
Sweden	0.86	0.75	0.67	0.60	0.53	0.53	0.38
Switzerland							
United Kingdom	2.39	1.96	1.54	1.02	0.84	0.63	0.55

For the heating demand, the data of 12 countries is not available and, therefore, filled in by the average value for the respective country clusters, which can lead to incorrect demands. Overall, the demand decreases the later the building was constructed. In some countries, the demand of the construction years 1945-1969 is lower than the demand of buildings built before 1945. A possible reason for that can be the lack of building materials in the post-war period, which leads to less insulation of the building. This can also be seen in Table 7 where the U-values are also higher during that period. The U-values reveal how buildings are constructed in different countries. While the northern buildings of Finland and Sweden already had U-values underneath 1 W/(m²K) before 1945, other countries achieved such low values as recently as 1970/1980. Whereby in some of the southern countries like Cyprus or Spain, buildings do not need this much insulation due to warm weather conditions.

As expected, the northern countries have the highest heating demands in general, but because of their low U-Values the heating demand of buildings after 2010 of the clusters North, Central and East are nearly identical. Even considering the low insulation standards, the southern countries still have the lowest heating demand, due to the warmer climate. On the contrary, the south has the highest cooling demand, followed by the eastern countries. The cooling demand in Ireland is even lower than in the northern countries. A reason for this could be the mild climate in Ireland during summertime, whereby the northern countries tend to have a short but hotter summer.

Figure 5-1 shows the average HDD and CDD from 2011-2020 of the EU27 (Eurostat 2022). There is a wide variation across the EU. Finland, Sweden and Estonia have the highest HDD, which means they have higher demands for heating compared to the rest of the EU. Cyprus, Malta and Greece have the highest CDD, while Ireland, Finland and Sweden have the lowest CDD (under one) (Eurostat 2022).

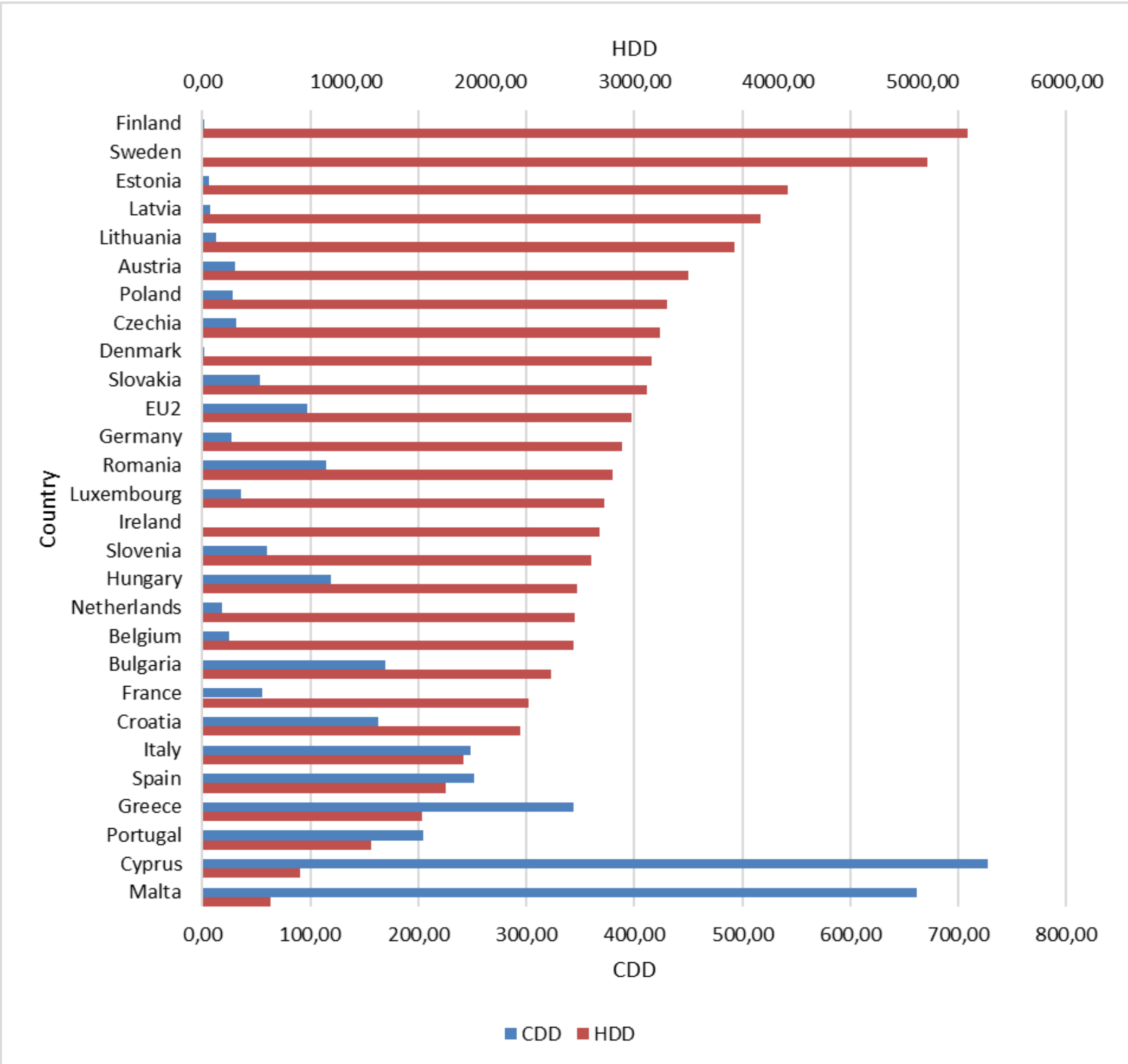

Figure 5-1: **Average heating and cooling degree days from 2011-2020 of the EU27 (Eurostat 2022)**

5.2 Domestic hot water (DHW) demand

The demand for DHW not only depends on the number of people living in the building but also on the country where the consumers live. Figure 5-2 shows how different the consumer behaviour is in the different European countries. With 1,95 MWh/a Denmark has the highest DHW demand per person, and Lithuania has the lowest with 0,55 MWh/a. There is no data available for Iceland and Switzerland.

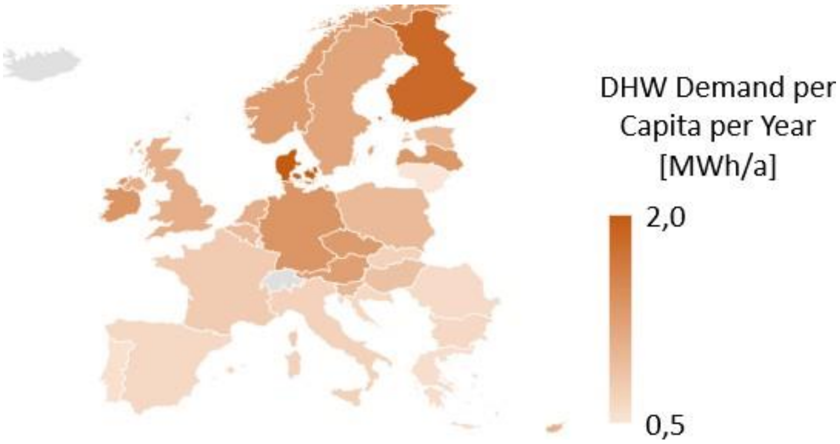

Figure 5-2: **Domestic hot water demand In MWh per Capita and year in European countries (Eurostat, 2019)**

5.3 Electricity prices and labour costs

The electricity price has an influence on the energy cost of the HP or boiler and the labour cost influences the installation costs.

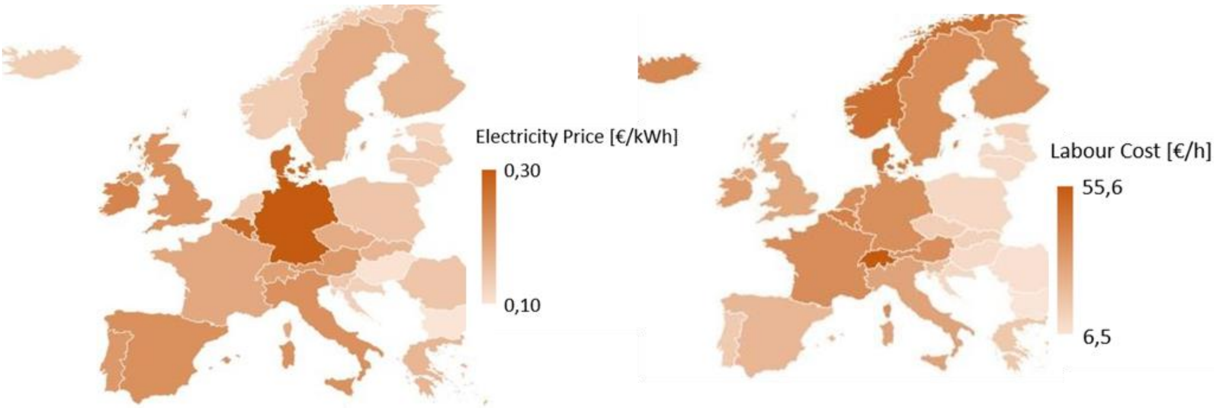

Figure 5-3: **Electricity price for household consumers in €/kWh and labour cost in €/h of the EU27+4 (Eurostat 2020; Statista 2020)**

Figure 5-3 shows how the electricity price for household consumers and the labour cost differs within the EU27+4 countries. The highest electricity prices are in Germany with 0.30 €/kWh followed by Denmark and Belgium. In general, the central and southern countries have the highest prices, while the electricity cost in the east and north are the lowest. The prices in Bulgaria are only one third of the ones in Germany.

The labour cost has an even wider variation. As well as the electricity price, the labour cost is also lower in the eastern countries. The highest costs are in the center and the north of Europe, with Switzerland having over 8 times higher costs than Bulgaria.

5.4 The required floorspace

The floor space per person influences the heating and cooling demand of a building as well as the size of the installed H&C equipment (HP or DH substation). It differs in the European countries and depends on the type of building. Figure 5-4 shows the floor space per person in two different building types (Rapf and Economidou 2011).

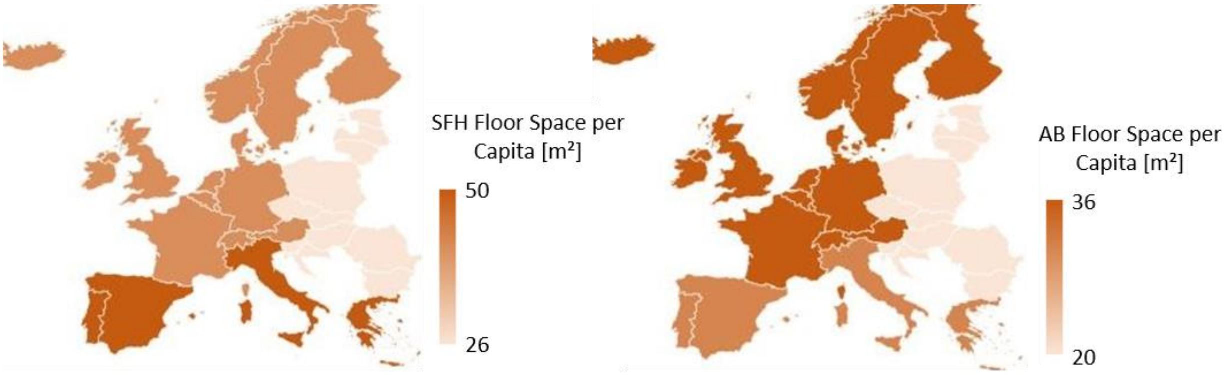

Figure 5-4: Floor space per person in m² for SFH and AB in the EU27+4 (Rapf and Economidou 2011)

Generally, the floor space per person in a SFH is higher than in an AB. In both, SFH and AB, the least floor space is used in the eastern countries. In the central and northern countries the floor space is equal for each building type. The southern countries need the most space per person in SFH, while the central and northern countries use the most floor space in AB.

5.5 Interest rate

The interest rate has an impact on the annualised capex. The data considered in the tool is only for the countries of the eurozone, which leads to the assignment of cluster values for over one third of the countries. For example, in the cluster North only data for Finland is available and no average value can be built which can lead to inaccurate numbers. Figure 5-5 shows the available data for the interest rate.

Figure 5-5: Interest rate in the countries of the eurozone (Oenb 2022)

5.6 Comparison of influencing factors within a cluster

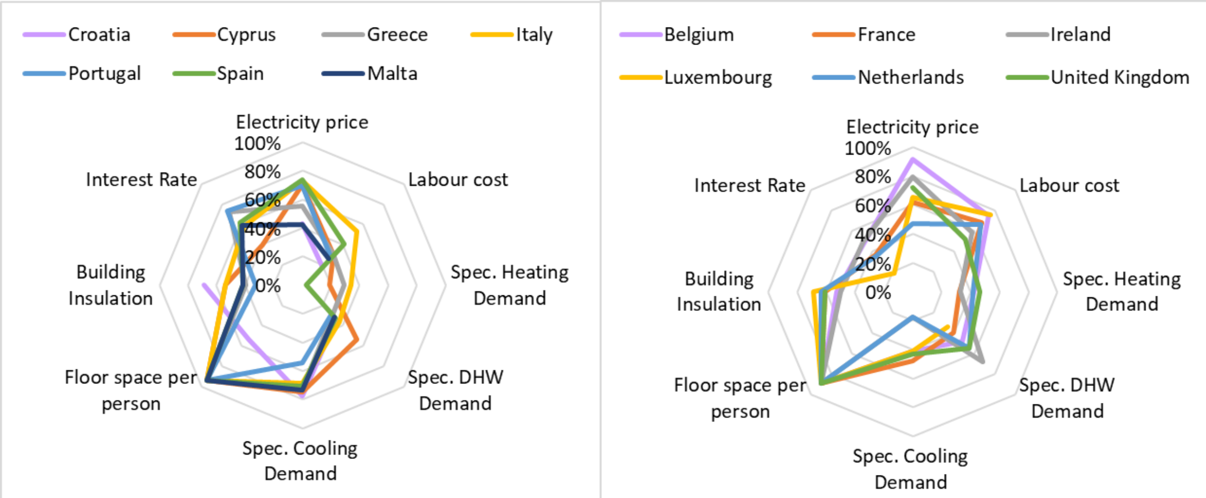

Figure 5-6: Comparison of influencing factors of countries within the clusters South and West

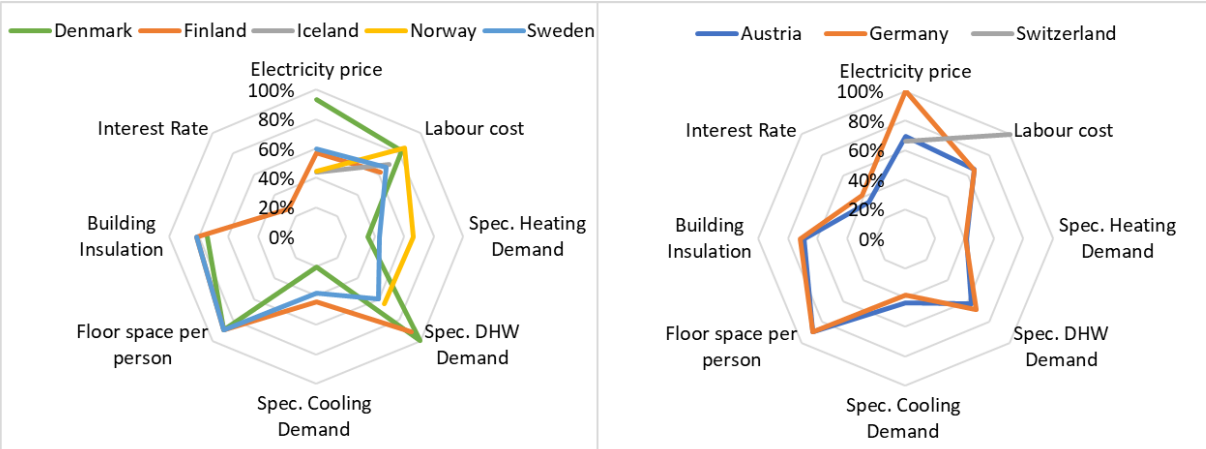

Figure 5-7: Comparison of influencing factors of countries within the clusters North and Central

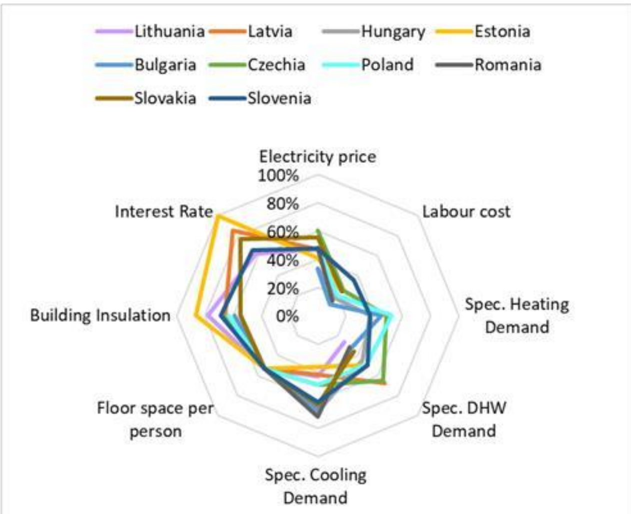

Figure 5-8: Comparison of influencing factors of countries within the cluster East

Generally, a clear pattern appears for the countries within one cluster, with only a few outliers. Examples for such outliers are the floor space in Croatia, the cooling demand in the Netherlands or the electricity price in Denmark and Germany. It can be said that the composition of the clusters appears to be reasonable. Countries that are not part of the EU (Norway, Iceland, Switzerland and the UK) have the least data availability, whereby the UK has the best availability out of the four because of their resent exit from the EU. When comparing the clusters with each other the *South* and the *West* seem to be similar. Whereby the *South* has slightly higher values for the interest rate and the cooling demand and lower values for the space heating and DHW demand as well as the building insulation and labour cost. Also, the *Central* and the *West* look similar. Except the average values in the *Central* are slightly higher than the one in the *West*. The *Central* and the *North* have the highest values in all categories except in the interest rate and the cooling demand. The *East* has the lowest values regarding the labour cost and electricity prices but the highest ones regarding the interest rate.

6 Results: Cost comparison by country

The following section compares and discusses the annual costs for DH, Air/Air HPs, Air/Water HPs and Ground/Water HPs.

For a fair comparison, the calculations are based on an average EU consumer, who lives in a multifamily house, built between 1990 and 1999, with a usual refurbishment, in a suburban area. The average EU consumer owns his flat, lives in a household of three persons and is not of low social status.

Consumer Characteristics	Average EU Consumer
Building Density	Suburban
Dwelling Type	Multifamily House
Construction Period	1990-1999
Renovation Status	Usual Refurbishment
Household Size	3 Persons
Tenure Status	Owner
Low Social Status	No

6.1 District heating costs

Figure 6-1 below shows the breakdown of the annual costs for a DH – System. Generally northern countries like Denmark, Norway and Sweden as well as Germany are the most expensive when it comes to DH Systems. This can be related to the fact of generally lower temperatures and higher heating demand. In high income countries, maintenance influence the total costs more due to higher labour costs. For the annualised capex, the interest rate (Figure 5-5) is a major factor. Therefore, Estonia, with the highest interest rate, has a high annualised capex, while labour costs are quite low. Croatia has the lowest costs, due to generally warmer climate and low labour costs.

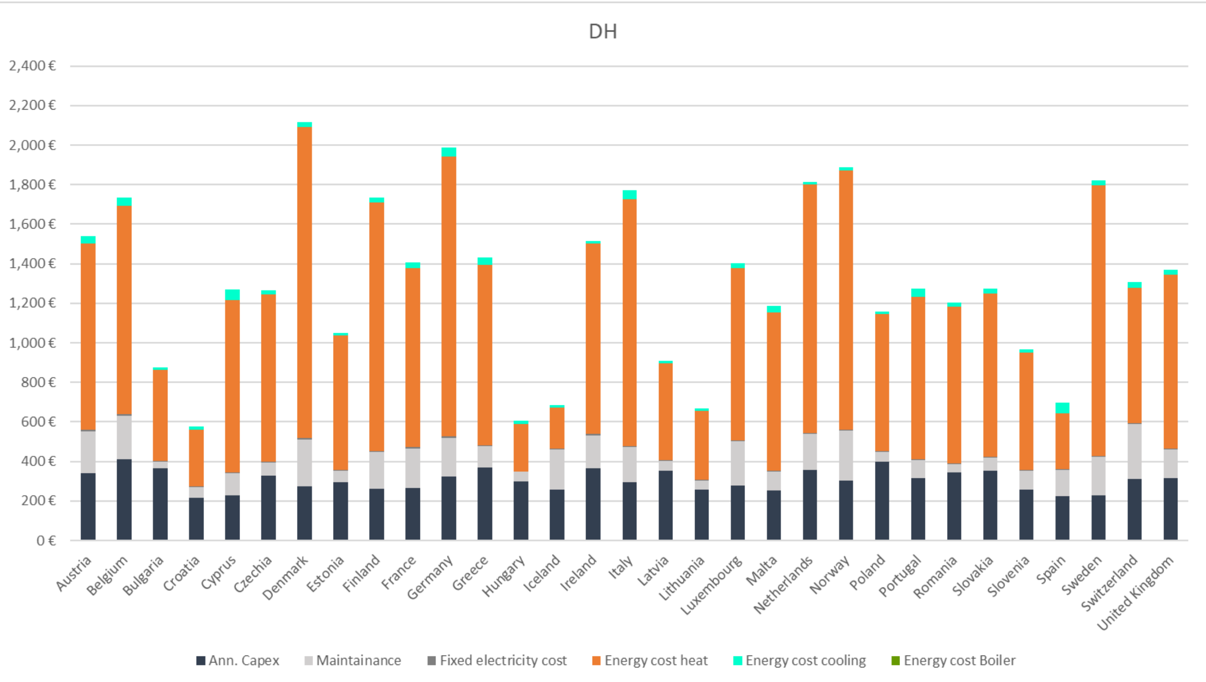

Figure 6-1: DH - Breakdown of Annual Costs

Figure 6-2 below shows the total annual cost of a DH system in a country comparison. While in western and northern Europe DH prices are high, it gets lower in eastern Europe. Denmark is the most expensive with an annual cost of 2117.95 € per year and Croatia has the lowest cost with 578.78 per year. In most cases, Croatia has the lowest overall costs due to low labour costs and warm temperatures, while Denmark is among the highest labour costs with generally colder temperatures.

Figure 6-2: DH - Annual Costs Country Comparison

6.2 Air/Air heat pump costs

Figure 6-3 below shows the breakdown of the annual costs for an Air/Air HP in Europe. The added cost of the boiler makes the Air/Air HP one of the most expensive systems. Denmark and Germany are the most expensive countries and Croatia has the lowest overall costs. As the Air/Air HP cannot produce hot water, an electric boiler was considered in the calculation. Due to low electricity prices and low warm water demands, Malta and Croatia are among the lowest costs.

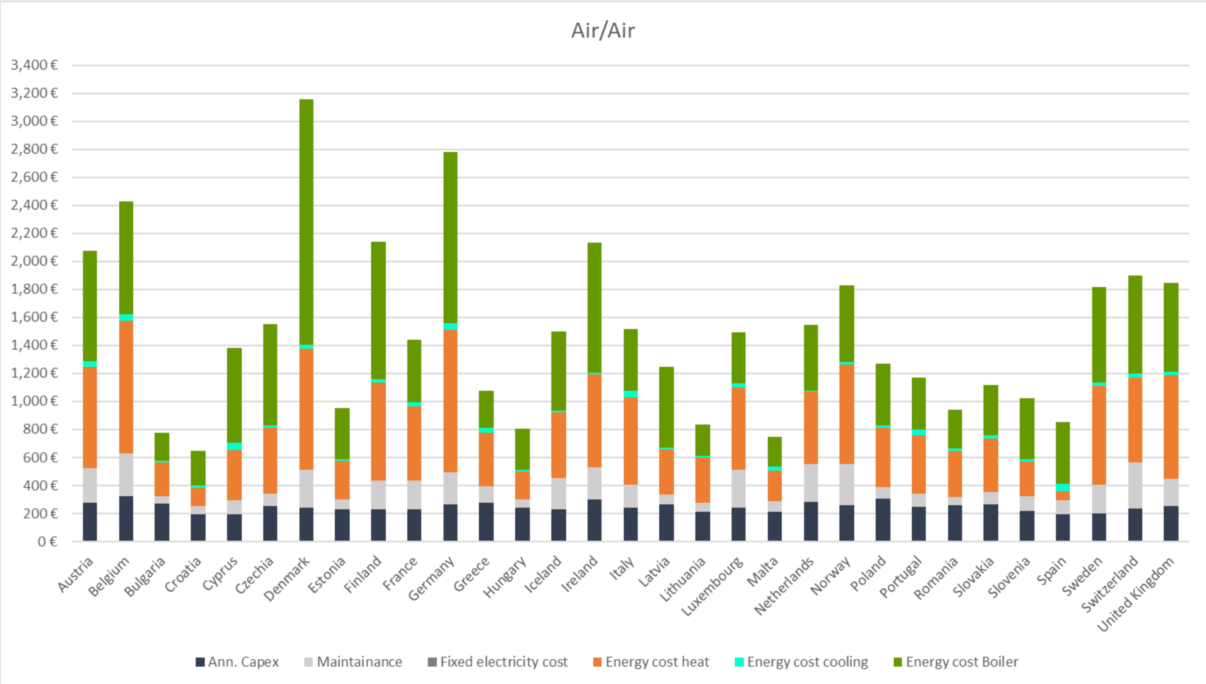

Figure 6-3: Air/Air HP - Breakdown of Annual Costs

Figure 6-4 below shows the country comparison of the annual costs of Air/Air HPs. Especially, central Europe ranks among the most expensive areas for Air/Air HPs and eastern and southern Europe is less expensive. Air/Air HPs also show the greatest difference between highest and lowest price. Countries with lower electricity prices have lower overall costs for the Air/Air HP because of assumed electric boiler.

Figure 6-4: Air/Air HP - Annual Costs Country Comparison

6.3 Air/Water heat pump costs

Figure 6-5 shows the breakdown of the annual costs of an Air/Water HP. High energy costs for heating play a major role in the cost structure. Denmark, Germany and Belgium are the most expensive countries, while Croatia is once again the cheapest. This can be related to low demands in Croatia, while the capex in Belgium is high compared to other countries.

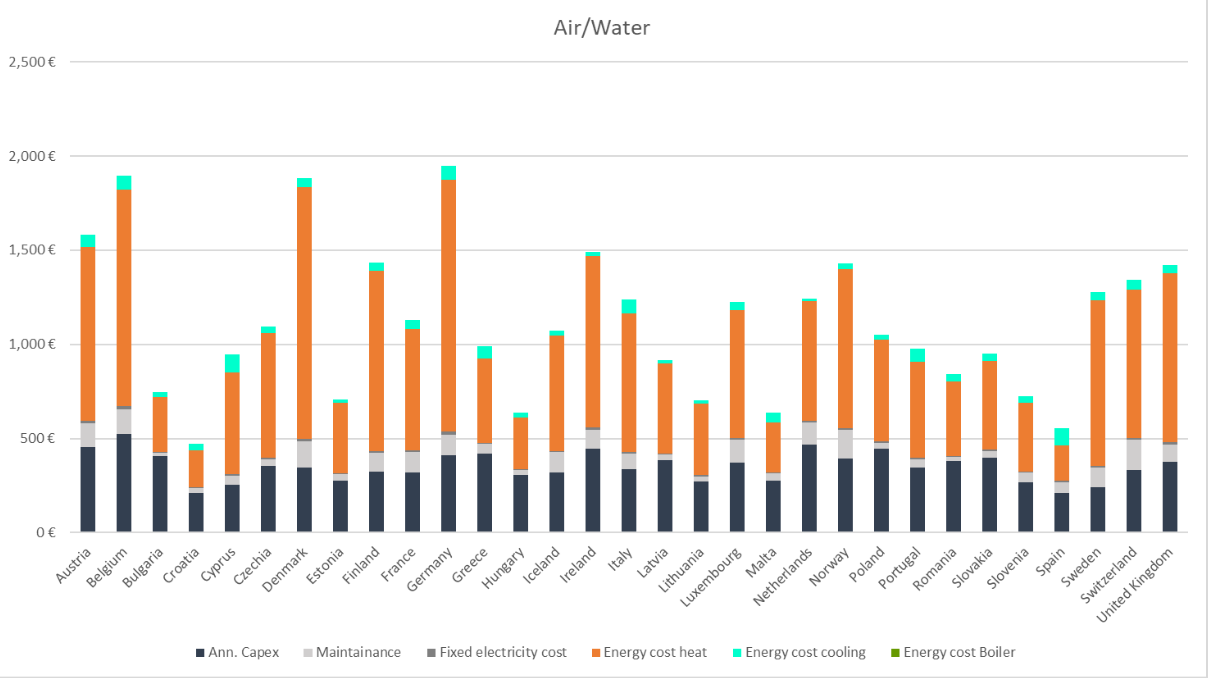

Figure 6-5: Air/Water HP - Breakdown of Annual Costs

Figure 6-6 below show the country comparison of the total annual costs for an Air/Water HP. Germany and the surrounding countries show the highest costs for the Air/Water HP, while mainly southern and south-eastern countries show lower costs, due to low demands and lower labour costs.

Figure 6-6: Air/Water HP - Annual Costs Country Comparison

6.4 Ground/Water heat pump costs

In Figure 6-7 below shows the breakdown of the costs for a Ground/Water HP. Germany and its surrounding countries range also the most expensive countries, with Croatia as the cheapest once again due to low costs and low demands. On average, the Ground/Water HP ranges as the cheapest system compared to the three other systems above. A great cost factor is once again the high energy costs for heating, while also the capex in Belgium is quite high.

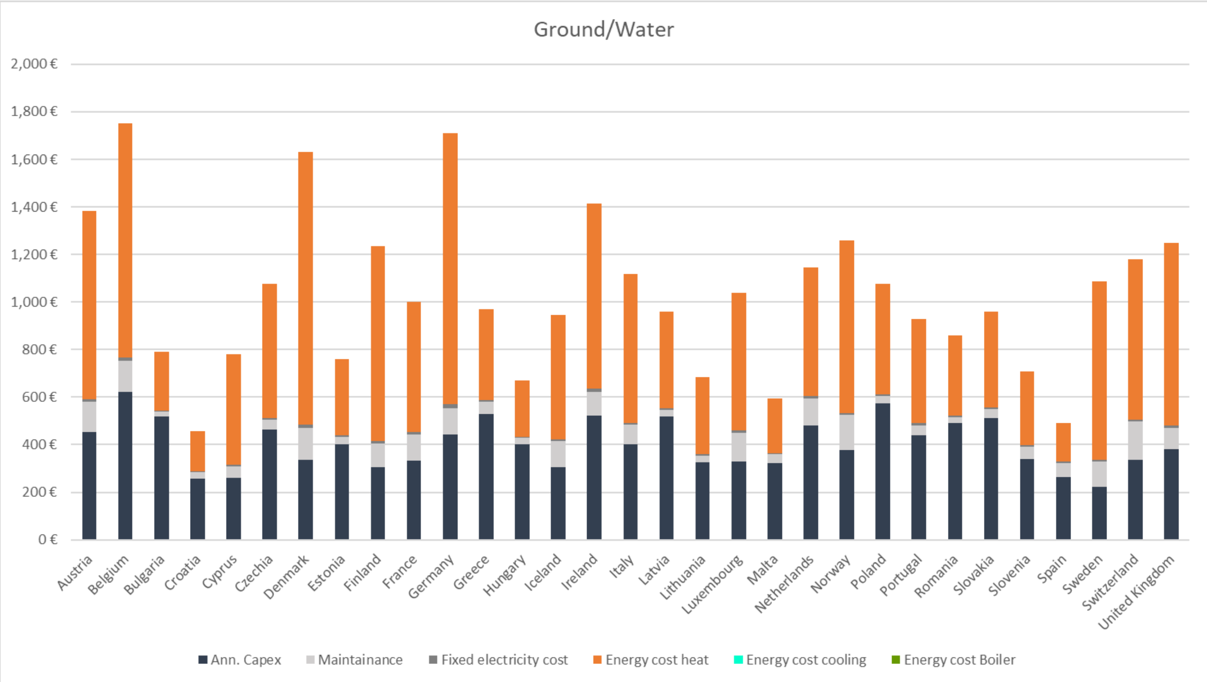

Figure 6-7: Ground/Water - Breakdown of Annual Costs

Figure 6-8 below show the country comparison of the total annual costs for an Ground/Water HP. Germany and the surrounding countries show the highest costs for the Ground/Water HP, while mainly southern and south-eastern countries show lower costs, due to low demands and lower labour costs. In Belgium the high capex cost plays a major role.

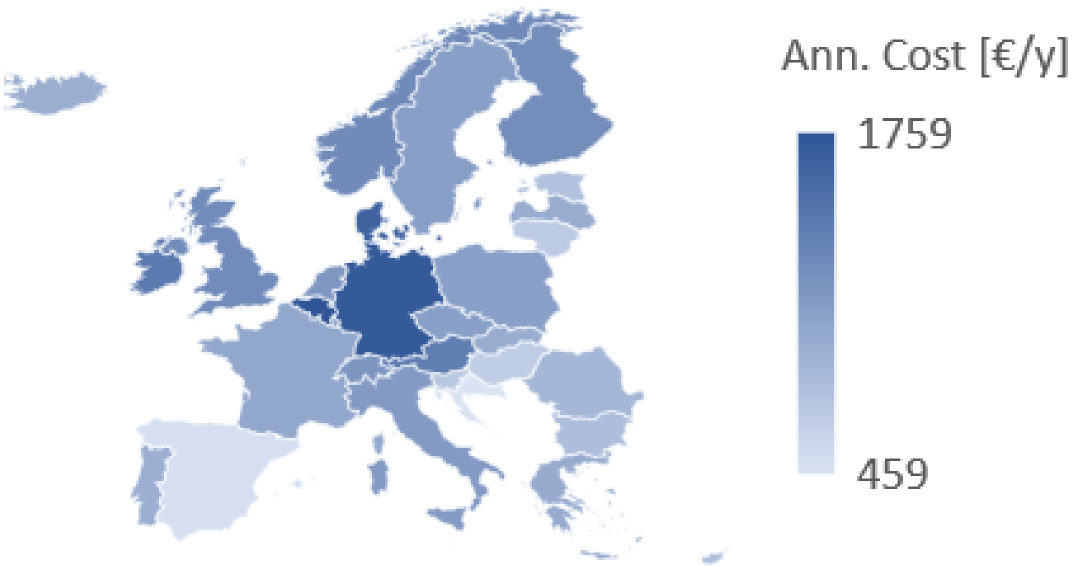

Figure 6-8: Ground/Water HP - Annual Costs Country Comparison

6.5 Summary

Figure 6-9 below shows the total cost comparison for each country and technology. In Belgium, Denmark and Germany, the cost for Air/Air HPs is significantly higher compared to the other technologies. This can be related to the highest electricity costs in Europe. Croatia, Hungary and Spain are the cheapest countries, due to low heating demand, low labour costs and low electricity prices.

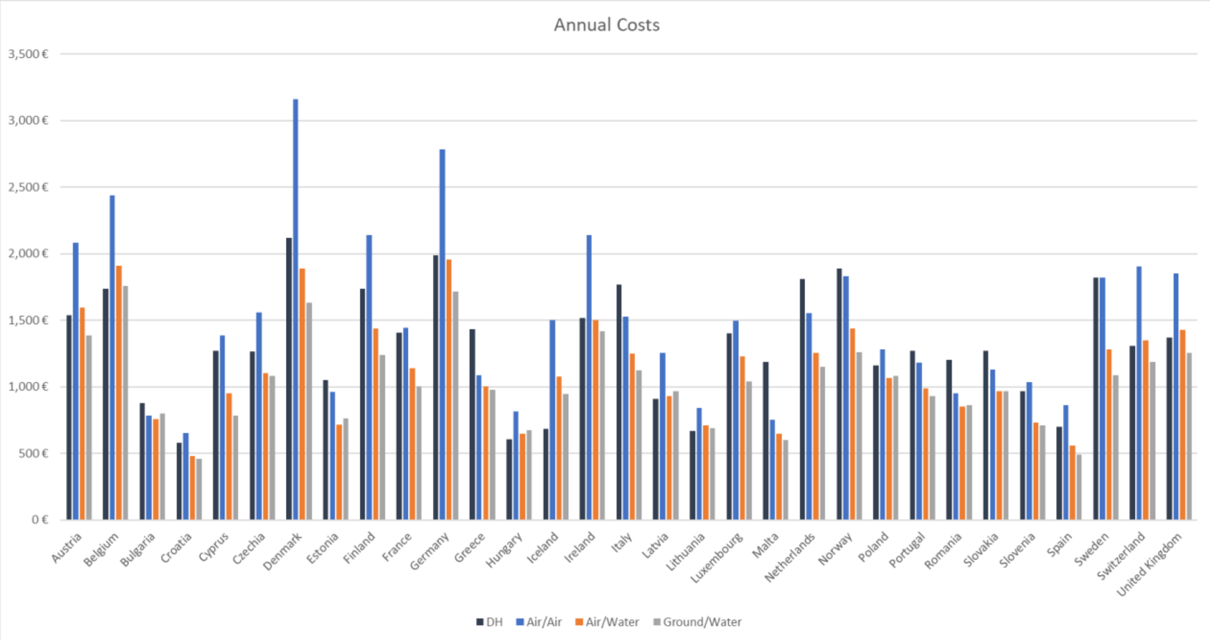

Figure 6-9: Technology Cost Comparison of all Countries

Figure 6-10 below shows the comparison of the annual technology cost by country cluster. Central Europe with moderate temperatures, higher labour costs and higher electricity costs is the most expensive cluster. Followed by the North, with colder, darker winters and generally higher labour costs. The western European countries resemble the north and the central cluster. The fact that all systems are slightly cheaper could be related to the milder temperatures. The southern cluster is among the cheapest, due to low labour costs and generally milder temperatures. For the eastern cluster the lower labour and energy costs play a more significant role, while also milder temperatures for more southern countries of the eastern cluster come into play.

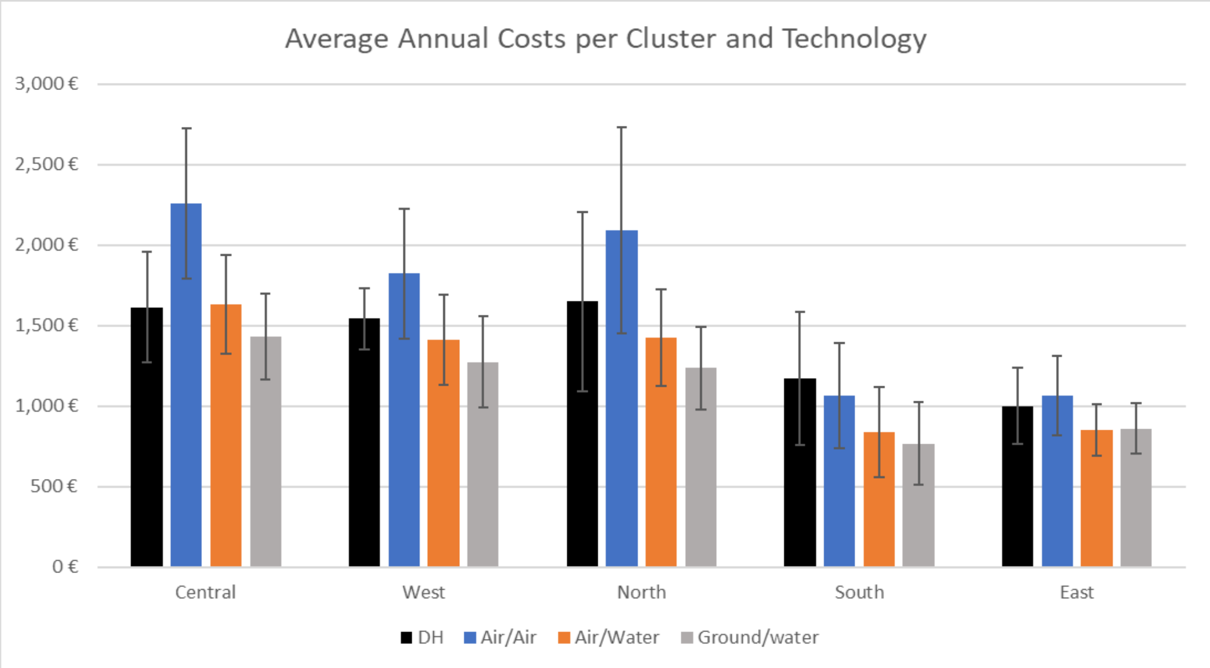

Figure 6-10: Technology Cost Comparison by Cluster

Figure 6-11 shows the mapped technology costs for each country. While for DH mainly the central European countries and the Scandinavian countries are among the most expensive ones, for HPs it comes down to Germany and its surrounding countries.

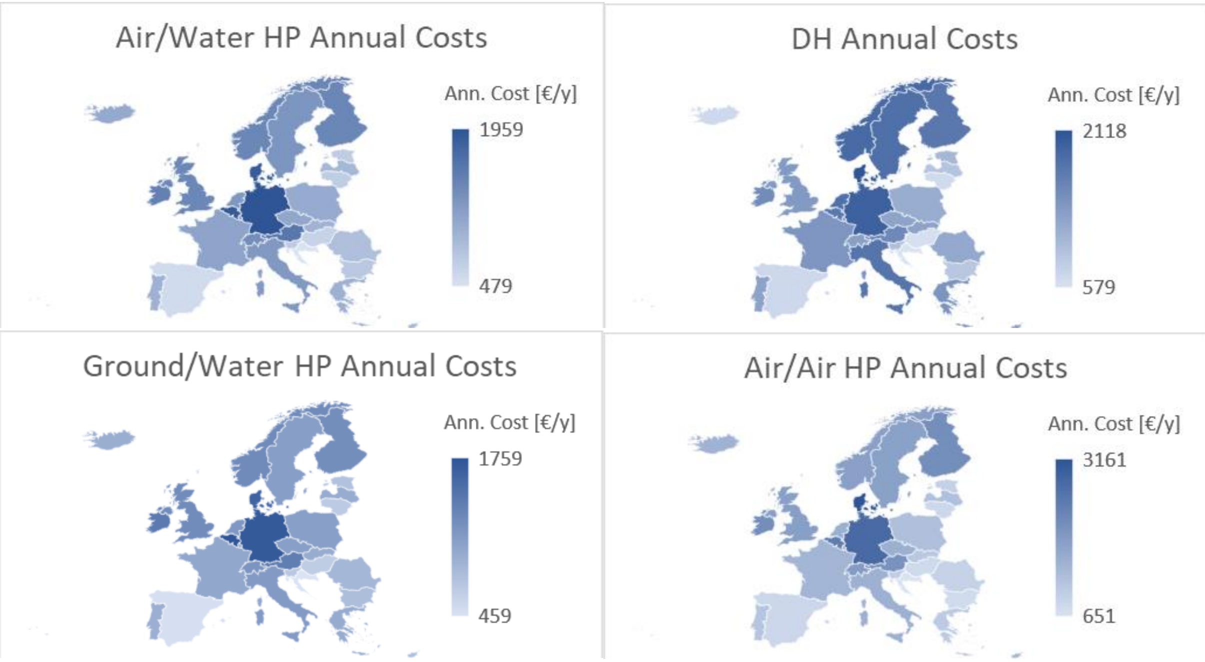

Figure 6-11: Technology Cost Comparison of all Countries - Map

7 Conclusions and data gaps

The overall conclusions and data gaps can be summarised as follows:

- One of the key challenges for calculating the end user costs was to identify and collect the required data for all countries considered.
  - International statistics, databases, and other sources (especially research projects and studies) do not necessarily consider all countries. In this report, average values from the respective cluster have been taken to solve this issue. However, this resulted also in inaccuracies.
  - Especially, DH tariffs are very individual for each city (sometimes even within a city), and very little data on the tariffs is easily available. In fact, most DH networks have their own tariffs, many publish this data on their website in a local language. Since more than 6 000 DH exist in Europe (counting only cities with more than 5,000 inhabitants), a network-specific evaluation of the individual DH tariff would be Sisyphean labour.
- For calculating realistic and fair costs, a set of complex technical combinations and conditions had to be considered.
  - One of the challenges was the preparation of DHW that cannot be prepared using air/air HPs. Also, it was considered that sometimes DH is turned off in summer times. For both cases, an electric boiler was integrated for DHW preparation.
  - Furthermore, it was required to research a wide range of data sources, engineering rules, and experts experience to properly calculate the costs for H&C for all types of residential end users as well as countries.
- There is very little data on cooling and especially district cooling.
  - There is a low data availability for cooling demand and cooling capacities. Especially, the share of building area that is cooled is mostly unknown, i.e. unlike for heating, people do not usually cool their whole apartment area.
  - In Europe, district cooling is very rarely used for residential customers. So this was excluded from the calculation and an air/air HPs were used.

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A.1 Appendix 1: Tool usability

For the user of the tool, there are six visible sheets: the intro gives a short description of the function of the tool, the input sheets 1-4 and the results of the calculation. To use the tool, it is recommended to go through the sheets in the order shown in Figure A-1. This chapter provides a detailed description of all output and input sheets.

Intro	1. Consumer Information	2. Building Information	3. Technology Information	4. Other Information	Results

Figure A-1: Visible sheets of the calculation tool

Figure A-2 shows the colour code of the sheets. The colour varies depending on whether the input is optional or mandatory, or the value is set by default.

	Default value
	Input is mandatory
	Input is optional

Figure A-2: Colour code

A.1.1 Consumer Information

To run the calculation, only three entries are necessary, which can be found in the sheet *1. Consumer Information*. At first, the country is chosen, and if only heating, or heating and cooling should be considered. Depending on the country, four typical consumers are suggested with seven properties, as shown in the screenshot below. If none of these consumers is suitable, it is possible to create a custom consumer. For reference, there are charts visualising the building situation in the chosen country and comparing significant parameters to the EU average. Next to the cell *Calculate for*, one of the displayed Typical Consumers or the Custom Consumer must be selected. For creating country reports, a directory needs to be entered.

Country	Austria
Heating and/or cooling?	Heating and Cooling
Directory for Country Report	

Consumer Charasteristics	Typical Consumer 1	Typical Consumer 2	Typical Consumer 3	Typical Consumer 4	Custom Consumer
Building Density	Urban	Suburban	Suburban	Rural	Urban
Dwelling Type	Apartment Block	Multi Family House	Single Family House	Single Family House	Apartment Block
Construction Period	1945-1969	<1945	1990-1999	1945-1969	1970-1979
Renovation Status	No Refurbishment	Usual Refurbishment	Advanced Refurbishme	Usual Refurbishment	No Refurbishment
Household Size	1 Person	2 Persons	3 Persons	4 Persons	2 Persons
Tenure Status	Owner	Tenant	Tenant	Owner	Tenant
Low Social Status	No	No	No	No	No

Calculate for	Custom Consumer

Create Country Report

Create **all** Country Reports

Figure A-3: Content of the sheet "1. Consumer Information" of the excel tool

The tool also allows to create individual PDF reports for providing an overview of the country-specific values by clicking on "create country report". A vba script is started that creates either a country report for the country selected, or for all countries investigated (EU27 + UK, Iceland, Norway, and Switzerland). The reports are saved in the "directory for country reports".

A.1.2 Building Information

In the second input sheet *2. Building Information,* all values are already filled with default values. These values are estimated values for each country based on statistics, and contain data about the building itself, as well as its heating, cooling and DHW needs. All the default values can be overwritten by the user in the column "Manual Value". If a manual value is set, the number in the column "Input for calculation" will change to this value and will be used in the further calculation.

The dwelling size refers to one housing unit in a multifamily house and to one flat in an apartment block, while the building size refers to the whole apartment block and multifamily house. In case a single-family house or terraced house is chosen, the dwelling size equals the building size and only the dwelling size can be filled in.

	Default Value	*Input for calculation*	*Manual Value*
Facility Specifications			
Size of the dwelling in m²	72	72	
Size of building in m²	936	936	
Number of dwelling units in building	13	13	

Figure A-4: Content of the sheet "2. Building Information" of the excel tool regarding facility specifications

The heating and cooling specifications contain the capacity of the installed system and the energy demand. In case of cooling, the share of the floor space that should be cooled can be changed (see 4.3.2 for more information).

Space Heating System Specifications			
Capacity of the heating system in kW (building)	82,85	82,85	
Specific energy demand for space heating in kWh/m²year	112,00	112,00	
Energy demand for space heating in MWh/year (dwelling unit)	8,06	8,06	
Cooling System Specifications			
Capacity of the cooling system in kW (building)	29,80	29,80	
Specific energy demand for space cooling in kWh/m²year	19,94	19,94	
Share of the floor space that has to be cooled %	0,50	0,50	
Energy demand for space cooling in MWh/year (dwelling)	0,72	0,72	

Figure A-5: Content of the sheet "2. Building Information" of the excel tool regarding specifications for space heating and cooling

The consumer can choose, if DHW should be considered in the calculation. If yes, the energy demand and the needed capacity can be adapted. For DH, the consumer can choose if DHW is also provided during the summer months. If not, the number of months can be chosen, and the tool will add the capex for an electric boiler and its opex for the selected period.

Domestic Hot Water System Specifications			
Domestic Hot Water (DHW) included?	Yes	Yes	
DHW energy demand per Person in MWh/a	1,25	1,25	
DHW capacity in kW per Person	0,25	0,25	
DHW capacity in kW (building)	6,50	6,50	
Is the district heating system turned off during summer?	No	No	
If the DH is turned off, for how many months per year?	4	4	

Figure A-6: Content of the sheet "2. Building Information" of the excel tool regarding DHW

A.1.3 Technology Information

The sheet *3. Technology Information* contains price information for all technologies considered in the tool and are set for all parameters, as well as upper and lower uncertainties. All values can be overwritten by the user.

For DH, it is also possible to select, if the consumer has to pay for the substation and which type of substation will be installed, as well as if a discount should be considered.

	Lower uncertainty	Default Value Estimated Value	Upper uncertainty	Input for calculation	Manual Value
District Heating					
DH Tariff					
Heating Price in EUR/MWh	54	61	68	61	
Substation					
Who pays for the substation?		Consumer		Consumer	
Substation Type		Indirect		Indirect	
Is there a discount on the substation?		No		No	
Discount in percent		0,00%		0,00%	
Substation equipment price in EUR	5467	6834	8201	6834	
Substation installation costs in EUR	1878	2347	2816	2347	
Lifetime in years		25		25	
Connection Fee					
Does the provider charge a connection fee?		Yes		Yes	
Distance from building to DH network in m	8	10	12	10	
Connection equipment price in EUR	2055	2568	3082	2568	
Connection installation costs in EUR	850	1063	1276	1063	
Fixed yearly costs					
Maintenance costs for the substation in EUR		51		51	
Electricity costs for the substation in EUR		15		15	

Figure A-7: Content of the sheet "3. Technology Information" of the excel tool regarding DH

For HPs, the preferred type of the selected country is suggested, but can be changed by selecting another type from the dropdown list. Also, a reduction of the electricity price can be entered (for more information see 4.3.8).

	Lower uncertainty	Default Value Estimated Value	Upper uncertainty	Input for calculation	Manual Value
Heat Pump					
HP preference in your country		Air/Water		Ground/Water	Ground/Water
Electricty price EUR/kWh		0,21		0,21	
Reduction of the electricity price (HP tariff or flexibility) in percent		0,00%		0,00%	
Air/Air					
Equipment costs in EUR	14628	18285	21942	18285	
Installation costs in EUR	2930	3663	4396	3663	
Capex in EUR	17559	21948	26338	21948	
Energy Price heating in EUR/MWh	33,78	62,09	84,44	62	
Energy Price cooling in EUR/MWh	10,56	17,17	45,99	17	
Maintenance costs in EUR/a	1744	2181	2617	2181	
Fixed yearly electricity costs in EUR/a	0	0	0	0	
Lifetime in years		15		15	

Figure A-8: Content of the sheet "3. Technology Information" of the excel tool regarding HPs

For DHW it is possible to choose, if it should be provided by an electric boiler in case of no supply by the DH network in summer, or in case of an Air/Air HP. If "no" is selected, the cost for suppling the building with DHW is not included in the calculation.

	Default Value Lower uncertainty	 Estimated Value	 Upper uncertainty	Input for calculation	Manual Value
Electric Boiler for Domestic Hot Water					
Electric boiler supplementing district heating?		No		No	
Electric boiler supplementing heat pump?		No		No	
Electricty price EUR/kWh		0,21		0,21	
Capex					
Equipment costs in EUR	1825	2282	2738	2282	
Installation costs in EUR	627	784	940	784	
Opex					
Energy price in EUR/MWh		211		211	
Fixed yearly costs					
Maintenance costs EUR/a	17	21	26	21	
Lifetime in years		30		30	

Figure A-9: Content of the sheet "3. Technology Information" of the excel tool regarding electric boilers

A.1.4 Other Information

The sheet 4. Other Information contains the VAT, information about subsidies and the option to consider a price change of the opex (for more information see 4.3.7). The user can also choose, if an interest rate should be applied on the capex, and how high it should be.

	Default Value	Input for calculation	Manual Value
Value Added Tax (VAT)			
VAT on District Heating in percent	20,00%	20,00%	
VAT on Electricity inpercent	20,00%	20,00%	
Standard VAT in percent	20,00%	20,00%	
Interest rate			
Should an interest rate for a loan be considered?	No	Yes	Yes
Interest rate in percent	2,73%	2,73%	
Price change over the device's lifetime			
Expected price of HP Opex in 50 years in percent	100%	100%	
Expected price of DH price in 25 years in percent	100%	100%	

Figure A-10: Content of the sheet "4. Other Information" of the excel tool regarding VATs, the interest rate and price developments

The tool gives information about possible subsidies in the selected country, which are not automatically considered in the calculation.

If they should be considered, or other discounts are known, the user can either enter a discount in percent or an absolute value (if both are entered, both will be reducing the cost) for DH and HPs (for more information see 4.4.2). These values will be considered in the calculation.

Subsidies			
Discount on district heating capex - fixed value in EUR	0,00	0,00	
Discount on district heating capex in percent	0,00%	0,00%	
Discount on heat pump capex - fixed value in EUR	0,00	0,00	
Discount on heat pump capex in percent	0,00%	0,00%	

Information about subsidies in Austria		
Subsidy	**Effect/Requirements**	**Source**
"Out of Oil and Gas": switching from oil or gas heating to	50% (max. 7500€) of	https://www.umweltfoerderung.at
Local incentives	-	https://www.coolproducts.eu/wp-
-	0	0
-	-	-

Figure A-11: Content of the sheet "4. Other Information" of the excel tool regarding subsidies

A.1.5 Results of the excel tool

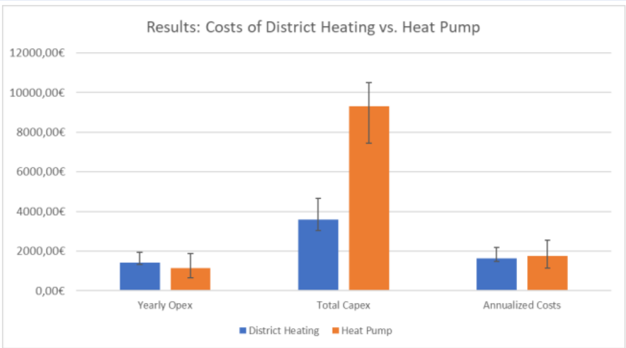
The sheet *Results* presents the calculated costs for the selected data for HPs and DH with an upper and lower value. The costs are also visible in two diagrams. One shows a cost comparison between HPs and DH for opex, capex and annualised costs including their uncertainty. The other diagram shows the annualised cost divided into capex and opex for HPs and DH.

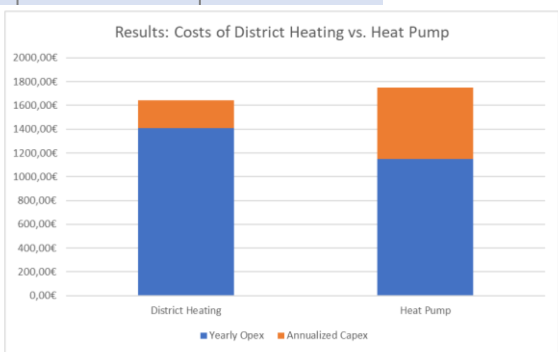
Final Results

OPEX			
incl. VAT	**Opex**	Lower Limit	Upper Limit
District Heating yearly OPEX	**1 409,38 €**	1 328,59 €	1 944,83 €
Heat Pump yearly OPEX	**1 151,49 €**	666,22 €	1 869,17 €

CAPEX			
incl. VAT	**Capex**	Lower Limit	Upper Limit
District Heating total CAPEX	**3 602,21 €**	3 046,99 €	4 671,43 €
Heat Pump total CAPEX	**9 307,24 €**	7 445,79 €	10 499,80 €

Total cost of ownership			
incl. VAT	**Total cost of ownership**	Lower Limit	Upper Limit
District Heating Annualized Cost	**1 640,95 €**	1 493,88 €	2 197,78 €
Heat Pump Annualized Cost	**1 749,17 €**	1 133,69 €	2 558,73 €





Underneath the final results, calculation details for all technologies are listed. They include all costs broken down by components.

Figure A-12: Content of the sheet "Results" of the excel tool

A.2 Appendix 2: Country Reports

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