

## H2020 Work Programme



# D3.1 - REPORT ON CURRENT BARRIERS TO INDUSTRIAL WH/C RECOVERY AND EXPLOITATION

**Lead Contractor: GOTE**

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Deliverable 3.1 Report on current barriers to industrial WH/C recovery and exploitation

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## Abbreviations

**CHP:** Combined Heat and Power (cogeneration)

**DH:** District Heating

**DHC:** District Heating and Cooling

**EED:** Energy Efficiency Directive

**ETS:** Emission Trading System

**EU:** European Union

**GHG:** Greenhouse Gas

**HVAC:** Heating, Ventilation, and Air Conditioning

**LNG:** Liquefied Natural Gas

**LULUCF:** Land Use, Land Use Change and Forestry

**NECP:** National Energy and Climate Plan

**NZEB:** Nearly Zero Energy Building

**PESTLE:** Political, Economic, Social, Technological, Legal and Environmental analysis

**RES:** Renewable Energy Sources

**We:** Watt electric (electric power)

**WtE:** Waste to Energy

**Wth:** Watt thermal (thermal power)

## Executive summary

In this report (D3.1), barriers to industrial waste heat and cold (WH/C) recovery and exploitation based on the experiences of the SO WHAT demo sites are presented.

Previous studies show that barriers could be of different character depending on the location and specific prerequisites of the industrial sites. Sometimes the prerequisites deteriorate the business case, but even when a good business case is present there can be barriers of non-economical character.

Interviews were conducted in the framework of the task to collect relevant information, both within the Swedish lighthouse cluster and the other national clusters involved in the SO WHAT-project.

Major barriers that deteriorate the business case are low costs of alternative heating, particularly natural gas, and the high initial investment cost for piping and other technology. It is important to focus on finding a win-win collaboration opportunity considering both costs and benefits of the potential partners. Since cooling currently is performed by electric chillers in most cases and the electricity price is much higher than the gas price across central and southern Europe, it appears efficient to examine the opportunity to use excess heat for cooling, e.g. through absorption chillers.

Other major barriers, apart from the economic ones are the lack of understanding of the involved parties (e.g. heat provider and energy company) systems and lack of trust between the partners.

In the countries where district heating is not an established technology, the lack of technical know-how and lack of regulatory procedures are significant barriers.

Taking the identified barriers into account it is shown that the SO WHAT is important to expand waste heat recovery in Europe. It can be used to identify and mitigate barriers by identifying profitable business cases. Mutual gain among the possible partners involved in the collaboration is key for success focus on the gain can be achieved by expanded system boundaries in the SO WHAT tool. By considering the total region and system at once, instead of one subsystem (the industry, the district heating system etc), gains that are otherwise not identified can be indicated.

The SO WHAT tool can also be used to increase understanding of the different stakeholders' systems.

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# 1 Introduction

In this report (D3.1), barriers to industrial waste heat and cold (WH/C) recovery and exploitation based also on the experiences of the SO WHAT demo sites are presented.

The work is performed by IVL with aid from the SO WHAT partners which are responsible for the industrial demo sites. Experiences from the Swedish lighthouse cluster have been collected from Varberg Energi and Göteborg Energi and served as the departure point for the analysis. Information is also collected from the REUSEHEAT project (coordinated by IVL) on urban waste heat recovery (waste heat of lower temperatures) and literature within the field.

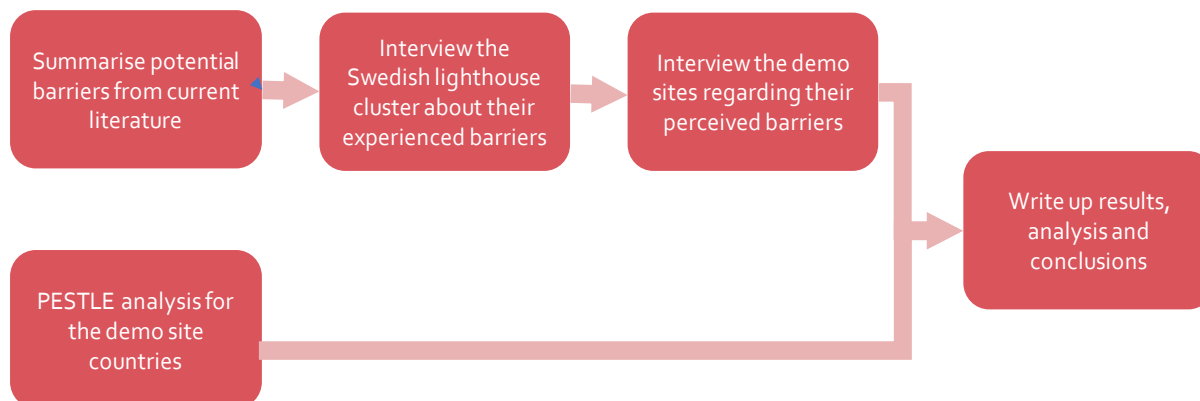
This deliverable is an important input to the deliverable on contractual arrangements based on the experiences of the demo sites (D3.3 "Report on current Contractual Arrangements for WH/C exploitation"), which has been prepared in parallel. Contractual arrangements can mitigate barriers to WH/C collaboration such as difficulties to agree on the value of the waste heat (its price), contractual length and the risk of the heat provider closing the waste heat recovery activity down.





## 2 Methodology

The work has been performed stepwise. An overview of the methodology of the study is presented in Figure 1.



*Figure 1: Overview of the methodology of the study*

Firstly, a literature review was made on barriers to industrial excess heat collaborations. The potential barriers were listed and categorised. In parallel, a macro-market analysis was performed to understand the potential market uptake for the technologies in SO WHAT. It entails an analysis of political, economic, social, technological, and environment aspects (PESTLE) and provides valuable insights on the barriers for waste heat recovery investments.

To collect data interviews were conducted with the Swedish lighthouse cluster and the SO WHAT demo sites. The interviews were semi-structured following a questionnaire (enclosed as Appendix A). The questionnaire was sent to the respondents before the interviews. The Swedish lighthouse cluster (Göteborg Energi and Varberg Energi) was interviewed jointly at the IVL offices in Göteborg in December 2019. Information from the other demo sites were collected through web-based interviews with the demo site responsible partner in each demo site country in January and February 2020. The demo site responsible partners gathered input from the relevant demo sites before the interview occasion. The data collected from the interviews was written down in conjunction to the performance of the interviews.

Finally, the results were described in this report and an analysis was performed. Conclusions were drawn in order to provide input to the SO WHAT tool.

### 3 Nature of barriers

The current knowledge concerning barriers to industrial excess heat recovery in district heating systems has been summarised in scientific articles and reports - e.g. Lygnerud and Werner (1), who focus on risks with industrial excess heat recovery in district heating systems in Sweden, Päävärinne et al (2), who identifies both success factors and barriers to WH collaboration in Sweden and Oldershaw et al (3) who describe factors that act as barriers or enablers to heat collaboration in the UK. The barriers from literature have served as a basis when gathering information from the demo sites.

In general, the barriers identified in the scientific literature can be divided into two main categories:

1. Barriers which deteriorate the business case
2. Non-economic barriers

The first category includes factors such as lack of existing infrastructure (e.g. no district heating network to recover the heat in), low prices for the competing energy sources and that current policy incentives promotes other forms of heat supply (1). Additional technical obstacles that could deteriorate the business case are long distance between supply and demand, supply and demand not matching (in volumes and/or time), not sufficiently high-grade heat, and varying seasonal demand (the demand for heat is usually low in summer) (2). The risk that the excess heat provider will terminate its industrial activities is often found to be a barrier to collaboration (1). This risk is often mentioned as a main barrier to waste heat recovery investments. In (1) a first assessment of the risk is made based on operational data in Swedish waste heat recovery investments during 1974-2014. In the study, it was shown that the risk of termination of the waste heat recovery is linked to the size of the heat recovery and to the inclusion of heat pumps. Small heat recovery investments appear to be more risky than large ones and the added dependency on electricity when including heat pumps leads to greater risk exposure. Lygnerud and Werner highlights a common barrier that the provider and the district heating company hold different views of the quality of the excess heat (1). A finding in the REUSEHEAT-project is that the different stakeholders have different views of the value of the heat (4). Due to seasonal variation in heat demand, the heat is regarded to have a lower value in the summer by the end user, but the excess heat deliverer might still need to cool off as much heat independent on season. This kind of disagreement of the price of the waste heat is a known deal breaker.

The second category includes barriers which in *neoclassical economic theory* are called “market failures”. In neoclassic economic theory, it is assumed that the actors are perfectly economic rational and are fully informed. As expressed by E.Roy Weintraub, the neoclassic economics rests on three assumption (5):

1. People have rational preferences between outcomes that can be identified and associated with values.
2. Individuals maximise utility and firms maximise profits.
3. People act independently on the basis of full and relevant information.

Hence a profitable collaboration should always be carried out, otherwise a market failure must be there to hinder. Market failure is the failure of the free market to allocate resources efficiently.

According to political economy, these barriers should be removed with the help of policy instruments as far as possible. However, barriers which are not “true” market failures, should not be tackled by public authorities since that would risk causing market imbalance.

In terms of barriers to waste heat recovery Oldershaw et al describe that the availability of capital expenditure (CAPEX) funds could be a barrier to industrial waste heat exploitation, particularly for smaller companies (3). Lack of financial funding is mentioned by Päivärinne et al as well (2). When profitable investments are not made due to funding shortage it is a sign of an imperfect financial market.

The neoclassic economists assume that man always acts in an economically rational way. However, *behavioural economists* nuance the assumption of the perfectly economic rational actor. Richard Thaler founded this new economic discipline, inspired by the work of Kahneman and Tversky (6; 7). The latter had researched the idea of human limits to rationality and had shown that decisions were not always optimal. For example, our willingness to take risks is influenced by the way in which choices are framed. In addition, it is common that organisational barriers affect the investment decisions.

Companies prioritise core-business investments even though excess heat collaboration has a good business case which could be categorised as an organisational barrier. This barrier is described in different ways by several authors and is regarded as a main barrier. For example, Oldershaw et al describes: “*The extent to which energy is a corporate priority and the resources companies commit to monitoring energy consumption influence the willingness and ability of companies to make progress at each stage of the heat recovery journey*” (3). Lygnerud and Werner describes that competition with alternative use for investment capital is a main barrier to waste heat collaboration (1).

In addition, the interorganisational relations are essential for exploitation of industrial excess heat. Lack of trust and communication difficulties are examples of barriers related to this (2). Lygnerud and Werner highlights a common barrier that the provider and the district heating company hold different views of the quality of the excess heat (1). As mentioned before, a finding in the REUSEHEAT-project is that the different stakeholders have different views of the value of the heat (4).

There are also examples from literature of barriers caused by imperfectly informed actors. Päivärinne et al highlights lack of knowledge about heating issues, lack of knowledge about the amount of excess heat and lack of knowledge about business agreements as common barriers to waste heat collaboration (2).

Even for the heat recovery investments that have positive net present value, the payback periods are long due to the high initial costs in excess heat recovery. Therefore, requirement for a short payback period for investments is an organisational barrier. Particularly private enterprises tend to have a requirement for shorter payback periods than public entities. In the REUSEHEAT-project it was found that the payback periods for urban waste heat recovery installations were 15 years or longer (4).

To summarise, the barriers found in earlier studies are:

1. Barriers which deteriorate the business case
  - Lack of existing infrastructure

- Low prices for the competing energy sources
- Current policy incentives promote other forms of heat supply
- Long distance between supply and demand
- Supply and demand not matching, not sufficiently high-grade heat, and varying seasonal demand
- Risk that the excess heat provider will terminate its industrial activities

## 2. Non-economic barriers

- Lack of financial funding
- Low priority to non-core business
- Lack of trust between the stakeholders
- Different views of the value of the heat
- Lack of knowledge about heating issues
- Lack of knowledge about the amount of excess heat
- Lack of knowledge about business arrangements
- Requirement for a short payback period

## 4 PESTLE analysis

In this chapter a summary of the macro economic analysis performed for considering market uptake of new products performed. It was done using the logic of PESTLE (Political, Economic, Social, Technological, Legal and Environmental) analysis for each of the countries engaged in the SO WHAT-project. The full text PESTLE analysis is attached in Appendix B PESTLE analysis. The presented PESTLE includes aspects that may create opportunities and barriers for waste heat and cold recovery from industries, as well as the waste heat and cold integrated with RES, and results from it are relevant for this deliverable.

### 4.1 Belgium

**Political** - Belgian policy is mainly pushing for the investment in solar thermal, heat pumps and CHP. District heating is indirectly pushed for in policies for zero-emissions new buildings. Residual heat and cold is not mentioned in policy and RES targets are relatively moderate compared to other EU Member States.

**Economic** - Natural gas, and other fossil fuels, are the strongest competitors to waste heat and waste cold in the thermal sector. The lack of existing infrastructure to recover waste heat and cold induces large investments cost and longer payback times which could discourage investors.

**Social** - The price and availability of energy are the two aspects that Belgians are most concerned about when it comes to energy. Main health issues today are particulate matter and NO<sub>x</sub> emissions from fossil fuels in urban areas.

**Technological** - The potential for RES is low, especially in the heating and cooling sector, so waste heat and cold coupled with RES is not such a viable option. However, there is large technical potential for waste heat in Belgium. District heating is in a developing phase.

**Legal** - Social tariffs and taxes primarily incentivize natural gas as an energy carrier.

**Environmental** - Environmental concerns mentioned in the heating and cooling sector are mainly GHG emissions, such as CO<sub>2</sub> and NO<sub>x</sub>, and particulate matter as well as soil pollution from leaking heating oil tanks.

### 4.2 Italy

**Political** - New policies proposed in the National Energy and Climate Plan targets biomass-fired, individual heating systems to become more efficient, renovation of the building stock and solar thermal and district heating. There are currently several different policies related to heating and cooling, mainly incentivizing solar thermal, heat pumps, geothermal and biomass. Technologies such as CHP and district heating are also covered by support schemes. As the development of photovoltaics has exceeded the initial national targets PV is exempted from most of the RES electricity support schemes, there is however support for other types of RES. Waste thermal energy is not explicitly mentioned in policy.

**Economic** - Natural gas, and to a lesser extent other types of fossil fuels, are the main competitors to an increased waste energy recovery in the thermal sector. A large share of the heat and cold is supplied from individual solutions. Natural gas is cheaper than district heating and the profitability of

district heating networks is strongly dependent on the existence of incentives for co-generated electricity.

**Social** - The share of the population that claim that they are unable to keep their homes warm are higher than the EU average. Italy is also experiencing a high level of heat-related effects on daily mortality, both hot temperatures and overall summer temperatures. In addition to this primary and secondary pollutants, associated with health issues, is an issue in the major cities and areas with intensive industrial and agricultural activities. Biomass combustion in individual heating systems also contributes to this issue.

**Technological** - Around 5% of the population is served by district heating networks and there are some district cooling networks available as well. Biomass is playing a major role for the RES share in the energy sector and is the major supplier to the district heating together with waste incineration and natural gas co-generation. The potential for waste heat recovery has been assessed in different studies but the role of waste heat in reaching a larger share of RES in the heating and cooling sector is unclear.

**Legal** - There is an obligation to include RES or district heating in buildings to be granted a building permit, but compliance with this is generally ensured particularly by solar PV and solar thermal. Legislation also required all new buildings within one km of district heating system to be connected to it, that all municipalities above 50,000 inhabitants establish development plans for heating and cooling networks and that all companies obliged to carry out an energy audit in compliance with the EU Energy Efficiency Directive to carry out a feasibility study for the connection to a DH network, if available within a few kilometres.

**Environmental** - Environmental concerns associated with heating and cooling are mainly related to emissions from biomass-fired, individual heating systems. There are also risks associated with heat pumps that uses groundwater.

### 4.3 Portugal

**Political** - There is no direct push for the recovery of industry excess heat and cold in the Portuguese energy policy. The focus is on electrification, solar thermal, heat pumps and biomass.

**Economic** - Gas, coal and oil dominate the heating and cooling supply in Portugal. Process heating contributes to the largest demand before space heating. The demand for space heating and cooling is in general low in relation to other countries in Southern Europe, thanks to Portugal's mild climate.

**Social** - No social aspects were found through literature review or in the responses to the questionnaire.

**Technological** - Portugal has a large RES potential, especially heat from cogeneration with renewable origin and biomass could contribute to the heating sector. The share of district heating is very low, and the potential is also low due to low demand. There is some potential for waste heat and cold recovery, mainly from industrial sites and thermal plants.

**Legal** - Buildings codes are pushing for solar thermal for heating domestic water, rather than district heating and excess heat recovery.

**Environmental** – As in most European countries, the energy sector is one of the main contributors to the Portuguese GHG emissions.

#### 4.4 Romania

**Political** - There is an existing state aid program giving incentives to investments in efficient cogeneration from residual industrial process heat. Investments in district heating and cooling is identified as one way to reach energy efficiency objectives.

**Economic** - District heating has historically been a large part of the thermal supply in Romania but is in decline due to several reasons and competes with individual heating solutions, mainly with natural gas as the energy carrier.

**Social** - Fuel poverty as well as health and safety risks associated with the widespread individual heating solutions are among the greatest Romanian social concerns linked to the thermal sector.

**Technological** - The excess heat potential is considerable and combined with RES, mainly firewood and agricultural waste, it could heat a large share of the population. However, the district heating system, which is currently in decline, needs to be developed to make use of the potential.

**Legal** - There is a lack of regulation promoting waste heat and cold recovery.

**Environmental** - As in most European countries, the energy sector is one of the main contributors to the Romanian GHG emissions.

#### 4.5 Spain

**Political** - Electrification and RES in the thermal sector (mainly heat pumps) are considered key for decarbonization and pushed for while residual heat and cold is mentioned but not explicitly pushed for. Support schemes exist for district heating and cooling on national, regional and local level.

**Economic** - The main competitor to waste heat is gas, mainly used in individual solutions. Investment costs in heat and cold recovery are high and the incentives are low today, especially for industries that does not have a CHP plant already.

**Social** - Public concerns mainly focus on energy price and comfort levels. Energy poverty affecting the populations ability to keep warm during the winter, CO poisoning and issues with excessive temperatures are some of the health and safety issues associated with the current thermal energy system.

**Technological** - Individual solutions still dominate the thermal sector. District heating is getting more and more attention but represents a very small share. The lack of DHC infrastructure, in combination with the seasonality of demand, pose technical challenges to make use of the large waste heat potential.

**Legal** - New regulations are expected to boost a shift from gas heating to electric heat pumps. There are also European regulations mentioned that could possibly affect the waste heat recovery by restricting the use of the heat pumps using fluorinated greenhouse gases.

**Environmental** - GHG emissions are the most commonly mentioned environmental impact from the Spanish energy system. However, the energy sector is also the main contributor to several types of



emissions, among them SO<sub>x</sub> and PM<sub>2.5</sub>. With the increased recovery of waste heat there is a risk of a more extensive use of fluorinated gases which may exist in the heat pumps used, these are potent GHGs.

## 4.6 Sweden

**Political** - Swedish policy is pushing for a decarbonization of the energy sector, e.g. with CO<sub>2</sub> taxation and a renewable electricity certificate scheme. In parts thanks to the taxation on heating oil, individual oil boilers in single family houses have been substituted by heat pumps and biofuels to a large extent. Energy Efficiency Directive (EED) Article 14.5 has been implemented for plants larger than 20 MW.

**Economic** - A large share of the thermal energy is used for space heating, especially in the residential sector. Electricity and district heating contribute to major share of the heating and cooling in the residential and tertiary sectors, while biomass is the largest source for heating and cooling in the industrial sector. Fossil fuels have almost been phased out.

**Social** - Social concerns include risks for heating customers with a dependence on a single supplier and the absence of price regulation. Health and safety concerns include anticipated effects from climate change, such as the increased heat-related mortality and spread of infectious diseases.

**Technological** - The Swedish district heating is dependent on renewables such as biomass and waste and focus for future technological development is increased system efficiency. The availability of district heating is widespread, and there are also some district cooling networks. Sweden is leading in heat recovery and excess heat is 9 % of the total district heating supply, mainly from pulp and paper, steel and chemical industries.

**Legal** - The District Heating Act forces the district heating companies to investigate the economic viability of waste heat recoveries whenever such are possible. If the recovery is not deemed economically viable the investment is not a legal requirement.

**Environmental** - The introduction of district heating has reduced the local emissions in cities caused by solid fuel combustion. Regulations have also forced DH companies to reduce the nitrogen dioxide emissions and the use of fossil fuels. Climate change has replaced clean air as the dominating environmental issue associated with the thermal sector.

## 4.7 United Kingdom

**Political** - The UK policies mainly focus on supporting energy efficiency improvements and low-carbon technologies, such as heat pumps, biomass boilers and solar thermal, for heating of homes and businesses. There is also support for new heat networks to be built. Article 14.5 of EED has been transposed and a cost-and-benefit assessment of waste heat recovery used for cogeneration or connection to a district energy network is now required for being granted an environmental permit.

**Economic** - Natural gas is the main competitor to an increased waste energy recovery in the thermal sector. Other economic barriers to waste energy recovery are lack of CAPEX funds for smaller companies and relatively long payback periods compared to other investments. The lack of confidence in heat recovery technologies is affecting the pay-back calculations negatively. Companies also gives energy efficiency measures a lower priority.



**Social** - Raising energy bills are high on the political agenda and a concern of the public. Heat network customers are in general more positive about the price they pay than non-heat network customers. Air pollution from the burning of fossil fuels and biomass is of a health concern as this could be attributed to premature deaths, especially in the larger UK cities.

**Technological** - Progress with more renewables in the heating sector has been more challenging than in the electricity sector where the UK has large potential especially in wind. Possible low carbon technologies in the thermal sector are heat pumps, hydrogen, biogas, industrial excess heat and energy from waste. There is potential for more waste heat and cold recovery. District energy networks available are mainly supplying a single building.

**Legal** - There are suggestions for regulations on low carbon heating in homes. New legislation is also pushing for more efficient boilers in homes.

**Environmental** - GHG emissions from the energy sector in general, as well as leakages of the global warming potent F-gases from refrigerants used for space cooling specifically, are some of the environmental concerns associated with the heating and cooling sector.

## 4.8 Conclusions from the PESTLE

Natural gas is the main energy carrier in the European thermal sector and district heating as well as renewables make up a very small share of the heating and cooling demand in the EU28 countries. EU policy and legislation focuses on increasing the share of renewables and to decrease the demand for space heating in building. Excess heat and cold from industries are mentioned but no specific technology or application is promoted. The estimated EU technical potential is 300 TWh/year for waste heat, mainly from iron and steel industry, and 64 TWh/year for waste cold, LNG and WtE plants giving the highest potential.

In the SO WHAT deliverable 1.2 (8), the potential of the industrial sectors WH/C recovery potential is calculated by two methods. The results per country according to the study is shown in Figure 2, in comparison with the total final heat demand in 2015.

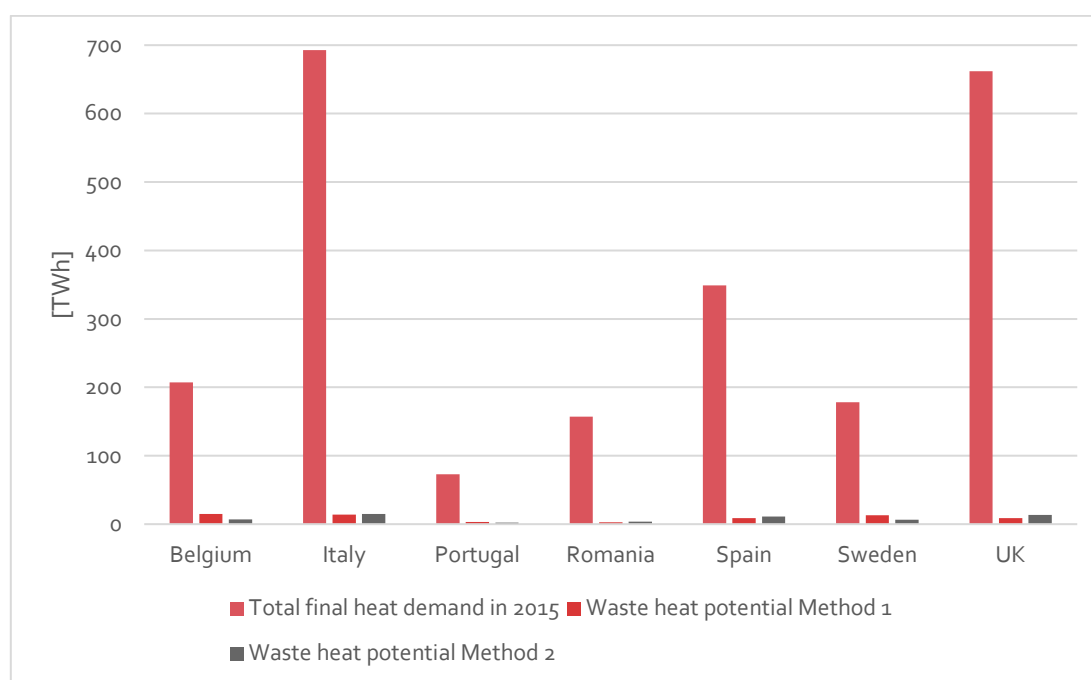


Figure 2: Comparison of heat demand in 2015 and waste heat potential per country. Data sources: Total final heat demand from Heat road map (9), Waste heat potential from SO WHAT D1.2 (8)

In Figure 3 the total final heating demand, by energy carrier, is presented for the countries covered by the SO WHAT-project. In relation to the other countries, Sweden has a low percentage of natural gas and a high percentage of district heating. Romania has the second biggest share of district heating of the studied countries, after Sweden. The share of district heating in Spain is marginal, and the other countries have small shares. UK is the country with the largest percentage of natural gas. Portugal, Romania and Sweden have the biggest shares of biomass when comparing the seven countries.

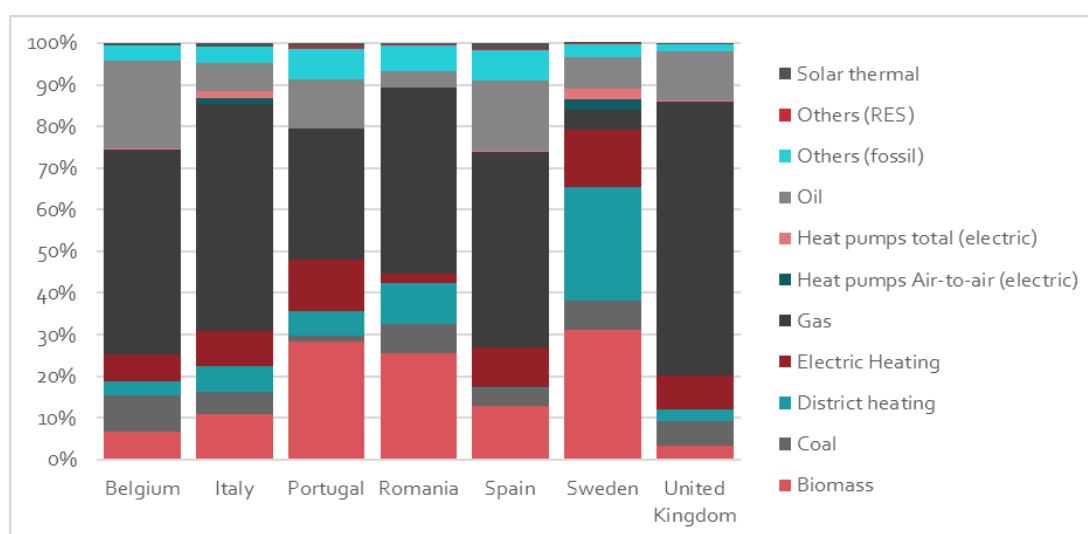


Figure 3: Heating, total final demand by energy carrier 2015 (9)

The heating and cooling demand could be divided into three sectors: residential, industry and tertiary (i.e. the service sector). The share of thermal demand by each sector and country is presented in Figure 4. The residential and industry sector contributes with the largest shares in all seven countries. In Belgium, Portugal, Spain and Sweden the industry has the largest thermal demand, while the residential sector has the largest demand in Italy, Romania and United Kingdom.

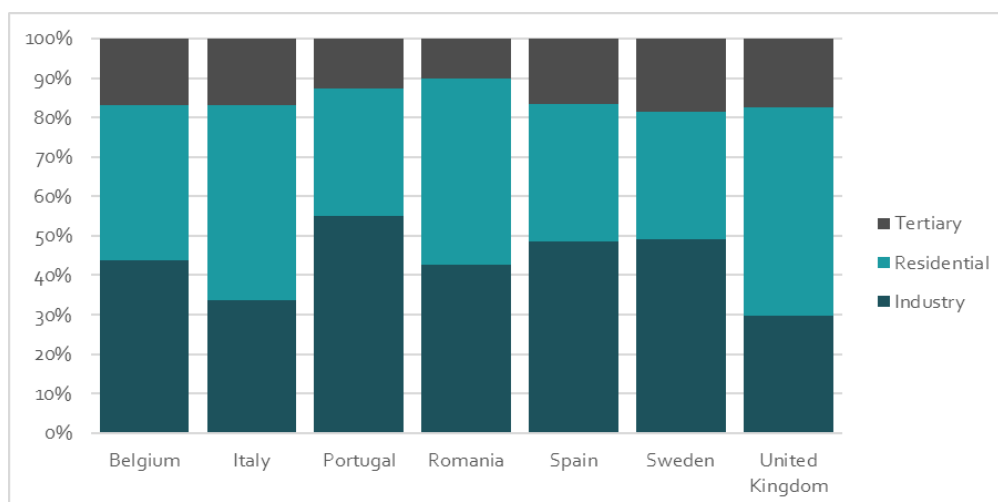


Figure 4: Heating and cooling, total final demand by sector 2015 (9)

The share of different types of heating and cooling demand can be seen in Figure 5. Space heating and process heating are the largest in terms of thermal demand for all countries, but the division between these two types varies. In Portugal process heating has the largest share, while countries such as Italy and United Kingdom have large shares for space heating. Cooling is a small share of the total thermal demand.

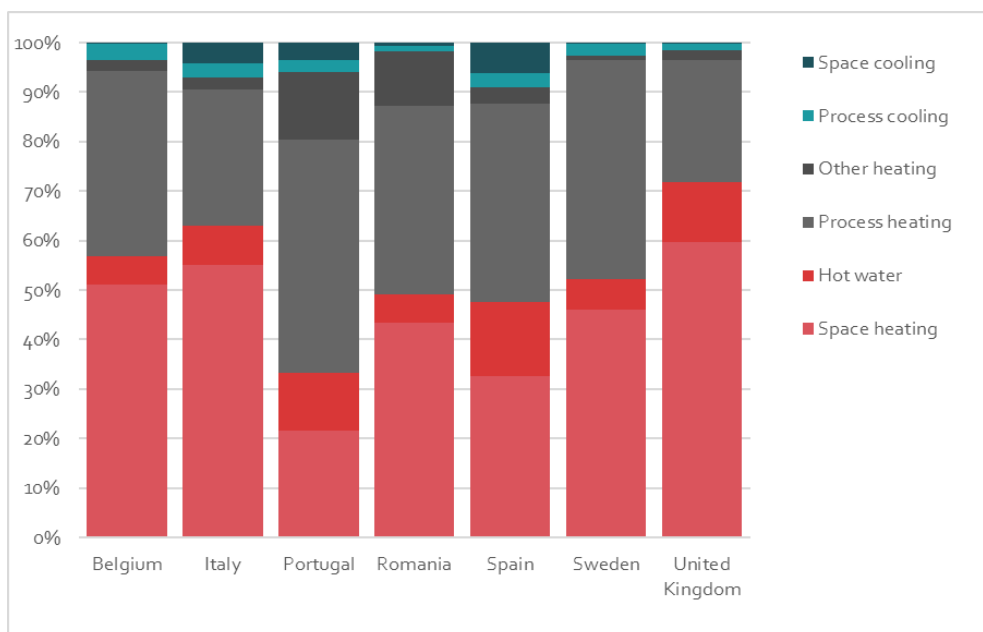


Figure 5: Heating and cooling, share of type of heat in total final demand 2015 (9)

Regarding cooling, both process and space cooling, the most common technique is electric compressor chillers in the studied countries.

## 4.9 Energy prices in the demo site countries

In Figure 6 the energy prices in the demo site countries are compared. Romania, UK, and Belgium are found to have the lowest natural gas prices for households, while Sweden has the most expensive. Note that in Sweden there is a great difference between the natural gas price for households and non-households due to a high tax. In all countries, electricity is more expensive than natural gas. With exception from Sweden, the electricity price is between 2.2 to 4.2 as high as the natural gas for households.

The figures for district heating prices are somewhat older than the figures for electricity and natural gas. The oldest figure is for district heating price in Italy, for year 2009. Hence, the columns in Figure 6 cannot be compared unreserved. However, the figure indicate that the district heating prices are in parity with the natural gas price for households in Italy and UK, while the district heating price in Sweden is lower than the natural gas price for households, and in Romania it is somewhat higher than the natural gas price for households.

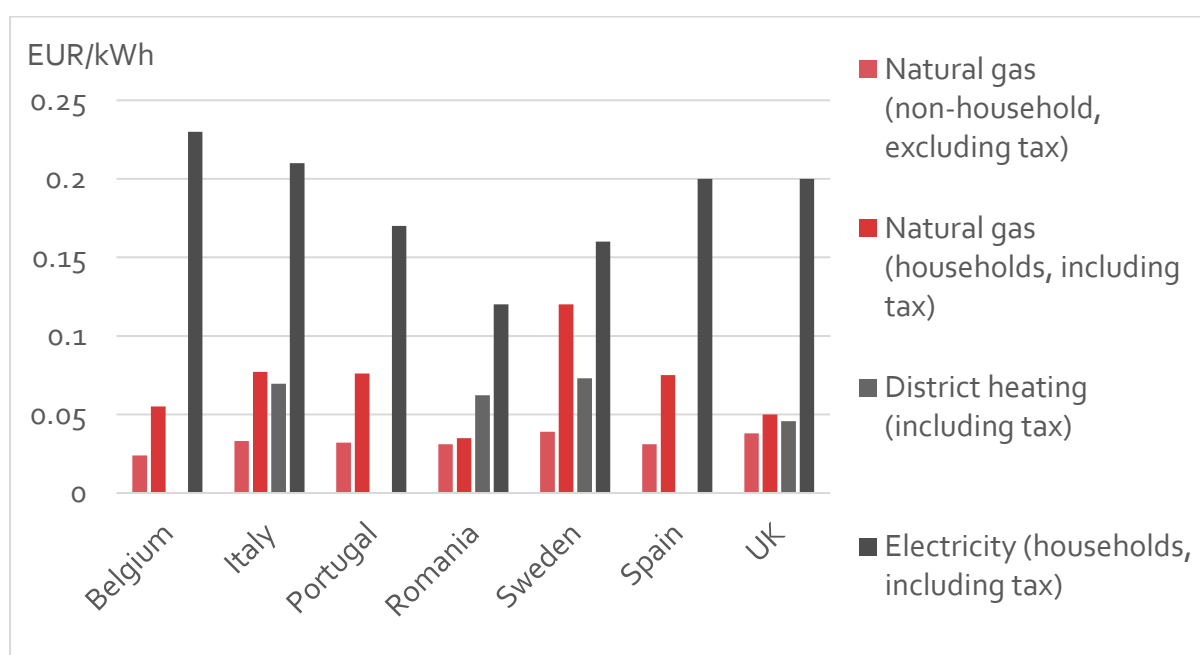


Figure 6: Energy price comparison of the demo site countries. Data sources: Natural gas and electricity prices (year 2019) from Eurostat (10), District heating prices (year 2013 for Romania, Sweden and UK and year 2009 for Italy) from Werner (11).

## 5 Barriers within the Swedish lighthouse cluster

### 5.1 Gothenburg, Sweden (GOTE) – Multiple heat source DH/C

#### 5.1.1 Description of the site

The demo site in Gothenburg in Sweden is represented by Göteborg Energi (GOTE), an energy company owned by the municipality of Gothenburg. The district heating network in Gothenburg was established in year 1953 and is based on heat from various heat sources and actors. The excess heat collaboration was established in the 1980s. The base load of the district heating in Gothenburg is heat from a waste incineration CHP plant owned by the waste and recycling company Renova, and industrial excess heat from two refineries (owned by St1 and Preem). This is complemented by heat from bio heat plants and heat pumps at the wastewater treatment plant, together with gas fuelled CHP and pellet, gas or oil fuelled heat plants. According to the climate strategy program of the City of Gothenburg, all district heating in 2030 will be produced by energy from renewable sources, waste incineration and excess heat. According to GOTE's forecast, the district heating demand will increase by 2 % in total until year 2035.

In addition to district heating, GOTE is offering district cooling since the mid-1990s. The cold production is currently based on absorption chillers driven by heat which in summer months could not be exploited for district heating due to low heat demand in the summer, in parallel with free-cooling (cooling towers or river water) and electric compressors. By year 2021, GOTE will need to expand their cooling production by another 20 MW to meet the sales forecast. Today two types of absorption chillers are under consideration. GOTE also look at utilizing low temperature heat for district heating network (i.e. server halls, data test cells). The demand of district cooling is predicted by GOTE to increase of 200 % within 2035.

*Table 1: Description of the site in Gothenburg*

Name, Partner	Location	Sector	Process	Temperature
GOTEBORG Multiple heat source DHN (GOTE)	Gothenburg (Sweden)	DHN, Heat from waste incineration and excess heat from refineries	GOTE DHCN is linked to different industrial facilities covering 90 % of the city demand. It is willing to expand this service.	70 - 100 °C

### 5.2 Varberg, Sweden (VEAB) – Pulp mill DHN

#### 5.2.1 Description of the site

The demo site in Varberg in Sweden is represented by Varberg Energi (VEAB), which is a municipality owned energy company providing district heating and other services in the area. The company's directive is to invest in sustainable energy resources on a local market and following this directive, they identified excess heat from the pulp mill Södra Cell Värö (SCV) situated about 20 km from the city as a promising source of excess heat to be fed into the DHN. Before the construction of Varberg district heating network in 2001, the excess heat from the pulp mill was cooled off and released to the environment. Excess heat is the main source for the district heating network, which is supplemented with conventional heat boilers based on wood chips, biogas and bio oil. VEAB and the

SCV are currently investigating the possibility to increase the amount of excess heat in the network through measures both at heat exchanger level and at customer level (i.e. lowering the return temperature). Furthermore, they are currently investigating the possibility to provide district cooling during summer via absorption chiller exploiting local excess heat.

*Table 2: Description of the site in Varberg*

Name, Partner	Location	Sector	Process	Temperature
Pulp Mill DHN (VEAB)	Varberg (Sweden)	DHN, Excess heat from Pulp Mill	VEAB DHN is linked to the nearby pulp mill providing excess heat via heat exchanger.	80 - 95 °C

### 5.3 Lighthouse cluster experiences of barriers to WH/C collaboration

In the interviews the Swedish lighthouse cluster partners GOTE and VEAB described their perceived barriers when initiating their WH/C collaborations.

One of largest barriers for GOTE to participate in the excess heat collaboration was the experiences of neighbouring district heating company, where the transmission line from the industry to the district heating network became very long and thus very expensive. For VEAB, the access of industrial excess heat was a prerequisite for the decision of investing in the district heating network. Without the availability of industrial excess heat the district heating network would not have been developed. SCV have also studied the possibility of deliver additionally excess heat to the town Kungsbacka. However, the distance between SCV and Kungsbacka is longer than to Varberg, which affected the capital investment cost of the district heating line negatively.

The high initial investment cost for distribution pipes etc, was a barrier which had to be overcome. A district heating network is unprofitable in the beginning. Therefore, it is important to have a long term thinking when deciding on the investment. The collaboration needs to be more competitive than the alternatives. The district heating companies' requirements for payback and the investment cost of the excess heat suppliers are reflected in the length of the contract. Both VEAB and GOTE have requirements of 10 years payback period for investments.

Other barriers which were emphasized as significant to handle when designing the contract, according to GOTE and VEAB, relates to the price and quality of the heat, agreements of planned revisions/stops of the excess heat and suitable contractual lengths due to pay back. GOTE also comments that the barriers are dependent on the individual excess heat collaboration, and therefore can be more relevant to handle in the contractual arrangement in some cases than others.

However, the general experience from the Lighthouse cluster is that the heat collaboration is a win-win and both parties are interested in the collaboration. The industries see the district heating companies as important customers, and are aware of the inconveniences that a stop in the industry would result in. A close cooperation and openness between the parties is regarded as keys to establishing a successful collaboration.

The industrial processes need cooling, and without the delivery of excess heat to the district heating networks the alternative would be to cool it themselves. That would be associated with a cost.

Technical obstacles were relatively small. Since the technology for excess heat recovery was mature when the two sites started the collaboration, the technology was not regarded as too complex. A dependable technology was a requirement for the collaborations. However, the technology for district cooling was not introduced until the 1980's, so that was somewhat less established.

The approximate time from idea to implementation was 3-4 years. Of this, at least one year was used to design the contractual arrangements. Even if this was not regarded as a barrier as such, it implicates that there is a high transactional cost for establishing heat collaborations of large scale.

To summarise, the barriers experienced by the Lighthouse cluster are:

1. Barriers which deteriorate the business case
  - Large initial cost for piping etc
  - High transactional cost in terms of required time for design contract etc
2. Non-economic barriers
  - To agree on price and quality of the heat
  - To agree on planned revisions/stops of the excess heat
  - To agree on suitable contractual lengths due to required pay back time

## 6 Barriers related to the SO WHAT demo sites

In this chapter, each SO WHAT demo sites are briefly described and their perceived main barriers to DH/C collaboration are presented in accordance with the interview results (subchapters 6.1 to 6.9). In subchapter 6.10, the demo sites have ranked identified barriers from recent studies and literature according to the relevance at their site. In subchapter 6.11, a summary of the results of the interviews with the demo sites is presented. The interviews were performed in January and February 2020.

Table 3 presents the respondents which have been interviewed. Most of the respondents are cluster leaders for the SO WHAT clusters and gathered input from the relevant demo sites before the interview occasion.

*Table 3: Interview respondents of the demo sites*

Country	Demo site	Respondent
Belgium	ISVAG, UMICORE and IMERYs	Kelvin Solutions
Spain	ENCE	Cartif and Eleukon
Portugal	LIPOR	2GoOut
Romania	RADET and Petromidia	Medgreen
Italy	M&R	Envipark
UK	MPI	MPI

### 6.1 Antwerp, Belgium (ISVAG) – Waste to energy plant

#### 6.1.1 Description of demo site

The Waste to Energy (WtE) plant ISVAG's location, close to the city of Antwerp, drove ISVAG to plan the construction of a new WtE plant on the site of the current power plant. Currently, only electricity is produced at the plant, but in the future the focus will be on maximising the energetic efficiency by additionally use heat for DHN. The incineration of the residual household waste takes place in a grate furnace. Different studies were carried out related to the use of heat (Feasibility study small scale district heating grid (3 MW), Feasibility study large scale DHN (>40 MW), Design heat use (3 MW) in the existing plant, Design new WtE plant).

Currently there are no existing WH/C collaborations in the demo site region. At the demo site the first steps are being taken now, no discussions prior the SO WHAT-project. In the project ISVAG wants to explore the potential for using waste heat and expand the grid by selling and distribution the heat from the waste incineration. The first step is the construction of a small scale DHN powered with heat from the existing WtE plant. ISVAG is also planning to scale up the heat production and wants to sell the heat and at a later stage expand the heat network to Antwerp. Another incentive for ISVAG is the environmental permit and to contribute to lower CO<sub>2</sub> emissions.

Discussions held between ISVAG and a logistic partner, which are interested in receiving the heat from the plant, have resulted in the logistic partner now is connected and receives heat from ISVAG. Feasibility studies are performed which look at the possibilities to expand the grid to the surrounding cluster of small companies (beverage, logistics etc). The demo site partners in the SO WHAT-project are ISVAG and the logistic partner.



Table 4: Description of site in Antwerp

Name, Partner	Location	Sector	Process	Temperature	WH/C collaboration or internal heat recovery
ISVAG Incineration (KELVIN)	Antwerp (Belgium)	Waste to Energy	ISVAG superheated stream power plant valorise via incineration local wastes and WH from the boilers.	400 °C	WH/C collaboration

### 6.1.2 Perceived main barriers to WH/C collaboration

- The **long-term commitment of the end users** to use the heat. The end user companies may feel that they will be too dependent on one supplier. The end users can't guarantee that they are in production in 10 years, or that they will need as much heat in the future.
- **The price of the heat** (CAPEX/OPEX). One main barrier is the competition from natural gas, and the end user's unwillingness to pay for the heat if the price is higher than the natural gas.
- When building DHN in Belgium, there are very **few contractors available**, since these contractors also build the gas grid. The prices of constructing the infrastructure can vary a lot depending on when and where the project is planned.

## 6.2 Olen, Belgium (UMICORE) – High tech manufacturing

### 6.2.1 Description of demo site

UMICORE Rare Material recycling and production centre is in Olen (Belgium). UMICORE is a global player in materials technology that develop technologies and produce/recycle materials for high-grade solar cells, rechargeable batteries, LED applications and catalytic converters. UMICORE plant is close to the current heat users on the Olen Campus site which are all supplied with steam generated in two Cogen turbines (12.8 MWe) and multiple steam boilers. A pre-feasibility study is ongoing to integrate a campus-wide heat network. This would enable the valorisation of multiple sources of excess heat, share them with neighbouring companies, and possibly even up to the city of Herentals, and/or to integrate new sources of renewable heat (e.g. deep geothermal energy). The already identified sources of excess heat derives from processes as hydrogenation (approx. 212 TJ/year, or 59 GWh/year) easily accessible) and pyrogenation (approx. 39 GWh/year), but other exothermic reactions could be a viable source of WH. These opportunities will be studied thanks to KELVIN support.

Currently there are no existing WH/C collaborations in the demo site region. Discussions have been held on high level regarding the demo site, but the company will at this point only build the heat grid at their own site, and maybe extend the grid to public later on. Umicore will in the SO WHAT-project see best practices and possibilities to use the excess heat outside the demo site, but the first focus is to build the heat grid within the demo site with the incentives of reducing the cost for energy and lower the CO<sub>2</sub> emissions.

Table 5: Description of site in Olen

Name, Partner	Location	Sector	Process	Temperature	WH/C collaboration or internal heat recovery
UMICORE Rare material Centre (KELVIN)	Olen (Belgium)	High tech manufacturing	UMICORE's Olen site revolves around recycling and production of high-tech materials based on cobalt and germanium.	50 – 265 °C	Internal heat recovery

### 6.2.2 Perceived barriers to WH/C collaboration

- **DHN is an unknown technology** at the demo site. Umicore is more familiar with the existing steam network, which the company have had for 40-50 years.
- It is not the core business for Umicore, and thereby it is difficult to get capital when competing with the core business investments.

## 6.3 Willebroek, Belgium (IMERYS) – Chemical manufacturing

### 6.3.1 Description of demo site

IMERYS carbon black and graphite manufacturing center is located in Willebroek (Belgium). IMERYS Graphite & Carbon is the world leader in high-tech, high performance solutions based on specialized graphite and carbons. IMERYS is situated on the industrial site of Willebroek Noord and in the direct vicinity of the industrial site of Puurs and the municipality of Willebroek with its own residential development projects. This offers an opportunity to valorize IMERYS excess heat to industrial consumers, public buildings and residential consumers. Considering that today almost no heat is recovered, a district heating network would make the site significantly more sustainable and futureproof. As a matter of fact, during the process of Carbon Black, a mixture of H<sub>2</sub> and CO is formed which is currently burned in a furnace and no heat is recovered of the max total of 30 MW. The production is 24/7, creating a continuous flow of waste heat at about 600 °C, available from the chimney gases of the furnaces. In order to valorise the waste gas stream, a study has been performed looking into different industrial options ranging from electricity production, over carbon valorisation via the production of chemicals such as methanol or paraffines, to heating circuits. This study will be used in SO WHAT as a benchmark for what it concerns both the techno-economic solution proposed and the necessary time and effort under KELVIN supervision.

Currently there are no existing WH/C collaborations in the demo site region. A feasibility study regarding possible heat consumers located in the area and economic evaluation, conducted by the municipality as a part of SO WHAT, is in the final stage. The next step is to discuss potential heat users around IMERYS and investigate the cost of a possible heat grid that could be constructed.

IMERYS is in the SO WHAT-project interested to assess the best options to use the excess heat, and how it would affect their environmental permit. IMERYS is also motivated to contribute and reduce the CO<sub>2</sub> emissions of the collaboration partners.

Table 6: Description of site in Willebroek

Name, Partner	Location	Sector	Process	Temperature	WH/C collaboration or internal heat recovery
IMERYS Carbon black manufacturing (KELVIN)	Willebroek (Belgium)	Chemical manufacturing	IMERYS manufactures Carbon Black producing a mixture of H <sub>2</sub> and CO as by-product which is currently burned in a furnace whose excess heat could be recovered.	600 °C	WH/C collaboration

### 6.3.2 Perceived main barriers to WH/C collaboration

The barriers are partly the same as for the ISVAG site in Antwerp, which also is situated in Belgium (Chapter 6.1).

- The **long-term commitment of the end users** to commit to use the heat. The end users may feel that they will be too dependent on one supplier. The end user companies can't guarantee that they are in production in 10 years, or that they will need as much heat in the future.
- **The price of the heat** (CAPEX/OPEX). One main barrier is the competition from natural gas, and the end user's unwillingness to pay for the heat if the price is higher than the natural gas.
- For Belgium a general, a main barrier is the **long distance from the industry to first large size potential end user**.

## 6.4 Navia, Spain (ENCE) – Pulp mill

### 6.4.1 Description of demo site

ENCE pulp mill was built in the 1960-70's and was then a government owned plant. ENCE has a production capacity of more than 950,000 tons per year of high-quality eucalyptus pulp through its plants in Navia (Asturias) and Pontevedra. Moreover, ENCE is Spain's leading producer of renewable energy using biomass, with an installed power of 220 MW in biomass. Pulp mills are relevant producer of waste heat. In this framework ENCE has already identified a project, consisting in the heat recovery from bleaching and causticisation stages to exploit it in a biomass dryer. Thanks to ELEU support, ENCE will analyse via SO WHAT tool for the biomass dryer as well as it will get benefit from similar WH valorisation process at VEAB in Sweden.

The region where the demo site is located has been the biggest coal production area in Spain. At this point the coal mines and thermal plants fuelled with coal are successively closing. There is no existing district heating network in the region. The regional government is currently pushing for waste heat recovery. Initial discussions between stakeholders as ENCE factory, Veolia (international ESCO company) and Unossa (Spanish ESCO company) regarding industrial waste heat recovery have been held on high level meetings since the beginning of 2019, but no deeper studies have been performed on the matter. Unossa is the owner of most of the coal mines in the region.

ENCE would like to sell the industrial excess heat, preferable with a third party (an ESCO company) between them and the heat users. ENCE gave a proposal in the beginning of 2019 to give the excess heat away for free if the collaborating company would take responsibility for the pipes etc. An important question to be addressed in a potential collaboration is which party will pay for the initial cost. Will it be the industry, the ESCO company, the end user or the government?

The incentives for ENCE to join a collaboration, except the revenue of selling heat, is the public opinion and policy demands. In Spain there are controversies about pulp mills partly due to the odour and partly that the white steam from the chimneys can be perceived as pollutant by the public.

*Table 7: Description of site in Navia*

Name, Partner	Location	Sector	Process	Temperature	WH/C collaboration or internal heat recovery
ENCE Pulp Mill (ELEUKON/CARTIF)	Navia (Spain)	Pulp Mill	This is the mill with the largest production capacity belonging to ENCE Group (535 ktons/year) and the most efficient pulp mill on the eucalyptus market in Europe.	70 - 230 °C	WH/C collaboration

#### 6.4.2 Perceived main barriers to WH/C collaboration

The perceived main barriers to waste heat/cold cooperation in the region of the demo site, according to the regional energy agency FAEN, are:

- **Lack of regulations and economic incentives.** Natural gas is cheaper. Subsidies will be needed to balance the economy.
- **Lack of experience and knowledge about the technology.**
- **Problem to deploy the pipes.** The deployment requires several regulations (river regulations etc) which are handled by regional authorities. The administration related to processes are considered as barriers. In the existing heat networks in Spain, the regional government owns the pipes and distribute to their own uses. In case the private ESCO company will be responsible for the deployment and distance to the administration will thereby be bigger.

### 6.5 Maia, Portugal (LIPOR) - Waste to energy plant

#### 6.5.1 Description of demo site

LIPOR participates in the SO WHAT-project mainly with respect to its waste to energy (WtE) plant located in Maia (Portugal), treating 380,000 tons of waste per year. The WtE plant composed by high temperature gases that go through an energy recovery boiler, which uses the heat to produce steam for power production. In this framework, it was developed in 2017 a study concerning the assessment of the technical-economic feasibility of recovery heat of LIPOR's WtE Plant and implementation of a district heating system connecting LIPOR and Francisco Sá Carneiro Airport, near Oporto. Multiple different options were considered (additional burning of waste in the boiler, additional drawing of turbine steam in medium pressure extraction, heat recovery of the exhaust gas from the boiler) and the second one has subsequently been the subject of detailed techno-economic feasibility analysis. Also, options for district cooling is considered regarding 3 absorption chillers of 4,000 kW of cooling

power. Thanks to SO WHAT LIPOR will go further in WH/C valorisation investments related to Oporto Airport.

In the region of the demo site no WH/C cooperation currently exist and in Portugal there is in total one district heating system. The waste incineration company LIPOR is studying, together with representatives from Oporto Airport and INEGI – Institute of Science and Innovation in Mechanical and Industrial Engineering, related with Oporto University, the possibility to recover the heat and share it. LIPOR is discussing different types of collaborations, mainly with Oporto Airport, which is a large consumer of energy and needs heating and cooling all around the year. Before the discussions will continue, assessment will be done on the costs, including investments, operational cost etc. LIPOR also considers collaborations with the hospital, pools and industries. There is no infrastructure yet, and LIPOR are looking into it with help from third parties and the INEGI. LIPOR wants to assess the possibilities to share the heat with actors in the surrounding within the SO WHAT project, and understand business models, contractual and financial agreements and map possible clients.

Today, LIPOR only sells electricity to the grid. LIPOR has a climate strategy and want to improve efficiency in all operations (recycling, waste incineration, increased heat recovery) and thus improve the profit, which is reinvested in a better service to the community.

*Table 8: Description of site in Maia*

Name, Partner	Location	Sector	Process	Temperature	WH/C collaboration or internal heat recovery
LIPOR Waste Energy (LIPOR) Maia to Plant	Maia (Portugal)	Waste to Energy	Two incineration lines in a continuous and almost automatic operation burn and treat 380,000 tons/year of municipal waste.	Outlet Flue gases 150 °C Steam to turbine 395 °C Condensates 55 to 60°C	WH/C collaboration

### 6.5.2 Perceived main barriers to WH/C collaboration

- The **lack of experience of heating/cooling network** systems in Portugal, currently there is only one existing (located in Lisbon). There is not a culture of using these systems. The lack of experience relates not only to construction phase but also operation and maintenance.
- Normally the **demand for heating (mainly) and cooling is low**. There is a low energy demand for heating and cooling, due to the mild climate at the demo site. However, there is need to improve the comfort in the existing building stock, and that would lead to increased demand for heating and cooling.
- **Large investments in infrastructure** will be needed. Due to the lack of investments related to DH/C network in the area of the demo site there will be a need of large and new type of investments to create a new network.
- The cultural aspect, **medium-long term cooperation and commitment** with large investments. To achieve DH/C cooperation new collaborations need to be developed between different actors and companies, and the contract length could be a large barrier between the partners. The waste to energy plant has stable operation the entire year (unless the shut-down periods for overhaul and preventive maintenance, normally two times per

year) and will be running for a long time, with the monopoly activity to burn waste in a not competitive sector. The risk of closure is small, and the supply is stable. The barrier with commitment applies more for the potential customers.

- **The price of the heat.** The issues of the price of heat/service and being competitive with natural gas and electrical solutions is important.

## 6.6 Constanta, Romania (RADET) – DHN, WH from local industries

### 6.6.1 Description of demo site

RADET Constanta, established in 1991, is the District Heating Company of the municipality of Constanta (RO), ensuring 70% of the urban heating demand (170,000 inhabitants). At the current state, RADET does not employ excess heat in its district heating network but thanks to SO WHAT-project RADET aims at injecting heat from neighbouring industries (petrochemical, manufacturing etc.) to become less fossil fuel (natural gas) dependent and to promote new business models. In this framework, the project will also promote the knowledge transfer from the world class district heating and WH recovery from the Swedish cluster to less advanced system in EU, becoming front-runner for Eastern Europe DHN renovation thanks to WH valorisation.

Currently WH cooperation has been discussed between the RADET and two companies CELCO and Dobrogea. CELCO is a manufacturer of construction material (autoclaved cellular concrete). The discussions with CELCO started one year ago. The dialog with Dobrogea (a bread and bakery company) started in November 2019, and the response have been positive. Dobrogea has a bakery with an area where the bread shall cool as a potential source of waste heat. Additionally, Dobrogea has its own plant for producing heat (natural gas boilers) but have very low usage. There is a possibility of optimizing the load of these boilers and inject heat into the DHN. Dobrogea will continue the discussions of collaboration with RADET in the SO WHAT-project. RADET is also in the process of identifying other partners.

RADET is currently retrofitting the district heating system. The system is from 1970's and includes the whole city. Since then not much investments have been conducted. There is a need of reconstructing the piping system and the concept of the district heating system is associated with huge costs for operating and maintenance. The price per MWh heat is 110 Euro for non-residential customers and 95 Euro for residential customers (compared to EU prices at approximately 40-60 Euro/MWh). The municipality subsidy the district heating in the winter season to be accepted by the market, and the citizens instead pay 45 Euro/MWh for the heat. The non-residential customers do not benefit of subsidies. The subsidy is a huge effort for municipality, thereby it is important to upgrade the system although the extensive project. Currently the regulatory framework allows waste heat in the DHN. The main objective for RADET is to reduce the cost for heat and buy heat at a lower price. Today the price is high which resulting in RADET loosing costumers.

*Table 9: Description of site in Constanta*

Name, Partner	Location	Sector	Process	Temperature	WH/C collaboration or internal heat recovery
Constanta DHN (RADET)	Constanta (Romania)	DHN, WH from local industries	RADET aims to renovate this old DHN valorising local industries WH.	70 - 250 °C	WH/C collaboration



### 6.6.2 Perceived main barriers to WH/C collaboration

In the interview the respondent of the demo site highlighted the following four barriers to WH collaborations:

- **The current organization framework for thermal energy production and supply.** The district heating network in the region has been inherited and was based on the interest of heat producers and to preserve the position of the heat producers. Thereby it is mostly beneficial from the perspective of large heat producers. In some cities in Romania the heat production and heat distribution can be in the same company. In Constanta though the heat production and distribution are performed by two different companies.
- **The DH is relying on one single thermal power plant.** The biggest part (93 percent) of the heat comes from the same power plant. The company administrating the power plant is a state-owned company and due to the lack of investment funds, it was not able to upgrade the technology and to reduce the production costs. At some apartment buildings, small natural gas boilers have been installed which covers the other 7 percent in RADET's DHN supply.
- **Obsolete infrastructure of the current district heating network.** If different companies would like to deliver heat to the DHN, the price should be smaller than the price of the power plant. The DHN is prepared for that technical solution, but it has very large losses and requires a huge refurbishment process. At present, the local municipality that owns the DHN is preparing a large project for re-sizing and upgrading it.
- **Regulatory and financial barriers.** The situation of the market. Even though RADET has the principal possibility to buy heat it is still complicated to implement the collaborations. This is due to that the heat producer must be certified etc to be able to sell the heat, and it can be difficult. Newcomers must build up their business plan and need to apply for loans at the bank or to other financing institutions, but there are still many risks and uncertainties. A new specific law that is regulating the district heating sector is at present under debate at the Romanian Parliament.

## 6.7 Navodari, Romania (Petromidia) – Refinery

### 6.7.1 Description of demo site

Rompetrol Refinery in Petromidia of Navodari is the largest asset held by the KMG International Group in Romania. The three production facilities of Rompetrol Refinery operate under an integrated system, in full synergy, by offering a wide range of products. Thus, Petromidia Refinery is one of the most complex refineries, which supplies the entire feedstock for the Polypropylene plant within the Petrochemical Division; it is the sole Romanian producer of polyolefins. The refinery produce relevant amount of excess heat, in the framework of SO WHAT-project two main areas of interest have been identified: two furnaces which discharge heat at 450°C to the stack and heat recovery from hot condensate from amine unit (140°C), currently dissipated in cooling water. A project to recover the heat from hot condensate from amine unit is under development and will be studied thanks to MEDGREEN.

Petromidia refinery is located far away from a DHN and thereby their focus in the SO WHAT-project will be on internal energy recovery, not WH/C collaboration with other companies.

Table 10: Description of site in Navodari

Name, Partner	Location	Sector	Process	Temperature	WH/C collaboration or internal heat recovery
Petromidia refinery (GREENMED)	Navodari (Romania)	Refinery	Petromidia is the largest Romanian refinery, and one of the most modern refineries in South East EU.	140 - 450°C	Internal heat recovery

### 6.7.2 Perceived main barriers to WH/C collaboration

The plan for the demo site is to perform energy efficiency measures at the refinery. The projects that are aiming the improvement of energy efficiency are considered as development projects and there are internal procedures and rules for promoting and implementing such projects. In principal, there are defined some criteria consisting on threshold values for indicators as IRR, ROI and other similar. In the case of the project defined as demo, due to the energy recovery will be achieved within the same plant and no collaboration with other companies, the questions regarding perceived barriers to DH/C collaboration between a heat supplier and a heat user for this deliverable are not applicable to the demo site.

## 6.8 Pessione, Italy (M&R) – Distillery, food and beverage

### 6.8.1 Description of demo site

In M&R Pessione industrial site all the products of the company are produced: Martini, sparkling wines and liquors, following their recipes. M&R demo site has been identified as particularly relevant for SO WHAT-project as the stabilisation of sparkling wines requires low temperatures, which are achieved via glycol-based refrigerators. The overall cooling production is of about 10 GWh/year employed in different areas of the plant. Considering the remarkable amount of low temperature fluids related to this production M&R is interested in analysing the possibility and potential benefits related to excess cold recovery. Because of the refrigerating power, in the plant it is produced a large amount of low temperature excess heat which is cooled in evaporative condensers and it accounts for about 15 GWh/year and which potential has already been identified as interesting. Moreover, another excess heat stream has been identified in the cooling circuit of air compressors, which is currently cooled in an evaporative tower, but it could be otherwise employed for about 170 MWh/year. Finally, M&R is committed in employing RES and the installation of solar thermal panels for process purposes is planned in the framework of SHIP2FAIR H2020 project: for the present reason, M&R is an optimal test case for the analysis of RES integration and its direct impact on the production.

M&R is evaluating different solutions for heat recovery and valorisation internally with the incentive of energy saving. Currently, no external solutions are under consideration. However, heat delivery to a nearby kindergarten has been considered earlier and it may be possible to further study this opportunity.



Table 11: Description of site in Pessione

Name, Partner	Location	Sector	Process	Temperature	WH/C collaboration or internal heat recovery
Pessione Distillery (M&R)	Pessione (Italy)	Distillery, Food and beverage	M&R Pessione plant processes requires heating (distillation, bottle warming etc.) or cooling (product, CO <sub>2</sub> injection, conservation etc.).	-8 - 60 °C	Internal heat recovery

### 6.8.2 Perceived main barriers to WH/C collaboration

M&R is evaluating different solutions for heat recovery internally. No external solutions and collaborations are under consideration because no factories or public buildings are located nearby. The heat and cold recovery will be used internally and valorised internally only. Due to the energy recovery will be achieved within the same company, the questions regarding perceived barriers to DH/C collaboration between a heat supplier and a heat user for this deliverable are not applicable to the demo site.

## 6.9 Middlesbrough, UK (MPI) – Steel industry

### 6.9.1 Description of demo site

MPI Steel Industry Research Pilot Plant in Middlesbrough is specialised in challenging processes, particularly those involving high temperatures, hostile environments and high specification materials. One of the main areas of expertise is in melting, alloying and casting of semi-finished product, produced at the Institute's production facility. The Institute operates pilot and demonstration Steel Industry plant including electric Arc Furnace and Continuous Casting Plant, the former used for both small scale commercial production and research activity and the latter solely for research activity. Both processes involve liquid steel at temperatures 1,600°C which generate large quantities of radiant heat at all stages in the process, also several defined cooling water streams. Clear sources of WH are the radiant heat (arising from the cooling of cast steel ingot, billet and slab), which is typical of steel industry worldwide, and cooling water for the furnace cooling that is often sent to external cooling towers/heat exchanger. While the latter is easier to recover, the former has proven very difficult to capture due to its scale and location. These two challenges are in line with SO WHAT objective to analyse the heat recovery from different sources and related to different streams. However, MPI will represent the Steel Industry in SO WHAT-project (a major sector also considering ARCELOR presence in the stakeholder group), having a great experience in the related activities and processes deriving both from research activities and from the actual pilot plant operation.

In the demo site region WH collaboration exist north of the river where a chemical plant delivers waste heat from synthetic ammonia production to the district heat network. South of the river there is currently no DHN available. However, a feasibility study is being funded. Potential customers are for example a hospital, a university and a harbour.

Table 12: Description of site in Middlesbrough

Name, Partner	Location	Sector	Process	Temperature	WH/C collaboration or internal heat recovery
Innovation in steel industry pilot (MPI)	Middlesbrough (UK)	Steel industry	MPI operates pilot steel industry plant including electric arc furnace and continuous casting plant, the former used also for small scale commercial production, beside research activities.	1,600 °C	WH/C collaboration

### 6.9.2 Perceived main barriers to WH/C collaboration

The main barrier to WH/C cooperation related to steel industries in general in UK are money and uncertainties. In general, the steel industries in UK have small profit margins and thereby are in the knife edge if they can keep running. The industries try to control their cost by savings in the core business. Often the organization is occupied with the core business, not issues regarding energy efficiency. There is a **lack of funding, capital and manpower for non-core investments** even if there is a good business case.

When energy efficiency actions have been performed, the following factors have been keys:

- Investments with shorter payback than 6 months, and few numbers of people to perform it. Example: Change of pumps
- Investments through the energy performance contract (EPC) business model. Example: Change of lighting

The respondent sees a need for more initiatives like this, requiring a low number of staff to be engaged and performed in stages.

## 6.10 Result of ranking of identified barriers from earlier studies

In the demo site interviews, the respondents were asked to rank a number of barriers that had been identified in earlier studies. The respondents ranked the barrier in a scale from essential, important to less important. Seven of the nine SO WHAT demo sites did the ranking. For the demo sites Petromidia in Romania and M&R in Italy the questions were not applicable due to energy recovery will be achieved within the same company. For the demo site in Navia the ranking has been done by the regional energy agency FAEN, but at the other sites the ranking was done by the participating industries.

The result of the ranking is that both barriers which deteriorate the business case and barriers which remain even though the business case is profitable, were regarded as essential barriers to industrial excess heat or cold exploitation. Five of the barriers were considered essential to all or most of the demo sites. Those were:

*Barriers which deteriorate the business case*

- Large initial cost (for piping etc.)
- Policy instruments favour other energy alternatives

*Barriers which remain even though the business case is profitable*

- Difficulties to agree on pricing
- Lack of knowledge or understanding of each other's systems, processes etc
- Requirements for a short payback period for investments

All the respondents perceived requirements for a short payback period for investments as an essential barrier to WH/C collaboration at their demo site. Lack of knowledge or understanding of each other's systems, processes etc were considered as essential by all demo sites except for RADET in Romania which perceived it as less important. At RADET a district heating network exist since the 1970's, which is not the case for the other demo sites. Difficulties to agree on pricing is also one of the barriers were all demo sites except one see as essential.

Five of the seven respondents identified different views of suitable contractual length as important and two saw it as essential.

Barriers which all or most of the demo sites considered as important, but not essential, were:

*Barriers which deteriorate the business case*

- Risk that the industry may not always supply heat
- Risk of industrial closure
- High costs (time-consuming) for developing contracts, procurement etc.
- Other energy alternatives are less expensive

*Barriers which remain even though the business case is profitable*

- Different views of delivery quality
- Different views of suitable contract length
- Other priorities in the companies

Uncertainty due to untested technology was not regarded as a major barrier by four of the respondents. However, the exceptions were the Spanish and Portuguese sites who regarded it as essential. Both Spain and Portugal have none or few district heating or cooling networks and have little DHN tradition. Also, the Romanian and UK sites regarded this barrier to be important.

The barrier that most demo sites (four of seven) considered as less important was complex technology, the other three respondents ranked it as important.

## 6.11 Summary of barriers perceived by the demo sites

Three of the nine demo sites (UMICORE in Belgium, Petromidia in Romania and M&R in Italy) are currently evaluating solutions for heat recovery internally in the companies, not collaborations with other parties. Due to this the questions related to barriers for collaboration in this deliverable was not applicable for Petromidia and M&R. However, UMICORE were able to comment on their perceived barriers related to WH/C collaboration since they are considering it in the long-term.

In this chapter, the main barriers identified by the responding demo sites are summarised and compared to the list of barriers found in earlier studies and/or experienced by the Lighthouse cluster (described in Chapter 0 and Chapter 5.3), summarised Table 13. In general, most of the barriers in the table are found at the demo sites as well, but to a varying degree depending on local prerequisites.

*Table 13: Barriers found in earlier studies and/or experienced by the Lighthouse cluster*

<b>Barriers which deteriorate the business case</b>	Lack of existing infrastructure
	Low prices for the competing energy sources
	Current policy incentives promote other forms of heat supply
	Long distance between supply and demand (large initial cost for piping)
	Supply and demand not matching, not sufficiently high-grade heat, and varying seasonal demand
	Risk that the excess heat provider will terminate its industrial activities
	High transactional cost in terms of required time for design contract etc
<b>Non-economic barriers</b>	Lack of financial funding
	Low priority to non-core business
	Lack of trust between the stakeholders
	Different views of the value of the heat (price and quality)
	Lack of knowledge about heating issues
	Lack of knowledge about the amount of excess heat
	Lack of knowledge about business arrangements
	Requirement for a short payback period (Different views on suitable contractual length)
	Different views on how to plan revisions/stops for the excess heat

### *Barriers which deteriorate the business case for WH/C collaboration*

- **Competition with natural gas.** Several the respondents (four of seven demo sites; two in Belgium, one in Spain and one in Portugal) highlights competition with the natural gas price as one main barrier for making a profitable case of the WH/C collaboration. Natural gas is identified in the PESTLE analysis for the countries (except for Sweden) as a strong competitor to waste heat recovery. For Belgium the PESTLE analysis also conclude that social tariffs and taxes primarily incentivise natural gas as an energy carrier. However, the importance of natural gas in heating homes, makes it difficult to raise taxes without causing a negative social effect. The respondents describe a lack of regulations and economic incentives, and the end users are unwilling to pay for the heat if the price is higher than the natural gas. Even though the industrial excess heat can be received at a low price, the total cost of the heat

increases when/if new infrastructure needs to be deployed. Thus, there is a risk of the business opportunity not being profitable.

- **Low demand for heating and cooling.** According to the demo site in Portugal, there is normally a low energy demand for space heating and cooling due to the mild climate, but the existing building stock has rather low thermal comfort. If the comfort was improved, the demand for heating and cooling would increase.
- **Large initial cost.** Different aspects of economic barriers have been identified by the respondents. Large initial investment cost of infrastructure to deploy the DHN is a common mentioned barrier and is ranked as essential according to many of the demo sites. Regarding Belgium there are very few contractors available which build DHN, since these contractors also build the gas grid. The prices of constructing the infrastructure can vary a lot depending on when and where the project is planned. According to the PESTLE analysis Romania has an existing state aid program giving incentives to investments in efficient cogeneration from residual industrial process heat. Investments in district heating and cooling is identified as one way to reach energy efficiency objectives. In Spain support schemes exist for district heating and cooling on national, regional and local level. The UK policies mainly focus on supporting energy efficiency improvements and low-carbon technologies, such as heat pumps, biomass boilers and solar thermal, for heating of homes and businesses but also support for new heat networks to be built.
- **Long distance between industry and end user.** General for Belgium a main perceived barrier is the long distance from the industry to the first large sized potential end user.

#### *Non-economic barriers*

- **Long-term commitment of end users.** Uncertainties of different aspects are perceived barriers according to several of the demo sites. For some of the demo sites (Portugal, UK and two in Belgium) the industries consider that the end users may feel too dependent on one heat supplier or that they can't guarantee that they are still in production and/or will have the same heat demand in for example 10 years. Thereby contractual lengths with medium to long term commitments between different actors could be a barrier. Different views of suitable contract lengths are ranked as an important or essential barrier according to the demo sites.
- **Unknown technology/lack of experience.** In countries or demo site regions with no or limited traditions of district heating the lack of experience is highlighted as a main barrier (Spain, Portugal and one in Belgium). The lack of experience relates to the construction phase, but also to operation and maintenance. The demo sites in Portugal and Spain also ranked uncertainty due to untested technology as an essential barrier. According to the PESTLE analysis district heating is indirectly pushed for in policies for zero-emissions new building in Belgium. In Spain support schemes exist for district heating and cooling on national, regional and local level.
- **Not core business, lack of funding for other investments.** Two of the demo sites (Belgium and UK) describes it difficult for the industries (in this case manufacturing and steel) to get capital to issues regarding to energy efficiency when competing with the core business investments. There is a lack of funding, capital and manpower for non-core investments even if there is a good business case. This is a main barrier to develop excess heat collaborations.

- **Barriers regarding regulations.** In the countries or regions with no or limited tradition of building DHN, lack of regulations is mentioned as barriers. This related to Portugal, Belgium, UK and Italy. Also, in Spain the deployment of the pipes requires complicated regulation processes. In the existing heat networks in Spain, the regional government owns the pipes and distribute to their own uses. In case the private ESCO company will be responsible for the deployment and the distance to the administration will thereby be bigger.
- **Requirements for a short payback period for investments** is ranked as an essential barrier according to all demo sites.
- **Difficulties to agree on pricing** is ranked as an essential barrier according to all but one of the demo sites.
- **Lack of knowledge or understanding of each other's systems, processes etc** is ranked as essential to all demo sites except for RADET in Romania.

The demo site RADET in Romania is the only of the demo sites which has a DHN infrastructure at this point. The following barriers was highlighted related to the specific situation at RADET.

- **Regulatory and financial barriers.** At the demo site there is principal possibility to buy heat, but it is still complicated to implement the collaborations. For example, the heat supplier must be certified to be able to sell the heat, and it can be difficult. The excess heat producers need to apply for loans at the bank or to other financing institutions. A binding paragraph in the contractual arrangements that states the way in which the DH company can guarantee that they are buying the heat supplied by the WH company could be a complement in the loan application.
- **Technical barriers.** RADET points out a technical issue of the current district heating network. The DHN is prepared for injecting excess heat, but it has very large losses and requires a huge refurbishment process. At present, the local municipality that owns the DHN is preparing a large project for re-sizing and upgrading it. The other demo sites consider technical barriers as less important barriers.
- **Competition with other heat production in DHN.** At the demo site RADET the district heating is to great extent relying on one single thermal power plant.

## 7 Discussion and conclusions

In this chapter the experiences from earlier studies are tied together with the results from interviews with the Swedish lighthouse cluster and the SO WHAT demo sites. Most of the barriers found in literature and experienced by the Swedish lighthouse cluster, are found at the demo sites as well. However, depending on local prerequisites the barriers occurs at a varying degree and shape from site to site.

### 7.1 Identify the win-win collaboration

The first step in the quest to valorise industrial excess heat is to find a profitable business case. However, due to low costs of alternative heating and the high initial investment cost for piping and other technology, that could be a challenge. According to the interviews performed in this study, a major barrier to an efficient business case is that policy promotes other energy alternatives than industrial excess heat.

In comparison with the other demo site countries, Sweden has a high natural gas price. Instead competition comes from low electricity price and heat pumps. Sweden has been engaged in industrial waste heat recovery for decades. For the industries in the SO WHAT collaborations, there is a great value in replacing the cooling equipment by excess heat delivery to a district heating network. Both in Varberg and Gothenburg, the business case of the excess heat collaboration has been considered as a win-win deal between the industry and the district heating company.

In addition, the owners of the district heating systems in Varberg and Gothenburg are the municipalities, and they had a political will to promote the heat collaboration. The municipalities regarded this as both a way to use local resources more efficiently and promote the local industries; an important enabling factor.

### 7.2 Opportunity to use industrial excess heat for cooling

Generally, in southern Europe where several of the studied countries are situated, the cooling requirements is relatively large. Furthermore, due to the competition with low price natural gas for heating, one alternative business case which potentially could have better profitability is using waste heat to produce district cooling. This could be done with absorption chillers, as it for example is done in Gothenburg. A common competitive way of producing district cooling is with compressor chillers, which use electricity. In all countries the electricity price is higher than the price of natural gas which makes this an interesting option. However, the compressor chillers generate more than three kWh cold per kWh electricity input, which flattens the cooling energy cost for compressor chillers. Hence, to compete with compressor chiller the price of alternative cold needs to be below one third of the electricity price.

### 7.3 Set the policy and regulatory framework

Policy support, such as financial support or legal requirements, would be needed to reduce natural gas use for heating and by that make the industrial waste heat more competitive. One example related to legal aspects from the PESTLE analysis is Spain where new regulations are expected to boost a shift from gas heating to electric heat pumps. On both national and European level, the use of excess heat should be equally promoted. With policy's promoting district heating and excess heat collaboration, the barrier can decrease.



In the countries or regions with no or limited tradition of building DHN, lack of regulations is mentioned as a barrier. Development of the regulatory framework is essential for the exploitation of industrial excess heat, e.g. permission process for piping.

## 7.4 Technical know-how

Lack of experience of the technology is one major barrier in many of the demo site countries. A barrier to realize the potential, is the limited access to technical knowhow. Knowledge transfer and development of tools to evaluate the techno-economic feasibility, through for example similar projects like SO WHAT, can potentially contribute to reduce this barrier in the long run.

## 7.5 Trust and understanding

In the Swedish lighthouse cases, an important enabling factor was trust between the collaborating parties. The experience is that close cooperation relation and openness between the parties are keys to establish a successful collaboration. Trust between the partners makes other barriers easier to overcome. On the other hand, lack of trust would be a barrier which makes other barriers even larger.

One part of building trust is to increase understanding about each other's systems. Lack of this understanding has been highlighted as a major barrier by the interviewed demo sites.

## 7.6 Remove the barriers with contractual arrangements

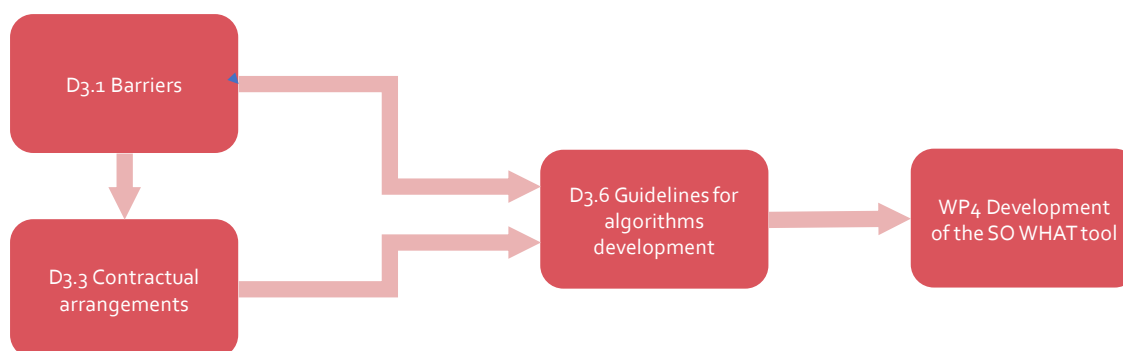
To summarise, the demo sites have considered different main barriers depending on the sector, level of earlier experiences and infrastructure of DHN etc. The mentioned barriers cover a wide range of areas and issues, some of them may be managed by contractual arrangements and some of them need to be handled by other measures. The following main barriers will be considered in deliverable 3.3 on current contractual arrangements for WH/C exploitation:

- Long-term commitment of end users
- Large initial cost
- Not core business
- Financial barriers
- Requirements for a short payback period for investments
- Difficulties to agree on pricing
- Lack of knowledge or understanding of each other's systems, processes etc
- The risk of industries shutting down. All demo sites except for one have ranked this barrier as important.



## 8 Input to the development of the SO WHAT tool

In Figure 7 an overview is shown for how the results from this report will be further used in the SO WHAT-project. The barriers that may be mitigated by contractual arrangements will be elaborated in D3.3. The results from both D3.1 and D3.3 will be developed into guidelines for algorithms development in D3.6. The guidelines will then be used in the development of the SO WHAT tool in WP4.



*Figure 7: Input flow from D3.1 to the SO WHAT tool.*

In the following it is discussed how the SO WHAT tool can be developed to remove barriers. The SO WHAT tool and project should, if not remove the barriers, support the stakeholders to better understand them.

Firstly, the SO WHAT tool could help to remove barriers through identifying profitable business cases. Important is to focus on mutual gain among the possible partners involved in the collaboration. This could be done by expanded system boundaries, i.e. looking at the total region at once instead of one subsystem (the industry, the district heating system etc) at a time. The purpose of the is to create a common ground where the partners agree on the benefits with collaboration. Possibly, this can be a part of the free version. In order to foster collaboration and identify opportunities, rough number can be used as input to the tool.

Furthermore, the SO WHAT tool could be used to increase understanding of the different stakeholders' systems. A major barrier to collaboration is the lack of understanding of each other's systems, and the SO WHAT tool could be used as a platform for the stakeholder to explain their technical prerequisites and other viewpoints.

Increased knowledge about each other's systems could reduce the experienced uncertainties regarding other partners activities. For example, with better understanding, the risk of an industry closing or a heat user to change heat source, could be evaluated more accurately.

In addition, if the SO WHAT tool could be used as a platform to start and elaborate a discussion about collaboration, trust could be built between the partners. Openness and dialogue are main components in trust building.

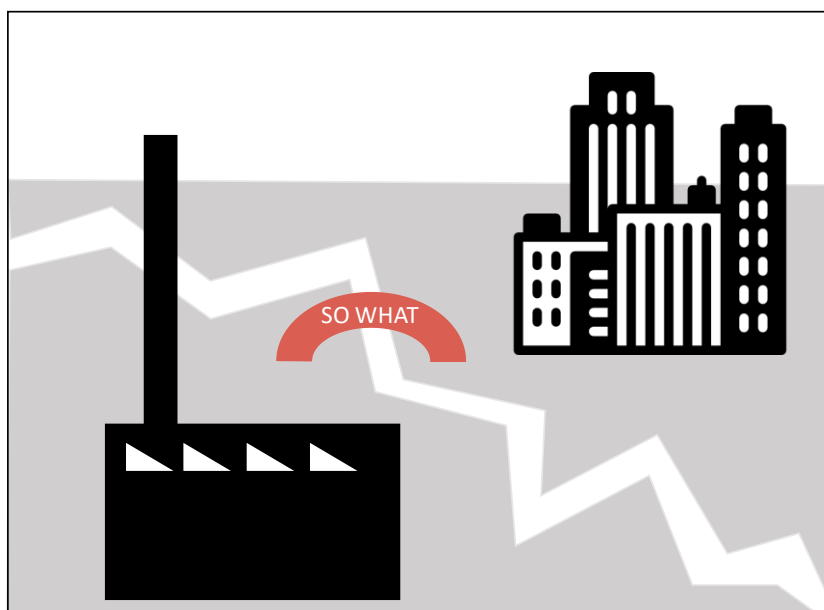


Figure 8: SO WHAT

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## Appendix A Questionnaire

### Background

1. Does WH/C cooperation already exist in the demo site region? (Between which partners, what is included etc?) If yes, what was the experience and what was concluded?
2. Has WH/C cooperation been discussed between partners within the demo site or with other stakeholders in the region earlier? (Which stakeholders? When? Any results so far?)
3. Which partners are considered for WH/C cooperation within the SO WHAT-project?
4. What do the demo site partners expect from the SO WHAT-project? (Why have they joined the project? Do they wish to sell or buy heat or cold?)
5. What incentives do different partners in the cluster have? (Extra revenue for selling heat or cold, policy demands on industries, avoid building new heat or cold production unit, etc)

### Barriers

6. What are the main barriers to WH/C cooperation within the demo site?
7. To what extent are these barriers, which have been identified in earlier studies, relevant within the demo site? Rank the barriers (Essential – Important - Less important)
  - a. Difficulties to agree on pricing
  - b. Different views of delivery quality
  - c. Different views of suitable contract length
  - d. Lack of knowledge or understanding of each other's systems, processes and traditions/organizational culture?
  - e. Risk that the industry may not always supply heat
  - f. Risk of industrial closure
  - g. Uncertainty due to untested technology
  - h. Complex technology
  - i. Large initial cost (for piping etc.)
  - j. Other priorities in the companies
  - k. High costs (time-consuming) for developing contracts, procurement etc.
  - l. Requirements for a short payback period for investments
  - m. Other energy alternatives are less expensive
  - n. Policy instruments favour other energy alternatives

## Appendix B PESTLE analysis

H2020 Work Programme



Work package 3  
PESTLE

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## Summary

PESTLE is an analysis tool which a company can use to assess a market in which it operates or in which it plans to launch a new project, product or service. The PESTLE presented in this report includes aspects that may create opportunities and barriers for waste heat and cold recovery from industries, as well as the waste heat and cold integrated with RES. The EU (present and former) member states that has been analyzed are Belgium, Italy, Portugal, Romania, Spain, Sweden and the United Kingdom.

Gas is the main energy carrier in the European thermal sector and district heating as well as renewables make up a very small share of the heating and cooling demand in the EU28 countries. EU policy and legislation focuses on increasing the share of renewables and to decrease the demand for space heating in building. Excess heat and cold from industries are mentioned but no specific technology or application is promoted. The estimated EU technical potential is 300 TWh/year for waste heat, mainly from iron and steel industry, and 64 TWh/year for waste cold, LNG and WtE plants giving the highest potential.

In Belgium the policies are mainly pushing for the investment in solar thermal, heat pumps and CHP. District heating is in a developing phase and is indirectly pushed for in policies for zero-emissions new buildings. Residual heat and cold is not mentioned in policy and RES targets are relatively moderate. The potential for RES is low, especially in the heating and cooling sector. However, there is large technical potential for waste heat in Belgium. Natural gas, and other fossil fuels, are the strongest competitors to residual thermal energy and social tariffs and taxes primarily incentivize natural gas as an energy carrier. The lack of existing infrastructure to recover waste heat and cold induces large investments cost and longer payback times which could discourage investments in residual thermal energy. The price and availability of energy are the two aspects that Belgians are most concerned about when it comes to energy. The main health issues today are particulate matter and NO<sub>x</sub> emissions from fossil fuels in urban areas. Environmental concerns mentioned in the heating and cooling sector are mainly GHG emissions, such as CO<sub>2</sub> and NO<sub>x</sub>, and soil pollution from leaking heating oil tanks.

In Italy policies mainly focus on solar thermal, heat pumps, geothermal and biomass. District heating and is also covered, e.g. with obligations to include RES or district heating in buildings and requirements on some new developments to be connected to district heating. Fossil fuels, and primarily natural gas, is the main competitor to other of thermal energy sources and district heating networks are dependent on incentives for cogeneration to be competitive. Currently 5 % of the population is served by district heating, mainly from biomass. Some of the main concerns with heating and cooling today are hot temperatures and overall summer temperatures that contribute to a high level of heat-related effects on mortality. In some areas the burning of solid biomass also contributes to pollutants associated with health and environmental issues.

In Portugal there is no direct push for the recovery of industry excess heat and cold in the energy policy. The focus is on electrification, solar thermal, heat pumps and biomass. Buildings codes are specifically pushing for solar thermal for heating domestic water. Gas, coal and oil dominate the heating and cooling supply today and the energy sector is one of the main contributors to GHG emissions. Process heating contributes to the largest demand before space heating and the demand for space heating and cooling is in general low, thanks to Portugal's mild climate. Portugal has a large

RES potential, especially heat from cogeneration with renewable origin and biomass could contribute to the heating sector. The share of district heating is very low, and the potential is also low due to low demand. There is some potential for waste heat and cold recovery, mainly from industrial sites and thermal plants.

In Romania there is an existing state aid program giving incentives to investments in efficient cogeneration from residual industrial process heat. Investments in district heating and cooling is also identified as one way to reach energy efficiency objectives. District heating has historically been a large part of the thermal supply in Romania but is in decline due to several reasons and competes with individual heating solutions, mainly with natural gas as the energy carrier. The excess heat potential is considerable and combined with RES, mainly firewood and agricultural waste, it could heat a large share of the population. However, the district heating system, which is currently in decline, needs to be developed to make use of the potential. There is no regulation directly targeting waste heat and cold recovery, but the existing legal framework could be applied to a certain point. Fuel poverty as well as health and safety risks associated with the widespread individual heating solutions are among the greatest Romanian social concerns linked to the thermal sector. The energy sector is also the main contributor to GHG emissions in the country.

In Spain electrification and RES in the thermal sector (mainly solar, but in reality, heat pumps) are pushed for while residual heat and cold is mentioned in policies but not explicitly pushed for. Support schemes exist for district heating and cooling on national, regional and local level. New regulations are expected to boost a shift from gas heating to electric heat pumps. The main competitor to waste heat is gas, mainly used in individual solutions that still dominates the thermal sector. Investment costs in heat and cold recovery are high and the incentives are low today, especially for industries that does not have a CHP plant already. District heating is getting more and more attention but represents a very small share. The lack of DHC infrastructure, in combination with the seasonality of demand, pose technical challenges to make use of the large waste heat potential. Public concerns in the country mainly focus on energy price and comfort levels. Energy poverty affecting the populations ability to keep warm during the winter, CO poisoning and issues with excessive temperatures are some of the health and safety issues associated with the current thermal energy system. GHG emissions are the most commonly mentioned environmental impact from the Spanish energy system. However, the energy sector is the main contributor to several types of emissions, among them SO<sub>x</sub> and PM<sub>2,5</sub>. With the increased recovery of waste heat there is also a risk of a more extensive use of fluorinated gases which may exist in the heat pumps used for recovery.

In Sweden policy is pushing for a decarbonization of the entire energy sector partly thanks to policies and regulations individual heat boilers have been substituted by heat pumps and biofuels to a large extent. The share of district heating is also large, especially in the residential sector. The residential sector is also the main user of heating and cooling in Sweden, thanks to a large space heating demand. Together with district heating, electricity is also of the main thermal energy supplies for the residential sector, while the industrial sector relies on biomass. Biomass and waste incineration are also the main contributors to the district heating systems, but the share of excess heat in district heating supply (9 %) is not negligible. The introduction of district heating has contributed to an improvement in local emissions, but the health risks associated with climate change such as heat-related deaths and the spread of infectious diseases are a concern.

In the United Kingdom policy is focusing on energy efficiency improvements and heat pumps, biomass and solar thermal. There is support for investments in new district heating networks. Today 2 % of the UK heat demand is supplied by district heating. Long payback-time and lack of confidence in recovery technologies are affecting industry investments in heat and cold recovery, as well as the strong competition from natural gas as the current main thermal energy supply. Raising energy bills for residential customers is one of the main social concerns, and health effects from the burning of fossil fuels and biomass is an issue especially in the larger cities. As a result, regulation is pushing for low carbon heating and more efficient individual boilers. GHG emissions as well as leakages of the global warming potent F-gases from refrigerants are some of the environmental concerns associated with the energy sector.





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# Approach and Methodology

## I.I. PESTLE

PESTLE is an analysis tool which a company can use to assess a market in which it operates or in which it plans to launch a new project, product or service [1]. The six letters in the acronym represents the aspects that are considered when assessing a market; Political, Economic, Social, Technological, Legal and Environmental. The PESTLE presented in this report includes aspects (presented in Figure 9 and briefly presented below) that may create opportunities and barriers for waste heat and cold recovery from industries, as well as the waste heat and cold integrated with RES.

Lygnerud and Werner [2] identified that existing policy incentives for alternative heat supply is one of the known barriers to the use of waste heat. In the sections focusing on policies and regulations the is being considered when analyzing the political and legal aspects that could possibly affect the use of waste heat and waste cold, as well as RES.

To analyze the risk of substitution to another supply, also identified as one of the greatest risks of terminated heat delivery by Lygnerud and Werner [2], the cost competitive heating and cooling supply has been identified. The general demand for thermal energy as well as the economic incentives to recover waste thermal energy is also investigated as part of the sections dealing with economy.

In the sections dealing with social aspects could be certain issues of public concern or health or safety concerns related to the thermal energy sector. Analogous to the social concerns, the environmental impacts of the current thermal energy system are analyzed as part of the environmental sections in the PESTLE.

As for the technical aspects, Lygnerud and Werner [2] highlighted that the absence of a district heating network could be a barrier to the use of waste heat. Hence the prevalence of district heating and cooling networks is analyzed. In addition to this, the general potential for RES and waste heat and waste cold is studied as part of the technological sections.

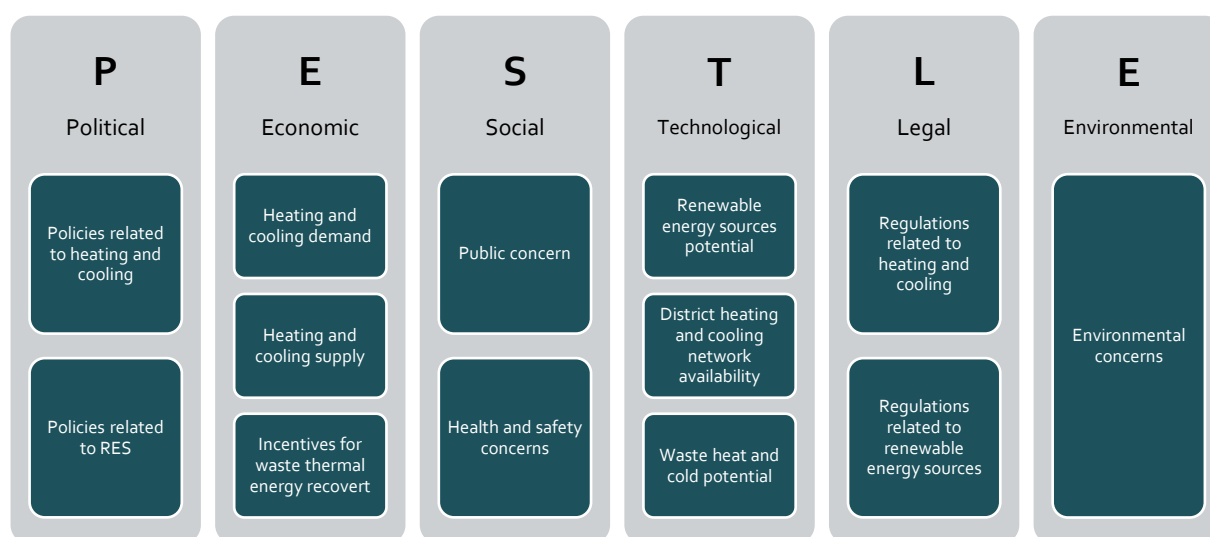


Figure 9: PESTLE aspects analyzed

## I.II.Literature review and questionnaire

In order to gather information about the different aspects related to the PESTLE two methods have been used: literature review and questionnaire.

The themes in the literature review were based on the above-mentioned PESTLE aspects. Sources of information have been findings from previous European projects, e.g. Heat Roadmap Europe 4 and ReuseHeat. Information has also been retrieved from reports published by international organizations such as the European Commission and the International Energy Agency (IEA). National reports as well as academic papers has also been of great value. For a full list of the references used, see the reference list in the end of this report.

The questionnaire contained questions related to the subjects in the PESTLE. Since the literature review had already given some hints, the questions were adapted to the individual country. As a result, six somewhat similar questionnaires were sent out to eight of the partners in the SO WHAT-project: Kelvin Solutions (Belgium), 2GO OUT Consulting (Portugal), MEDgreen (Romania) and Fundación CARTIF (Spain), Environment Park (Italy) and finally; University of Birmingham and Materials Processing Institute (United Kingdom). Out of these, answers were received from the following countries: Belgium, Portugal, Spain, Italy and the United Kingdom. There was no response from the Romanian partner. The questionnaires can be found in Appendix I. Sweden was not included in the questionnaire as the responsible for the PESTLE are based in Sweden.

Given the amount and the quality of the information gathered there is a more or less accurate representation of the opportunities and barriers for waste heat and cold recovery in the four countries. For transparency, Figure 10 is providing a score (0-5) for the availability of information gathered from the literature review and the questionnaire.

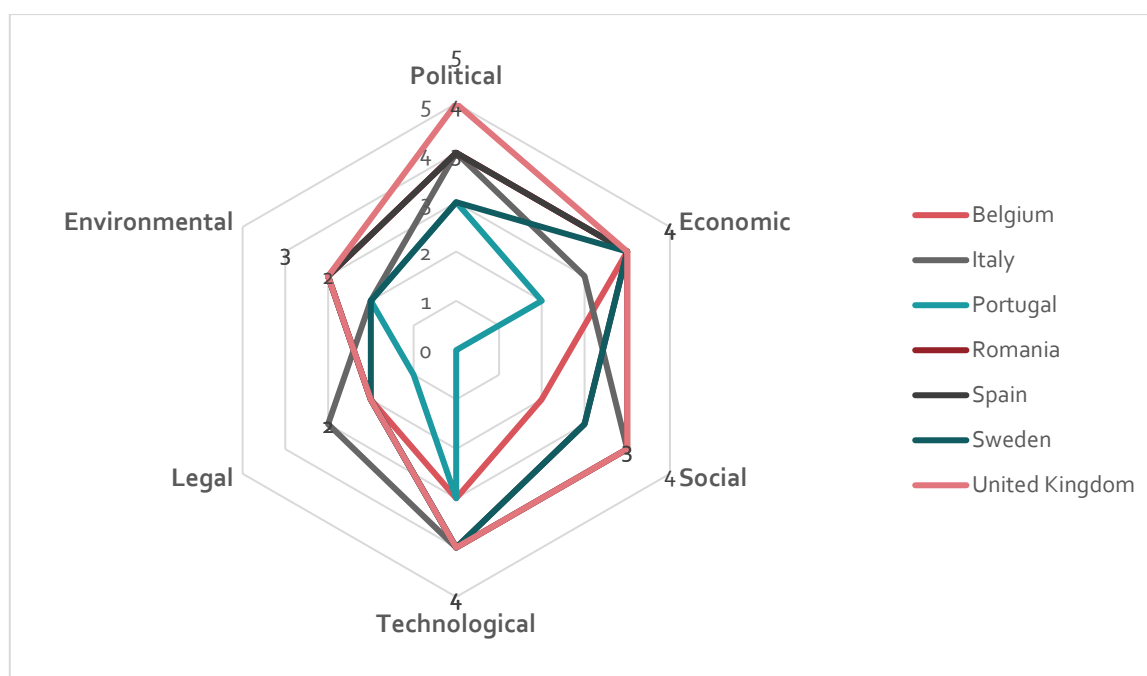


Figure 10: Availability of information as input for PESTLE

# I Heating and Cooling in EU

The countries in this PESTLE are all members of the EU and consequently effected by the EU regulations and the internal market. This section provides some background information about the heating and cooling sector in the European Union, the potential for excess heat and cold recovery as well as relevant legislation that effect all member countries.

## II.I.Demand and Supply

**Gas is the main energy carrier in the European thermal sector. District heating make up a very small share of the heating and cooling demand in the EU28 countries, and the renewable portion is also very low. Waste heat and cold is currently not noticeable in the thermal energy mix.**

In the Heat Roadmap Europe 4 project the heating and cooling demand in EU28 countries were analyzed based on 2015 values. This is the most recent statistics found that provide extensive information about the entire EU. The main energy carrier used for heating and cooling in total in the EU28 countries in 2015 was gas (see Figure 11). The final use is mainly space heating, with process heating second in use (see Figure 12). Space heating is the largest use in the service sector (tertiary sector) and in the residential sector, while process heating is the main application for heat and cold in the industry sector (see Figure 13). Gas is the largest energy carrier in all three sectors (Figure 14). In all countries the service sector is the smallest in term of demand of heating and cooling, but it varies between the countries if the residential or industry sector is the largest in demand (see Figure 15). Space heating and process heating contributes to the major part of the demand in most of the countries (see Figure 16). The energy carrier mix providing heat and cold in the EU28 Member countries varies between the regions (see Figure 17) [3].

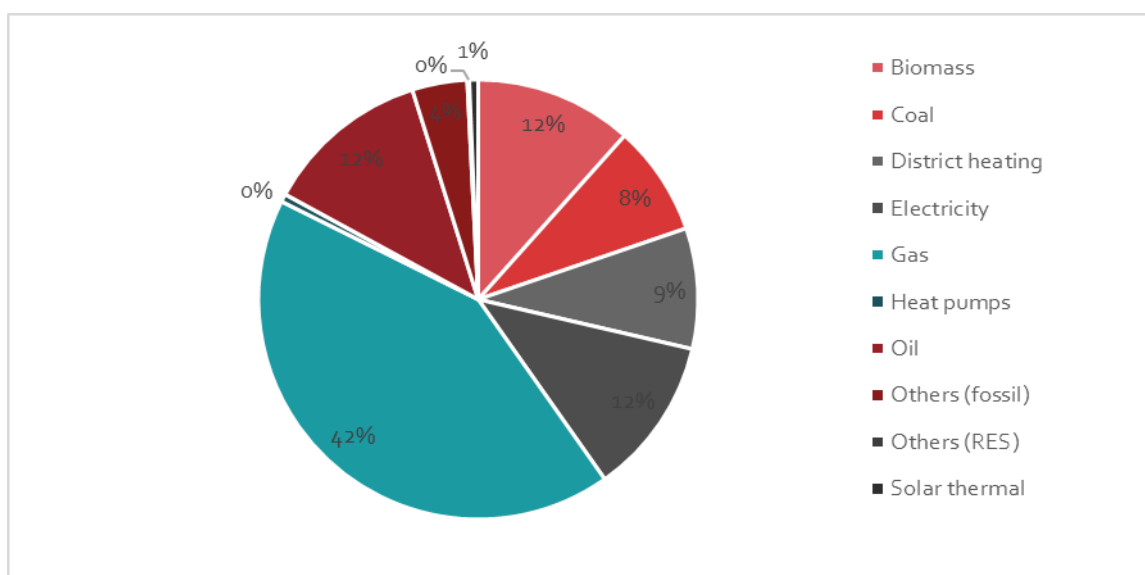


Figure 11: Share of energy carrier in the total final heating and cooling demand, Heat Roadmap Europe 4 2015 [3]

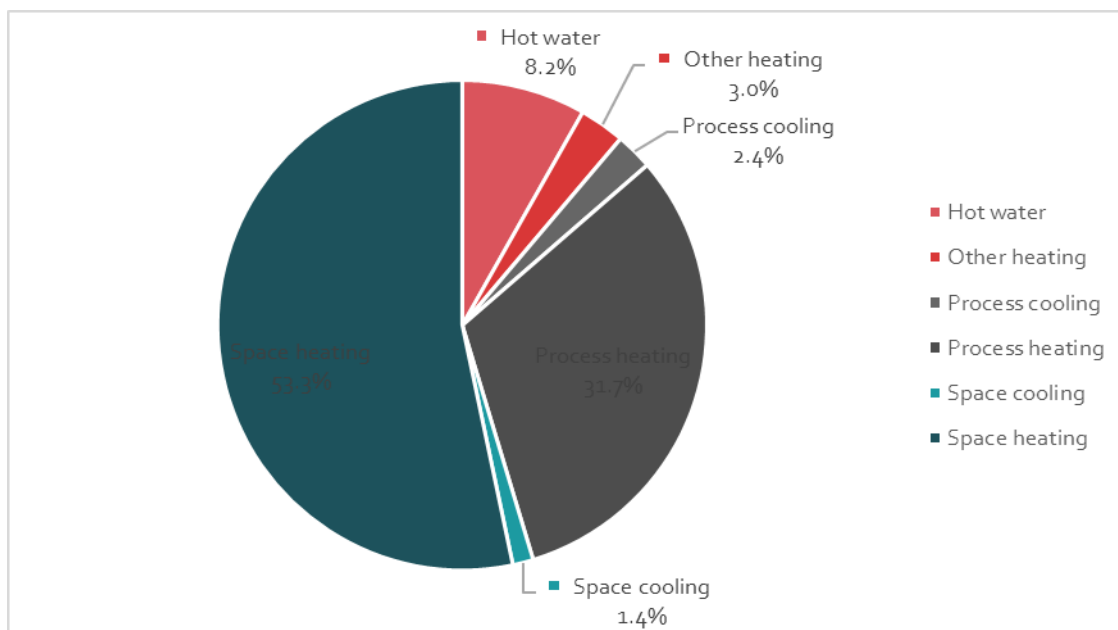


Figure 12: Shares of the different types of final heating/cooling, Heat Roadmap Europe 4 2015 [3]

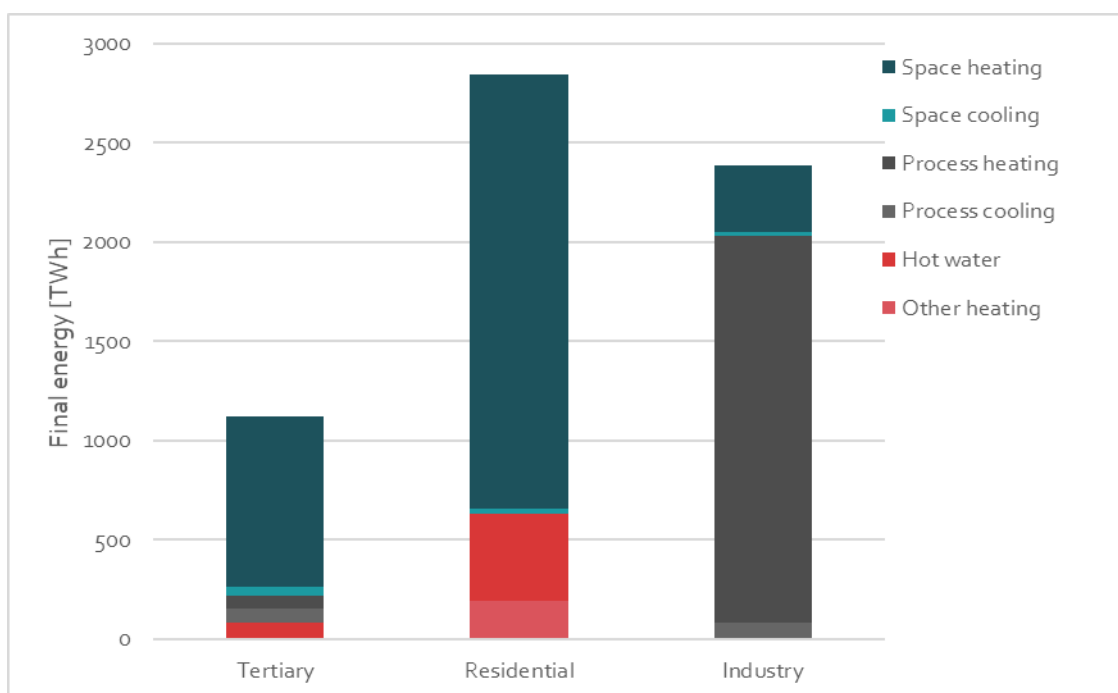


Figure 13: Shares of type of heat in final heating and cooling by sector, Heat Roadmap Europe 4 2015 [3]

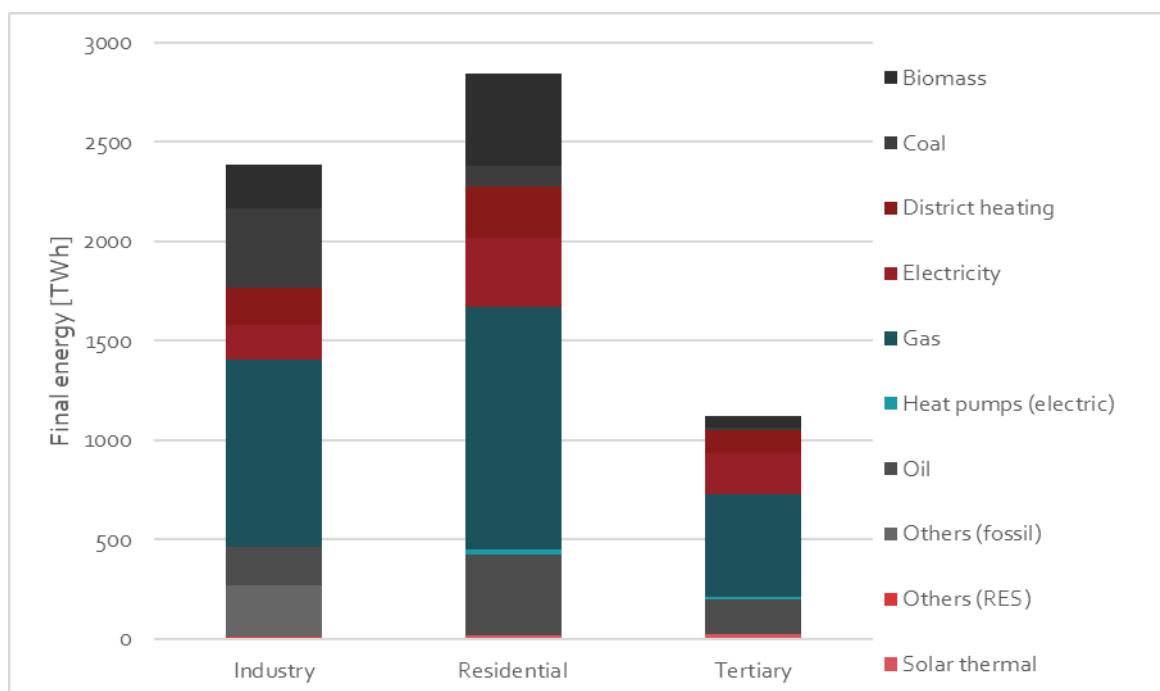


Figure 14: Shares of energy carriers in heating and cooling demand by sector, Heat Roadmap Europe 4 2015 [3]

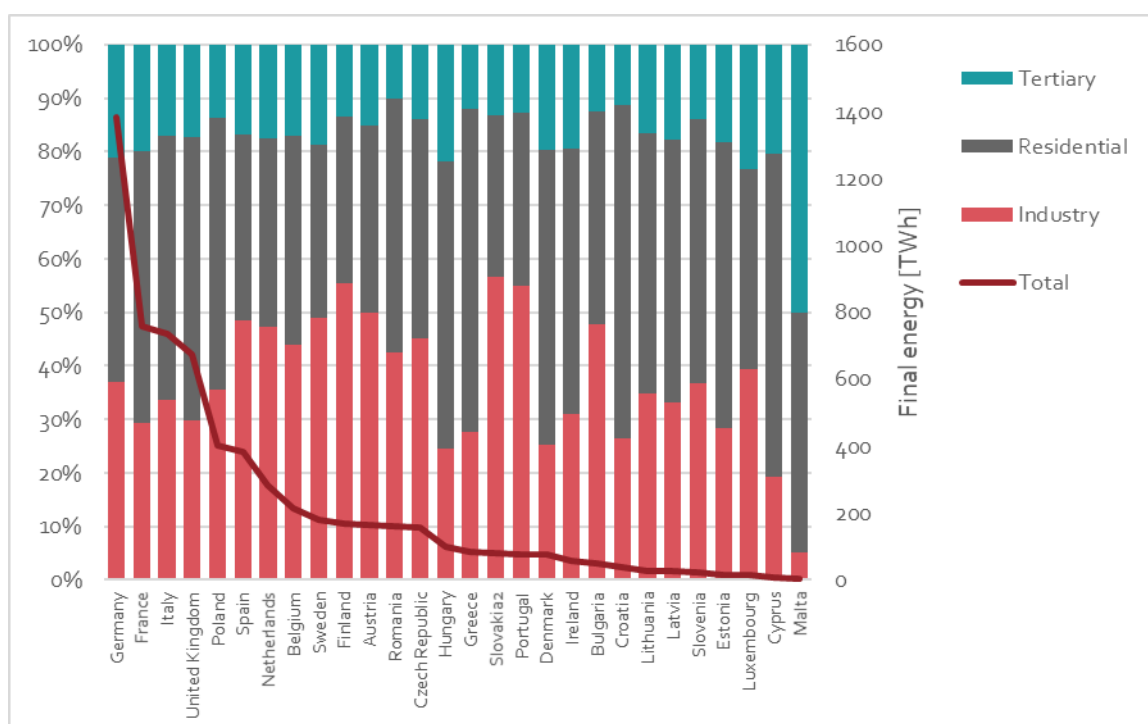


Figure 15: Heating and cooling by sector and country, Heat Roadmap Europe 4 2015 [3]

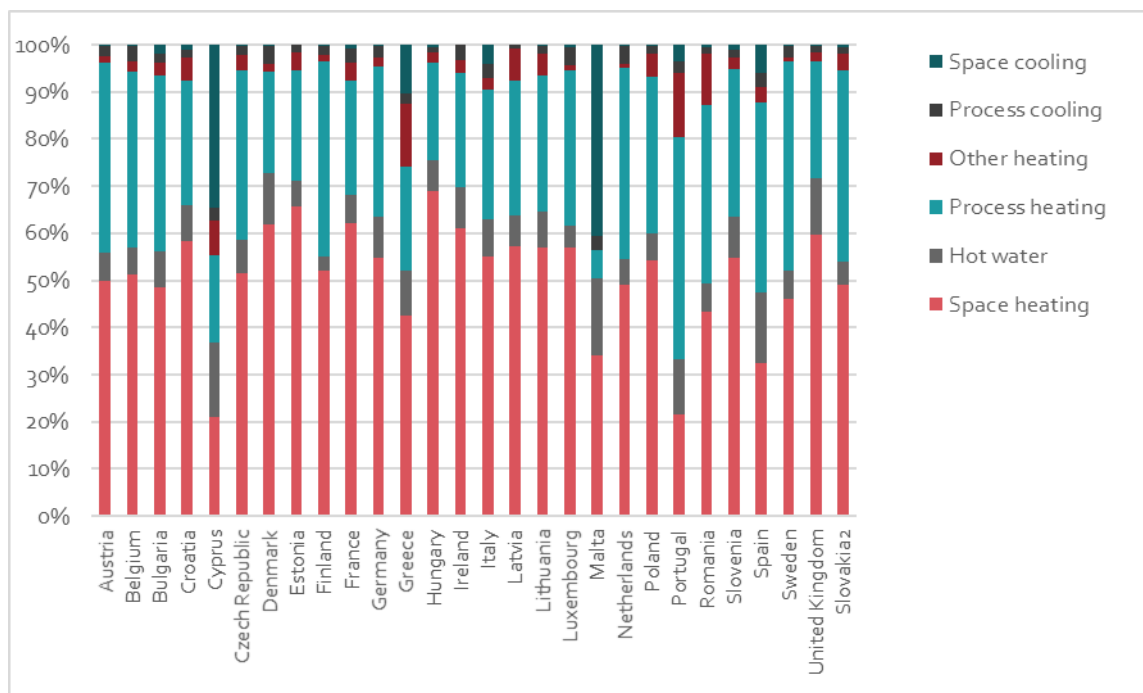


Figure 16: Share of type of heat in total final heating and cooling demand by country, Heat Roadmap Europe 4 2015 [3]

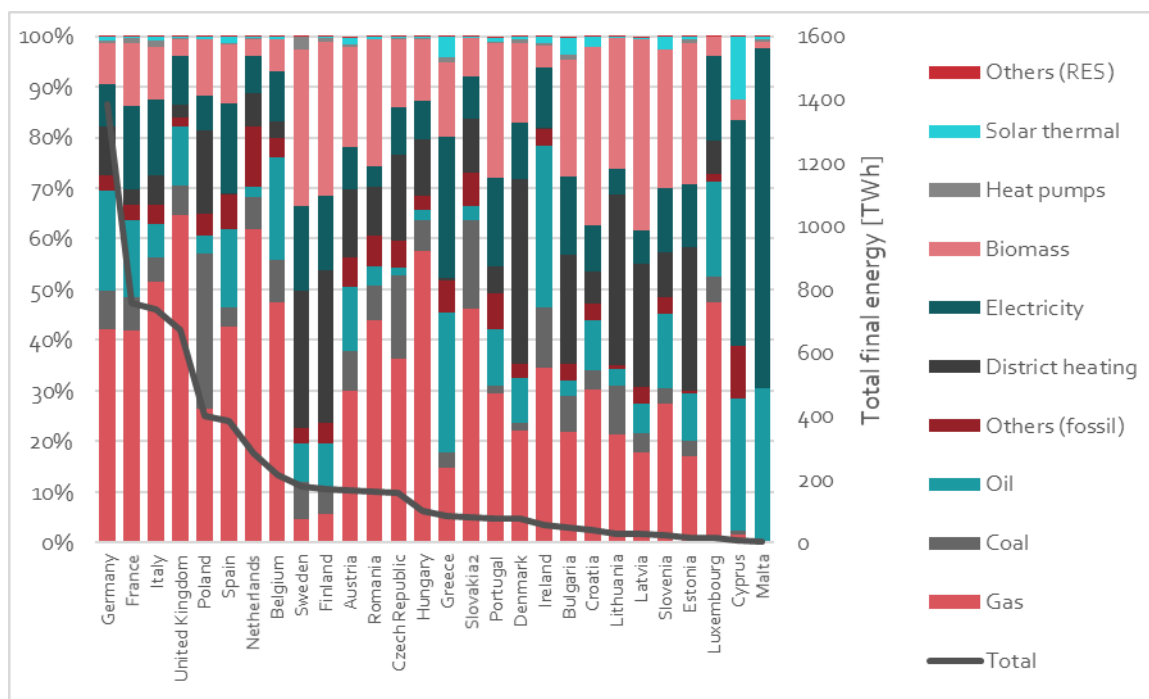


Figure 17: Share of energy carrier by country for the final heating and cooling demand for all sectors, Heat Roadmap Europe 4 2015 [3]

## II.II. Potential for Industrial Excess Heat and Cold Recovery

**The estimated EU technical potential is 300 TWh/year for waste heat and 64 TWh/year for waste cold. The largest potential for heating is in the iron and steel industry, and for cooling in LNG and WtE plants.**

The total technical potential for industrial waste heat utilization has been estimated to 300 TWh/year. One third of the energy corresponds to temperature levels below 200°C, referred to as low-temperature heat; about one-quarter is in the range of 200-500 °C and the rest is more than 500°C (mainly in the 500-1000°C range). The total waste heat potential per industrial sector in EU is the highest in the iron and steel industries [4].

The current utilization for recovered excess heat is low, compared to the total energy supplied in the national district heating sectors. Sweden has one of the highest shares of excess heat in the district heating system with 9 %, but most EU Member States have a share that is much lower [2].

Waste energy for cooling is mainly recovered from liquid natural gas (LNG) gasification plants or from waste incineration in waste-to-energy (WtE) plants. From these types of industries, the energy can be recovered at the right temperature and then absorption chillers help to produce cooling energy. The potential for cooling from LNG plants (37 in total in EU) have been estimated to 4.5 TWh/year [5] and the potential from WtE plants is estimated to be 59.5 TWh (with COP 0.7) [6].

## II.III. Policy and Legislation

**EU policy and legislation focuses on increasing the share of renewables and to decrease the demand for space heating in buildings. Excess heat and cold from industries are mentioned but no specific technology or application is promoted. Process heating is *not* mentioned in EU policy or legislation.**

### The EU Strategy on Heating and Cooling

In 2016 the European Commission presented the Heating and Cooling Strategy [7]. The strategy is part of the Energy Union Framework Strategy and is pushing for actions in a sector where renewables are not widely used. The strategy focuses on measures to optimize heating and cooling of buildings and industries and identifies the need for actions in four areas:

- I. Making it easier to renovate buildings;
- II. Increase the share of renewables;
- III. Reuse of energy waste from industry;
- IV. Getting consumers and industries involved.

The strategy referred to legislative reviews of the Energy Efficiency Directive, the Energy Performance of Buildings Directive and the Smart Financing for Smart Buildings Initiative in 2016; as well as the New Electricity Market Design and the proposal for a Renewable Energy Framework in 2016. It also highlighted some non-legislative actions aimed at energy efficiency measures in buildings [7].

In the area of waste energy from industries the strategy highlights some of the solutions that could be used: direct feed via district heating systems; cooling via cogeneration and absorptions chillers



that transform heat into cold and then used in buildings through a district cooling network; and general infrastructure development [7].

## The Clean Energy for All Europeans Package

In 2019 the EU agreed on an update on the energy policy framework [8]. The EU member countries now have 1-2 years to implement the updated directives into national law. The Clean energy for all Europeans package consists of eight legislative acts, of which four have direct connections with the heating and cooling sector:

- I. Energy Performance of Buildings Directive 2018/844
  - All new buildings must be nearly zero-energy buildings (NZEB) from 31 December 2020. Since 31 December 2018, all new public buildings already need to be NZEB.
  - EU countries must set cost-optimal minimum energy performance requirements for new buildings, for the major renovation of existing buildings, and for the replacement or retrofit of building elements such as heating and cooling systems, roofs, walls and so on.
- II. The recast Renewable Energy Directive (EU) 2018/2001
  - Binding target of 32% for renewable energy sources in the EU's energy mix by 2030.
  - Requirement on Member States to carry out assessments on the national potential for using renewables and waste heat and cold in the heating and cooling sector.
  - Each Member State shall try to increase the share of renewable energy in the heating and cooling sector by an indicative 1,3 percentage points as an annual average calculated for the periods 2021 to 2025 and 2026 to 2030, starting from the share of renewable energy in the heating and cooling sector in 2020.
- III. The revised Energy Efficiency Directive (EU) 2018/2002
  - Binding targets of at least 32.5% energy efficiency by 2030, relative to a 'business as usual' scenario.
  - EU countries must put measures in place to save on average 4.4% of their annual energy consumption between now and 2030.
  - Article 14 pushes the countries to promote efficiency in heating and cooling. It also requires the member states to ensure that cost-benefit analysis (CBA) is carried out to find the most efficient heating and cooling solutions and accommodate the development of high-efficiency cogeneration and the use of heating and cooling from waste heat and renewable sources. This has been in place since 2014 but is nonetheless relevant.
- IV. Governance of the energy union and climate action (EU) Regulation 2018/1999
  - Requirements on the Member States to draft an integrated 10-year national energy and climate plans (NECPs) for 2021 to 2030. The NECPs shall outline how the countries will achieve all their targets within the energy union and include a long-term view for 2050.

## Climate Policy and Regulation

With the 2020 climate package and the 2030 climate framework, the European Union decided to reduce GHG emissions by 20% from 1990 to 2020 and by at least 40% from 1990 to 2030. In 2050 the intention is to make the EU carbon neutral. There are specific targets for the Emission Trading System (ETS) and the non-ETS sector [9].

The ETS is a cap-and-trade system for large power and heat plants (minimum 20 megawatts thermal, MWth) and heavy industry. This system covers some 45% of the total emissions within the European Union. The legally binding, EU-wide target for the ETS is a 43% reduction in emissions from 2005 to 2030. There are no national targets [9].

The non-ETS sector includes transport, residential and commercial sectors, non-ETS industry, agriculture, and waste management. EU-level targets for GHG reductions in the non-ETS sectors are 10% from 2005 to 2020 and 30% from 2005 to 2030. The EU-level target for the non-ETS sector is translated into member states' national GHG emissions targets. The countries can use flexibility mechanisms to some extent, for example trading emission allowances between sectors and EU member states [9].

The European Union has a climate roadmap for 2050, stating that the European Union should reduce its domestic emissions to 80% below 1990 levels. The climate framework is the foundation for the collective commitment of EU countries to reduce GHG emissions to at least 40% below 1990 levels by 2030, according to the 2015 Paris Agreement [9].



## III Belgium

### III.I. Political

Belgian policy is mainly pushing for the investment in solar thermal, heat pumps and CHP. District heating is indirectly pushed for in policies for zero-emissions new buildings. Residual heat and cold is not mentioned in policy and RES targets are relatively moderate.

#### National Energy and Climate Plan (NECP)

A draft of the National Energy and Climate Plan was submitted to the EU in the end of 2018 [10]. The main objectives of the NCEP are:

- Reduction of GHG emissions by 35 % in 2030 compared with 2005 levels for non-ETS sectors.
- 18.3 % of the gross final energy consumption from renewable energy by 2030
- 26 % in primary energy savings and 12 % in final energy savings by 2030 compared with 2005 actual consumption, achieved mainly through EED Article 7 – requirement for energy companies to save an annual 1.5 % of their energy sales with additional energy efficiency projects

#### Policies related to heating and cooling

For CHP there are several policies, among them: investment support and green certificates in the Brussels-Capital and Walloon regions, and only certificates in the Flemish region, and tax deductions on investments in CHP on federal level [11].

#### Policies related to renewable energy sources

The existing measures to reduce CO<sub>2</sub> emissions from the energy-sector concentrate on energy efficiency and renewable energy. In the renewable energy sector, Belgium has several types of support policies for heat from renewable sources. At the federal level, investments in solar collector systems and heat pumps are tax-deductible for companies. In all three regions there are policies for zero-emission new buildings which also promotes renewable energy. There are also a number of different measures in the regions [11].

In the Flemish region, calls for tender have been for projects that produce renewable heat and for developing district heating from renewable sources or waste heat. The Flemish region also requires new buildings to cover a certain share of their energy use from renewable sources has been in place since 2014. It can include thermal solar, solar photovoltaics, biomass boilers/stoves, heat pumps, connection to a district heating or cooling system using renewable energy, or at least 10 kWh/year per m<sup>2</sup> of energy derived from renewable energy sources [11]. The Flemish support scheme also includes a quota system for RES, giving the grid operators and municipalities responsibility for setting up premium schemes [12].

In the Walloon region, the authorities have organized project calls to promote heat from renewable energy [11]. The generation of heat through renewable resources is also promoted by a system of energy subsidies, the possibility to be granted a zero-percent loan as well as investment incentives for companies [12].

The Brussels-Capital region is promoting heat from renewable energy sources through subsidies and investment assistance for companies. The region has also committed itself of reaching 30% renewables in the total energy consumption of new public buildings [12].

### Energy Efficiency Directive (EED) Article 14.5 implementation

The implementation of the EED is mainly the responsibility of the three regions. As of 2016 the article had been implemented in the Brussels-Capital Region and the Walloon Region. There was no information about the current status of implementation in the Flemish Region. The Walloon Region has implemented the cost benefit analysis of individual installations in the environmental permit regulation and it is also included in pre-engineered building permits procedures [13].

## III.II. Economic

**Natural gas, and other fossil fuels, are the strongest competitors to waste heat and waste cold in the thermal sector. The lack of existing infrastructure to recover waste heat and cold induces large investments cost and longer payback times which could discourage investors.**

### Heating and cooling demand

Heating and cooling is the majority of the energy demand in Belgium, with 51 % of the final energy demand [14]. More than half of that is used for space heating while 38 % is spent on process heating (see Figure 18). Cooling, the total of both space cooling and process cooling, comprises less than 4 %.

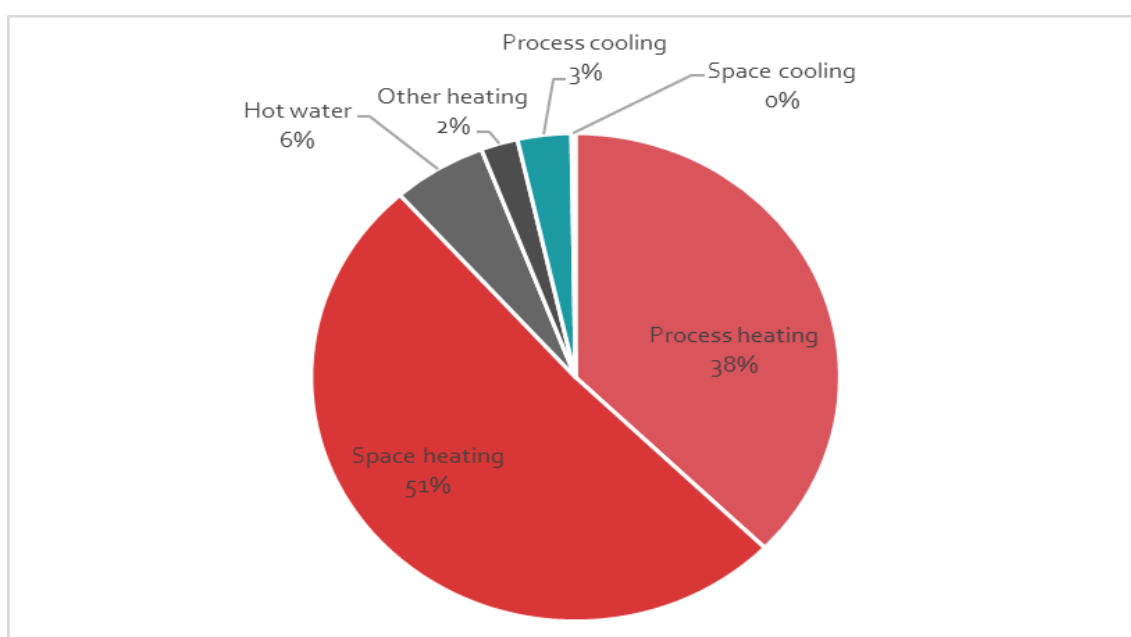


Figure 18: Shares of the different types of final heating/cooling, Belgium [3]

The industry and residential sectors contribute with the largest demand, but their end-use differs a bit (see Figure 19). The industry mainly demands process heating, while the residential sector uses heat mainly for space heating.

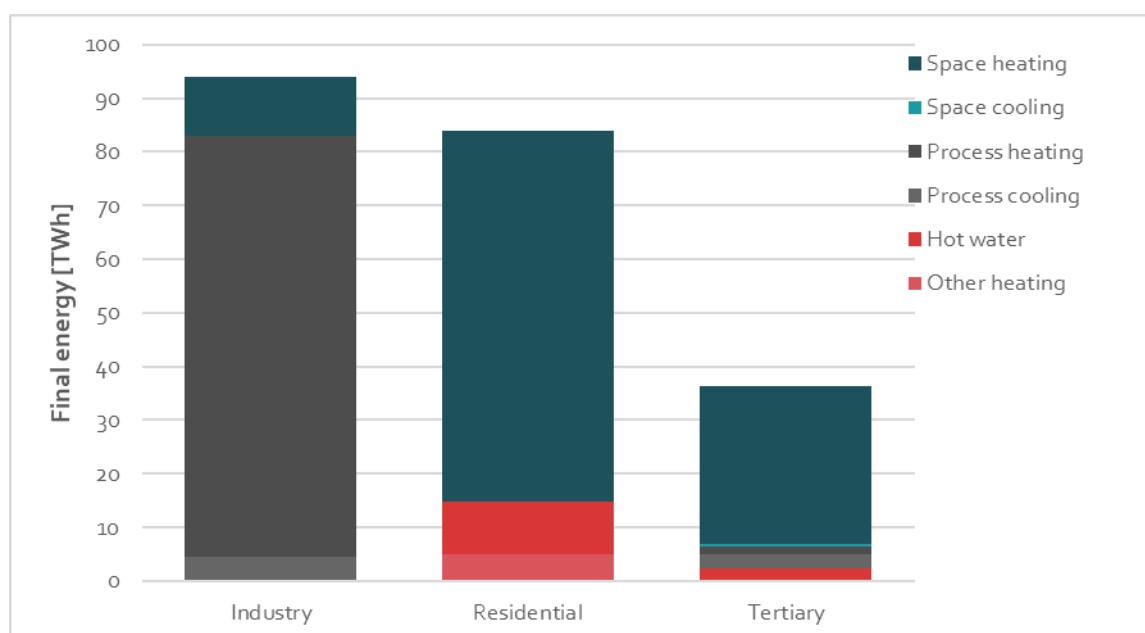


Figure 19: Shares of type of heat in final heating and cooling by sector, Belgium [3]

The Heat Roadmap project estimates that the total energy demand for heating and cooling will increase by 2 % from 2015 to 2050, including the effects of existing policies. Space heating is predicted to remain the largest demand in the heating and cooling sector. Demand in process heating and hot water demand is expected to rise by almost 20 % as a result of the lack of policies targeting these areas. Cooling is the fastest growing part of the thermal sector and is also expected to increase, especially the demand for process cooling which will increase by 40 % to 2050 [14].

### Heating and cooling supply

Out of the installed capacity for heating in 2015, 87 % came from individual boilers and the rest from district heating. In the cooling segment as much as 100 % came from individual cooling solutions [15].

The dominant energy carrier for Belgium's industry is gas, see Figure 20. The residential sector, Belgian households, mainly uses gas and oil for heating and cooling. No district heating, solar thermal or heat pumps are being used by the residential sector. The service sector, or tertiary sector, mainly uses gas as well.

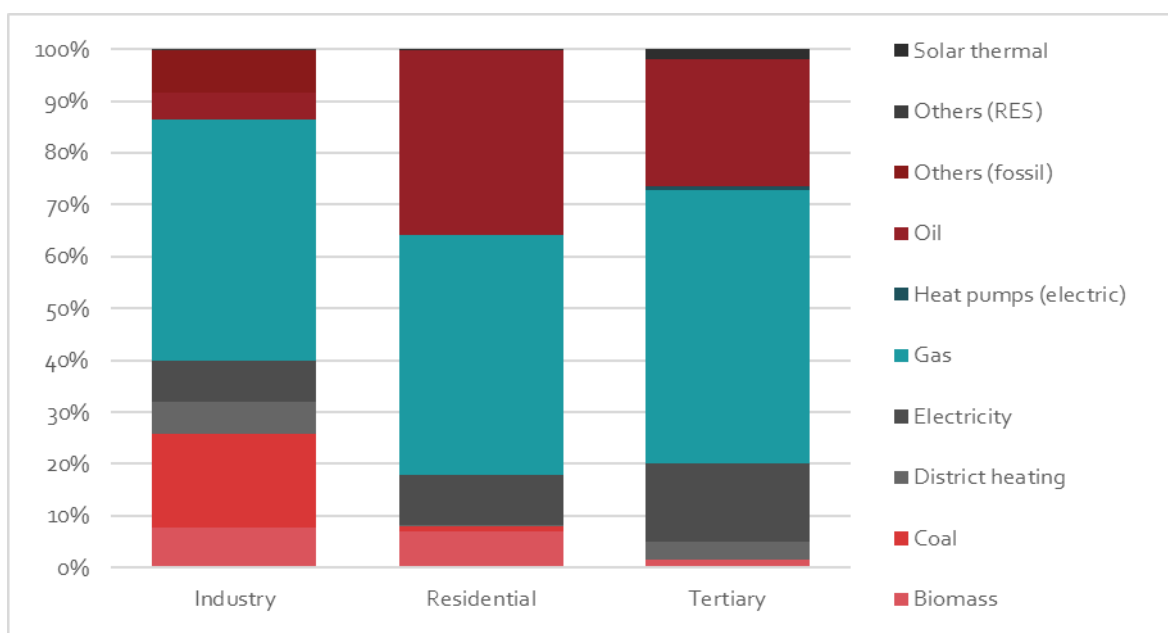


Figure 20: Shares of energy carriers in heating and cooling demand by sector, Belgium [3]

Belgium is highly dependent on other countries for its energy supply, and imports most of the oil, natural gas, coal and nuclear fuel. The country's total primary production accounts for about 20 % of its total primary energy consumption [10].

Oil heating remains common and Belgium has one of the lowest heating oil prices among the IEA member countries, mainly due to low taxes. The heating oil (gasoil, kerosene and propane) is also subsidised for low-income families. An ongoing trend is the expansion of gas distribution grids and the replacement of oil heating by gas boilers [11].

Interest in district heating and CHP using renewables or waste is growing. However, it competes directly with natural gas heating that still dominates. In 2013, Belgium's CHP facilities had a total capacity of about 2 600 megawatts electrical (MWe), compared with a total conventional thermal capacity of 7 559 MWe. CHP capacity has increased consistently from around 1 500 MWe in 2005 when financial support for the sector was introduced through CHP and green certificates. Most of the capacity is in the Flemish region (around 2 100 MWe) and linked to industry. Heat from CHP facilities is competitive at industrial facilities. However, in space heating, large-scale use of CHP for district heating remains marginal as it typically competes with the dominant gas boiler solutions [11].

In 2017, the share of RES in heating and cooling was 8 % [16].

### Incentives for waste thermal energy recovery

Interviewed Belgian district heating company in the REUSEHEAT-project states that the recovery of waste heat is in a too early stage of development as the district heating grids are in an early stage. In addition to this energy infrastructure projects tend to get expensive in Belgium, mainly due to high taxes and complex federal governance [17].

Local authorities also tend to favor natural gas grids and the price of natural gas is currently low which makes it challenging for district heating developments to be competitive. District heating is currently

more expensive than gas. The existing support schemes also tend to favor CHP to the expense of district heating. It is often more beneficial for e.g. a greenhouse to install its own natural gas fueled CHP plant than to connect to the district heating grid [17].

Some of the incentives for the industry to recover waste heat and cold, mentioned by the respondents of the questionnaire, are synergies with internal waste heat and waste cold recovery, to comply with the EU ETS regulations if applicable, reduce the greenhouse gas emissions from the plant or reduce the investments in cold and heat installations thanks to a more efficient use of thermal energy. The main economic challenges with recovering excess heat and cold is the limited existing infrastructure which induces a need for large investments that can have 3-4 times longer payback time than what is common in the industry sector.

### III.III. Social

**The price and availability of energy are the two aspects that Belgians are most concerned about when it comes to energy. Main health issues today are particulate matter and NO<sub>x</sub> emissions from fossil fuels in urban areas.**

#### Public concern

The main public concerns with the current thermal sector are the price of the energy and the availability of heat energy, according to the respondents of the questionnaire. They also mean that the main concerns with an increased use of waste heat and cold are an increase in the cost of energy due to large investments in distribution networks, e.g. district heating networks. There are also concerns that the large infrastructure works needed would generate more traffic congestion in areas that already are facing these issues.

#### Health and safety concerns

The main health and safety issues mentioned by the respondents of the questionnaire, are particulate matter and NO<sub>x</sub> emissions from the fossil fuels used for heat production in densely populated areas.

### III.IV. Technological

**The potential for RES is low, especially in the heating and cooling sector, so waste heat and cold coupled with RES is not such a viable option. However, there is large technical potential for waste heat in Belgium. District heating is in a developing phase.**

#### Renewable energy sources potential

According to the NECP, the potential for renewable energy generation is relatively low in Belgium. The country is flat, with a relatively low number of sunshine hours and is also densely populated. Hydropower, onshore wind power and solar generation is challenging due to land use restrictions and lack of public acceptance. In 2016, the share of renewable energy in total final energy consumption was 8.7 %. In the heating and cooling sector 8.14 % of the energy was renewable in 2016, and in this sector the share of renewable is increasing more slowly than in for example electricity generation [10]. The renewables that have some potential for heating and cooling are: deep and shallow geothermal energy, biomass, process heat from water treatment, surface water and solar thermal among others [18].

### District heating and cooling network availability

District heating production amounted to roughly 8 TWh in 2015. More than 90 % of the heat produced in district heating came from CHP with the rest being fuel boilers and a very small share of geothermal [15].

District heating is in a developing phase in Belgium and there is expansion potential. Most of the competence is at regional level. For example, in the Brussels-Capital region there is hardly any district heating grids, despite the heat density and the close presence of a waste incinerator [17].

Some of the examples of district thermal networks mentioned by the respondents of the questionnaire are described here. The city of Antwerp has plans to supply a big residential area with waste heat from an industry cluster and other sources in the vicinity, among them a wastewater treatment plant. In the city of Gent there are studies on how the existing district heating system could be fed by waste heat. It is now fed by natural gas run cogeneration. In the city of Ostend there is a district heating network in expansion with heat coming from waste incineration. Finally, there is a project called MIROM Roeselare that relies on waste heat from waste incineration. No district cooling networks are of any considerable size, electricity is the main energy carrier used for cooling in Belgium.

### Waste heat and cold potential

Around 87 TWh could be recovered, calculated from the 87 biggest facilities in Belgium (using Peta 4.2) [19]. This would cover 73 % of the final energy demand for space heating and hot water. The largest excess heat sources are concentrated in the northern regions of the country and include chemical and petrochemical facilities as well as thermal power generation and iron and steel industries.

According to the respondents of the questionnaire, the larger thermal energy intensive industries, such as metallurgy, have been downscaling in Belgium in the past and there are more and more, but smaller, waste heat and cold suppliers in the past. The waste heat is mainly used for space heating or process heating within the company who produces the waste heat.

## III.V. Legal

**Social tariffs and taxes primarily incentivize natural gas as an energy carrier.**

### Regulations related to heating and cooling

There is an obligation of unbundling network operators from energy supply producers. The REUSEHEAT identifies this is a barrier to adopting a flexible systemic approach that could include cogeneration and other local sources, such as excess heat and cold [17].

Social tariffs for low income consumers, subsidizing part of the bills, are only applicable to gas infrastructure. Currently, the legislation does not foresee that the same would apply for heat networks [17].

Most of the taxes are on electricity, while taxes on gas are limited. The tax framework in Belgium includes charges to finance energy efficiency and renewable energy support schemes. The taxes are applied on electricity, but not on fuels such as gas [17].



According to the respondents of the questionnaire the focus until now has been on the electricity and transport sectors to achieve the abovementioned objectives. The heating and cooling sector is mainly affected by regulations focusing on the building sector, such as a minimum share of renewables and energy performance of new buildings. There are now new regulations foreseen in the coalition agreement of the Belgian regions, according to the respondents of the questionnaire. Some of the more specific measures is the prohibition of new, or replacing old, heating oil installations as well as the prohibition of individual gas installations for new residential buildings.

### III.VI. Environmental

**Environmental concerns mentioned in the heating and cooling sector are mainly GHG emissions, such as CO<sub>2</sub> and NO<sub>x</sub>, and soil pollution from leaking heating oil tanks.**

#### Environmental concerns

According to the NECP draft, Belgium see a downward trend (-19.7 % in 2016 compared with 1990 levels) in GHG emissions. The identified drivers are a reduction in the use of liquid and solid fuels in favor of gaseous fuels; increased energy efficiency; changes in the structure of the economy with fewer energy-intensive industries such as steel, and more value in sectors such as services and retail. The only two sectors that have been growing in terms of GHG emissions are transports and commercial [10]. Emissions from public electricity and heat production, i.e. electricity generation, combined heat and power generation, and heat plants, were 13 % of the national total (including international aviation) in 2017 [20].

Belgium has set up two funds to tackle both actual and potential soil pollution from leaking oil tanks at filling stations and oil-heated buildings. The first fund helps to pay for service station clean-up projects. The other fund will help to clean up soil polluted by leaking heating-oil tanks and to prevent future leaks, it will also focus on developing quality standards for the tanks, as well as developing and promoting leak detection devices and informing end-users [11].

The respondents of the questionnaire mention CO<sub>2</sub>, NO<sub>x</sub> and PM emissions, as well as the forming of heat islands in large cities due to decentral and individual heating solutions based on fossil fuels are mentioned as some of the main environmental concerns with the current heating and cooling system in Belgium.

## IV Italy

### IV.1. Political

Suggested new policies in the NECP targets biomass-fired heating systems to become more efficient, renovation of the building stock and solar thermal and district heating. There are currently a number of different policies related to heating and cooling, mainly incentivizing solar thermal, heat pumps, geothermal and biomass. Technologies such as cogeneration and district heating are also covered by support schemes. As the development of photovoltaics has exceeded the initial national targets PV is exempted from most of the RES electricity support schemes, there is however support for other types of RES. Waste thermal energy is not explicitly mentioned in policy.

### National Energy and Climate Plan (NECP)

A draft of the National Energy and Climate Plan was submitted to the EU in the end of 2018. The main objectives of the NCEP are:

- Reduction of the GHG emissions by 33 % in 2030 compared with the 2005 levels for all non-ETS sectors.
- 30 % of the gross final energy consumption from renewable energy by 2030, and 33 % renewables in the heating and cooling sector by the same year.
- 43 % reduction in primary energy consumption compared to the PRIMES 2007 scenario.

In addition to these quantified objectives there are a set of general objectives that Italy aim to attain, one of them a full decarbonization of the energy sector by 2050.

The draft NECP suggests targeting new biomass-fired heating systems in order to promote high-efficiency systems that meet high environmental quality standards. It also suggests introducing more stringent performance requirements on existing biomass-fired systems in order to stimulate renewal and investments in more emission-low technologies. The National Energy and Climate plan also suggests that renovation of the building stock will improve RES shares and energy efficiency. The Italian NECP acknowledges that the heating sector plays an important role in attaining the renewables target. Solar thermal and district heating (based on RES and high-efficient cogeneration) are mentioned for future policy [21].

### Policies related to heating and cooling

There are a number of existing instruments to promote the use of renewables in the thermal sector.

Tax deductions for energy-efficient retrofitting and restorations of existing buildings facilitates investments in solar thermal, heat pumps (aerothermal, geothermal and hydrothermal), geothermal and biomass installations [1]. The scheme allows for a 50-75 % tax deduction [22].

The “Conto Termico”, or Thermal Energy Account, is an economic incentive for promoting the production of renewable thermal energy and the implementation energy efficiency measures [1]. The incentive is a price-based scheme focusing on small scale renewable thermal energy sources and eligible for the same technologies as the tax deduction described above. The incentive that could be

granted between 2 and 5 years [22] and are intended to support up to 40 % of the investment costs [23].

Furthermore, the White Certificates systems, or “Titoli di efficienza energetica”, issues tradeable certificates for energy savings and larger electricity and gas distributors are obliged to make energy savings or buy certificates. The certificate system includes savings as a result of high-efficiency cogeneration, including those utilizing RES or connected to district heating systems [1]. According to the respondents to the questionnaire, the white certificates system is under revision.

To encourage district energy, e.g. district heating and cooling, there are subsidies set up for cogeneration installations which results in increased heat production capacity [1]. A guarantee fund is set up (within the “cassa congruaglio” for the electricity sector) for supporting the development for district heating networks. An additional fee is added to the consumption of natural gas to support this fund [22]. Furthermore, there are tax credits on district heating networks fed by biomass and geothermic energy [21].

### **Policies related to renewable energy sources**

The main support system for renewable energy in Italy is the auction system that was introduced in 2011. For installations other than photovoltaics, there is a reverse auction procedure based on the offer of a discount on the installation costs. This targets plants with a minimum of 5 MW installed capacity. For example, by the end of the auctioning procedure in 2016 wind power plants were offered the maximum discount available of 40 % [24].

Small RES, except PV, with a capacity between 1 kW and 5 MW are eligible for a premium tariff, based on installed capacity. Installations between 1 kW and 500 kW may choose between the premium and an all-inclusive feed-in tariff (“Tariffa Onnicomprensiva”). The all-inclusive feed-in tariff has been in place since 2008 and the level of the incentive differs between technologies and also depend on the energy fed into the grid. PV is also excepted from this feed-in tariff since the development have exceeded the initial national targets and there is no longer any budget available for this technology [24].

There is also a regulation (“Ritiro Dedicato”) that regulates the sale of electricity from all renewable technologies and facilitates the purchase and resell arrangements. Through this the Italian Agency for Energy Services (GSE) acts as a mediator between the energy producers and the market [24] and the producer is guaranteed a minimum price for every kWh purchased [22].

For all RES plants up to 500 kW installed capacity there is also a net metering scheme (“scambio sul posto”) available, supporting prosumers. Since 2009 CHP up to 200 kW is also eligible for net metering. Once a year, the balance between fed-in and consumed energy is calculated and the difference is paid out by the GSE [24].

### **Energy Efficiency Directive (EED) Article 14.5 implementation**

Parts of Article 14 has been implemented in Italian law. An assessment of the national potential of the application of high-efficiency cogeneration and district heating and cooling has been performed, as well as the identification of measures to be taken during 2020-2030. There is also an obligation for district heating project owners to perform a cost benefit analysis [13].

## IV.II. Economic

Natural gas, and other types of fossil fuels, are the main competitors to an increased waste energy recovery in the thermal sector. A large share of the heat and cold is supplied from individual solutions. Natural gas is cheaper than district heating and the profitability of district heating networks is strongly dependent on the existence of incentives for co-generated electricity.

### Heating and cooling demand

The final gross consumption for heating and cooling is around 56 Mtoe, which is equivalent to almost 50 % of the final overall energy consumption [21]. More than half of the energy used for heating and cooling is spent on space heating (see Figure 21). Cooling, the total of both space and process cooling, contributes to 7 % of the demand.

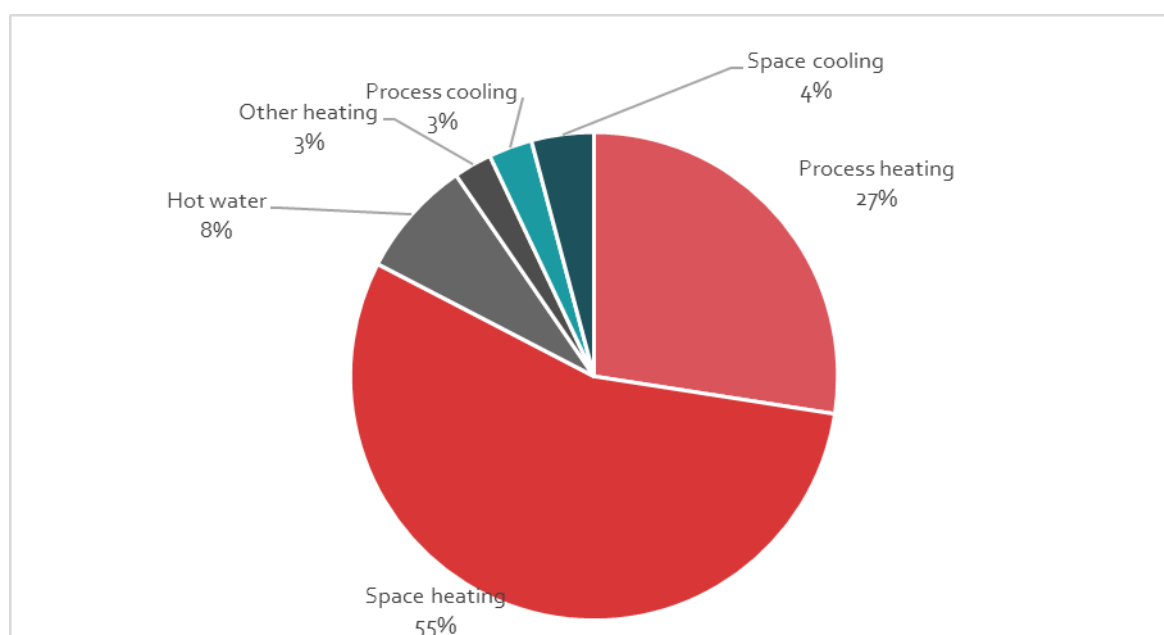


Figure 21: Shares of different types of final heating/cooling, Italy [3]

The residential sector contributes to the largest demand, followed by the industry (see Figure 22). The end use of these two sectors differ quite a bit. The major part of the industry final energy demand is process heating, while the residential sector uses the thermal energy mainly for space heating.

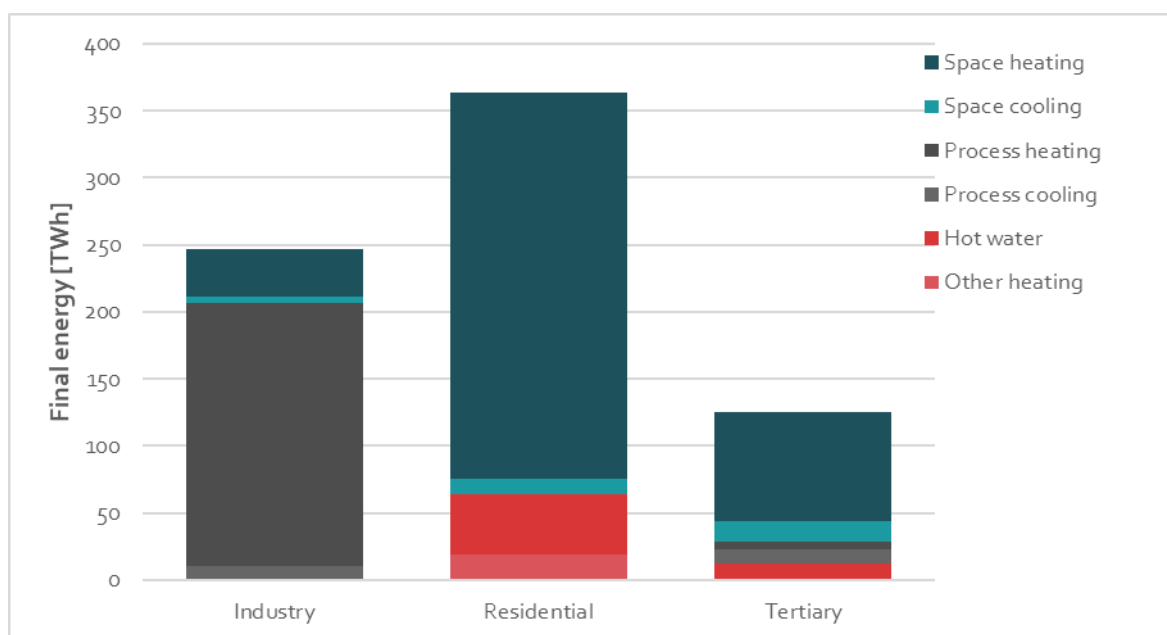


Figure 22: Shares of type of heat in final heating and cooling by sector, Italy [3]

The Heat Roadmap project estimates that the total energy demand for heating and cooling will increase by 8 % from 2015 to 2050, including the effects of existing policies. Space heating is predicted to remain the largest demand in the heating and cooling sector. Demand in hot water and process heating is expected to rise by almost 12%, due to the lack of policies targeting these areas. Cooling is the fastest growing part of the thermal sector and is also expected to increase and may contribute to 32 % of the heating and cooling sector in 2050 [25].

### Heating and cooling supply

Out of the installed capacity for heating in 2015, 86 % came from individual solutions such as boilers or heat pumps. The rest is primarily CHP and boilers. In the cooling segment, 100 % came from individual cooling solutions [15].

The dominant energy carrier supplying the Italian industry with heating and cooling is gas, see Figure 23. The same applies to the residential and tertiary sectors. The share of district heating is about the same size in all three sectors.

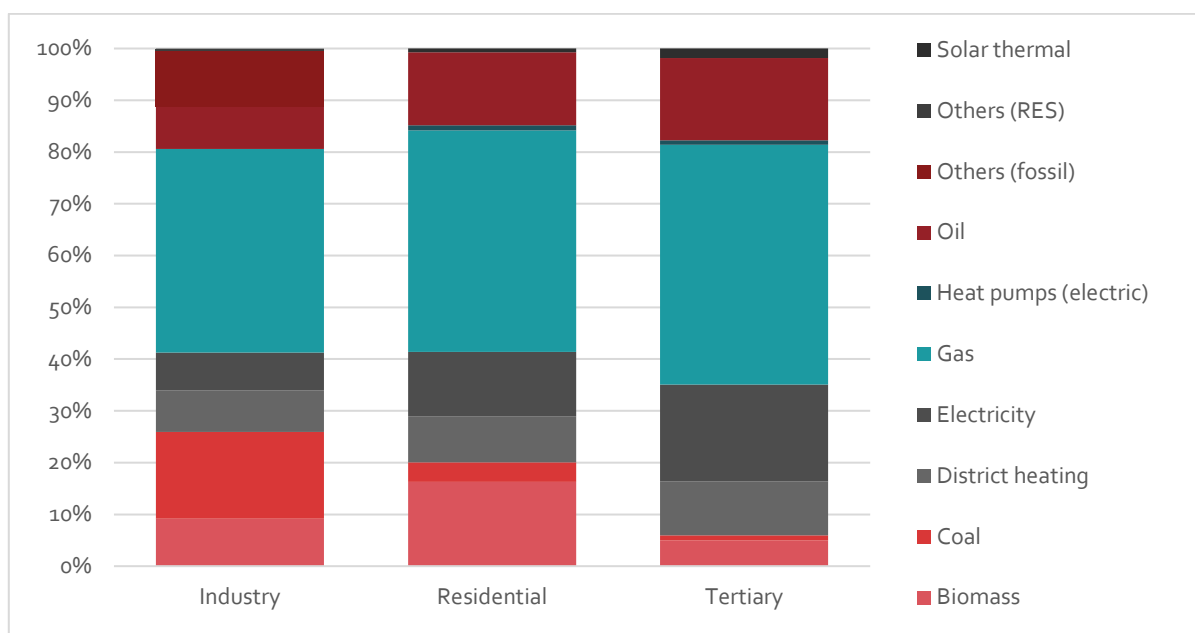


Figure 23: Shares of energy carriers in heating and cooling demand by sector, Italy [3]

Around half of the Italian energy produced, is from fossil-fired co-generation plants. RES and heat pumps contribute to around one fifth of the heat generated. Remaining generated heat comes from integration, reserve and base boilers which are powered by fossil fuels [23].

### Incentives for waste thermal energy recovery

Unlike in some of the Nordic countries, district heating is not the least expensive heating system in Italy. According to IEA [23] this is due to the prevalence of natural gas as an alternative. Part of the difference in price between district heating and natural gas heating could be explained by the higher costs associated with the district heating networks. In some areas the profitability of district heating networks are strongly dependent on the existence of incentives for co-generated electricity [23]. This might give incentives for the increased use of waste thermal energy in the fuel mix of the district heating systems.

According to the respondent of the questionnaire, the recovery of excess heat represents an economic saving which can also reduce energy consumption. However, quantifying the value of the excess thermal energy is not always easy and the energy has often a lower temperature than what could be utilized.

## IV.III. Social

The share of the population that claim that they are unable to keep their homes warm are higher than the EU average. Italy is also experiencing a high level of heat-related effects on daily mortality, both hot temperatures and overall summer temperatures. In addition to this primary and secondary pollutants, associated with health issues, is an issue in the major cities and areas with intensive industrial and agricultural activities.

## Public concern

In 2018, 14 % of the population stated that they were unable to keep their homes warm, higher than the EU average for the same year that was 7.4 % [26]. In 2017, 4.8 % of the population has arrears on utility bills (compared to 7.0 % in the EU) [27].

## Health and safety concerns

In an international context, Italy is situated on the higher end when it comes to heat-related effects on daily mortality, both hot temperatures and overall summer temperatures. The heat effects are greater in urban areas such as Turin, Milan, Bologna, Florence, Rome and Naples. The WHO highlights that the increase in frequency and intensity of heat waves combined with an ageing population will drastically affect the national health in the future. As an instance, in the summer of 2015 there was a 13% increase in deaths among the population aged 65+ associated with the heat [28].

There has been progress improving the outdoor air quality in Italy. The primary pollutants, such as SO<sub>2</sub>, CO and C<sub>6</sub>H<sub>6</sub>, have decreased in concentration. However, both these primary pollutants and secondary pollutants (PM<sub>10</sub>, PM<sub>2,5</sub>, NO<sub>2</sub> and O<sub>3</sub>) still remain a concern. PM<sub>2,5</sub> annual mean levels in most of the major cities remain above the WHO guideline. Non-compliance with annual or daily mean air pollution limits is still of great concern to Italy. There are a number of areas that have been identified to have particularly high contributions to the air pollutions, among them the Po Valley in the north of Italy where there are intensive industrial and agricultural activities as well as burning of biomass [11]. Biomass combustion in individual heating systems also contribute to this issue.

## IV.IV. Technological

**Around 5 % of the population is served by district heating networks and there are some district cooling networks available as well. Biomass is playing a major role for the RES share in the energy sector and is the major supplier to the district heating together with waste incineration and natural gas co-generation. The potential for waste heat recovery has been assessed in different studies but the role of waste heat in reaching a larger share of RES in the heating and cooling sector is unclear.**

## Renewable energy sources potential

In 2017 the share of renewable energy in the electricity sector was 34.1 % while the RES share in heating and cooling sector was 20.1 % [16]. Out of the total final energy consumption, solid biofuels and renewable waste is the major contributor to the renewable share [29]. In 2030 the electric RES share is projected to reach 55.4 % and in the thermal sector it is estimated to reach 33.1 % [21].

The National Energy and Climate plan projects that the major part of the Italian growth in renewables in electricity generation will be thanks to development of photovoltaics and wind power technology. The wind production is estimated to double from 2017 to 2030 and the solar electricity will more than double between the same years. In the thermal energy sector, the increase in renewables is expected to be provided primarily by heat pumps. Bio energy will still also play a major role in renewables in 2030, even though it is expected the decrease in absolute terms [21].

## District heating and cooling network availability

The development of district heating in Italy started with a number of networks being built in the north of Italy in the 1970s. Currently 85 % of the heating volume is concentrated to the regions of Lombardy,

Piedmont and Emilia Romagna. Around 5 % of the population is served by district heating networks [23]. In 2015, Italy had 303 district heating systems supplying 43.5 TWh [30].

Most of the networks are small to medium-sized and use a variety of generation technologies, mainly biomass-fired for the small ones and gas co-generation and municipal waste for larger networks. There are also examples on district heating supplied by geothermal energy or energy from heat pumps [23]. In 2015 68 % of the district heating was produced in CHP plants, mainly supplying the industrial sector [30].

There is currently around 4 100 km of district heating and cooling networks in Italy [21]. The economic growth potential for district energy has been assessed and estimated to 4 000 GWh. This would be attained by extending the current networks by 900 km. The increase in district heating would also mainly be based on natural gas, biomass and waste-to-energy conversion [21].

The district cooling capacity in 2013 was 182 MW<sub>th</sub> (compared to 8,056 MW<sub>th</sub> of district heating capacity the same year). There is about 67 km of district cooling networks [31].

### Waste heat and cold potential

The role of waste heat in reaching a larger share of RES in the heating and cooling sector is unclear, according to the European Commission's assessment of the Italian National Energy and Climate Plan [32].

The practical utilization potential for waste heat has been estimated to 37.5 TWh [33]. The potential was identified for four categories: data centres (5.7 TWh), metro stations (1.6 TWh), service sector buildings (19.1 TWh) and wastewater plants (11.1 TWh). The industrial waste heat recovery in the country has been estimated at 30 TWh/year [4]. Another study identified the potential at 95 TWh [34]. Yet another study has estimated the available excess heat to 259 TWh, equivalent to 56 % of Italy's space heating and hot water demand. The study calculated the potential based on the 271 largest facilities in Italy, mainly in the northern regions [35].

## IV.V. Legal

**There is an obligation to include RES or district heating in buildings to be granted a building permit, compliance with this is generally ensured by solar PV or solar thermal. Legislation also requires all new buildings within one km of district heating system to be connected to it, that all municipalities above 50,000 inhabitants establish development plans for heating and cooling networks and that companies obliged to carry out energy audits also carries out feasibility studies for the connection to a district heating network.**

### Regulations related to heating and cooling

There is a mandatory integration of energy from renewable sources in buildings ranging from 20 to 50 % depending on when the building license was submitted [1]. For public buildings there is an additional 10 % obligation and regions may also choose to increase the percentages through a regional law. It is important to note that the obligation does not cover buildings that are connected to district heating that cover the buildings entire demand for heating and heated water [22], even though it is a fossil-fired district heating system. A breach of the obligation to include RES or district heating in the heating system of the building results in denial of a building permit [3]. Compliance is generally ensured by solar PV and solar thermal.



As district heating and cooling networks are managed at local level in Italy, national legislation only provides the framework legislation. There is however an obligation for municipalities above 50,000 inhabitants to establish development plans for district heating and cooling networks [22].

Both national and regional legislation for energy efficiency has had an impact on the competition between heating systems. The legislation for energy efficiency and energy performance of buildings has given district heating systems priority over fossil-fired heating systems. District heating has been granted the same status as production based on RES. National legislation also requires all new buildings within one kilometre from a district heating system to be connected to it and that that all companies obliged to carry out an energy audit in compliance with the EU Energy Efficiency Directive to carry out a feasibility study for the connection to a DH network, if available within a few kilometers [3].

According to respondents of the questionnaire, there is a decree for air quality in the Piedmont region. This decree puts a limit on emissions related to biomass cogeneration plants in order to safeguard the air quality in the region.

#### IV.VI. Environmental

**Environmental concerns associated with heating and cooling are mainly related to emissions from biomass-fired heating systems. There are also risks associated with heat pumps that uses groundwater.**

##### Environmental concerns

One of the main environmental concerns in the heating and cooling sector is related to the impacts of emissions from solid biomass-fired heating systems [21]. Out of the total GHG emissions (incl. international aviation, but without LULUCF) in 2017, 17.8 % could be related to the public electricity and heat production [20].

According to the respondent of the questionnaire there are also environmental concerns of NO<sub>x</sub> emissions, particulate matter but also the use of heat pumps that use groundwater and then risk disturbing the groundwater microclimate.

## V Portugal

### V.I. Political

**There is no direct push for the recovery of industry excess heat and cold in the Portuguese energy policy. The focus is on electrification, solar thermal, heat pumps and biomass.**

#### National Energy and Climate Plan (NECP)

The NECP draft was submitted to the EU in December 2018, and the main objectives presented in it are the following [36]:

- EU requirement to reduce GHG emissions by 17 % in 2030 compared with 2005 levels for non-ETS sectors. Other national target is a 45-55 % reduction by 2030 in respect to 2005.
- 47 % of the gross final energy consumption from renewable energy by 2030.
- 35 % in primary energy savings by 2030 compared with 2005 actual consumption, achieved mainly through EED Article 7 – requirement for energy companies to save an annual 1.5 % of their energy sales with additional energy efficiency projects

#### Policies related to heating and cooling

Portugal aims to be carbon neutral by 2050 and the Roadmap for Carbon Neutrality 2050 (RCN 2050) is now in progress [36]. The objective is to reduce emissions by 65-75 % by 2040 and by 85-90 % by 2050 with respect to 2005 levels. For the decarbonization in the residential and housing sector the roadmap forecasts a continued trend towards electrification. Electricity is already the main energy used, but biomass and natural gas will continue to be an option at least until 2020-2040. The RCN also mentions the vast electrification of services along with solar thermal for heating water and heat pumps for heating spaces. For the industry the decarbonization focuses on electrification and use of biomass.

#### Policies related to renewable energy sources

The NECP identified that one of the actions to promote the production of electricity and heating and cooling from renewable energy sources is to simulate the acquisition and use of district heating from renewable sources, with focus on solar thermal [36]. Incentives for solar thermal has been in place in Portugal since 2009 with the Solar Thermal 2009 program [37], and has also been encouraged for residential and service buildings by Decree-Law 78/2006, following Directive 2002/91/EC.

#### Energy Efficiency Directive (EED) Article 14.5 implementation

Article 14 was transposed in national law by Article 25.º of Decree-Law n.º 68-A/2015, which amended Decree-Law n.º 23/2010 [13].

### V.II. Economic

**Gas dominates the heating and cooling supply in Portugal. Process heating contributes to the largest demand before space heating. The demand for space heating and cooling is in general low, thanks to Portugal's mild climate.**

#### Heating and cooling demand

In 2017 about 7 % of the total final consumption of energy in Portugal was heat [38]. Almost half of Portugal's heating and cooling demand is used for process heating, space heating is only 22 % (see Figure 24). Cooling, the total of both space cooling and process cooling, comprises around 6 %.

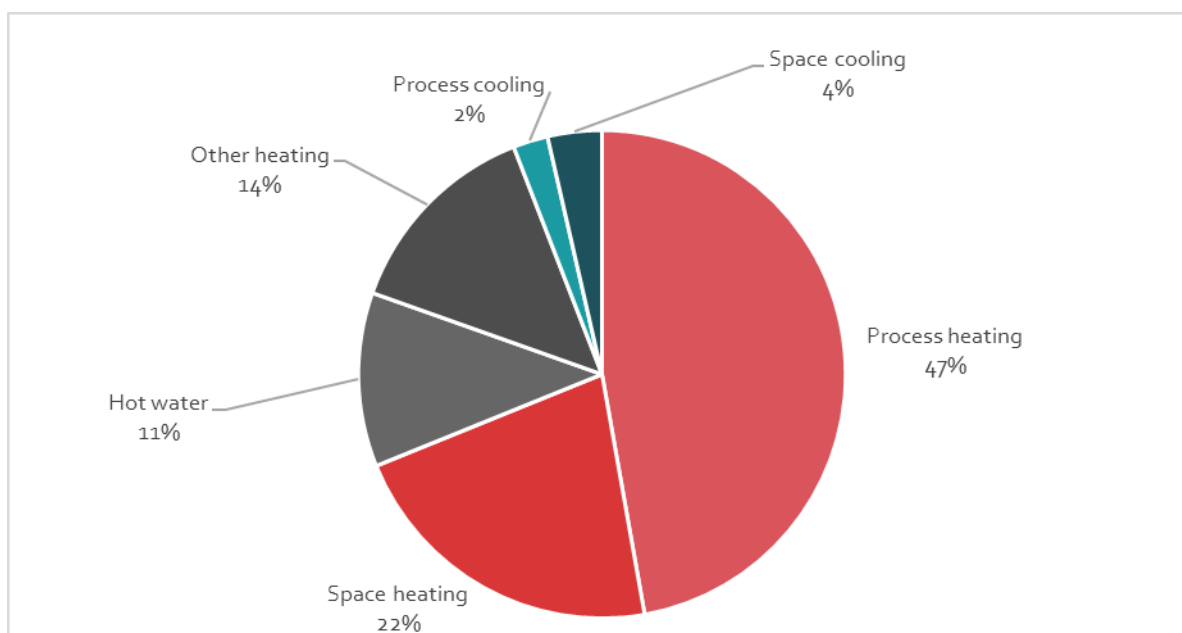


Figure 24: Shares of the different types of final heating/cooling, Portugal [3]

The heating and cooling demand in the residential sector is low, thanks to Portugal's mild climate [36]. There are very few homes with central heating and a significant number of houses does not even have a record of any type of heating. For the industry the major part of the heating and cooling demand is used to heat processes, see Figure 25.

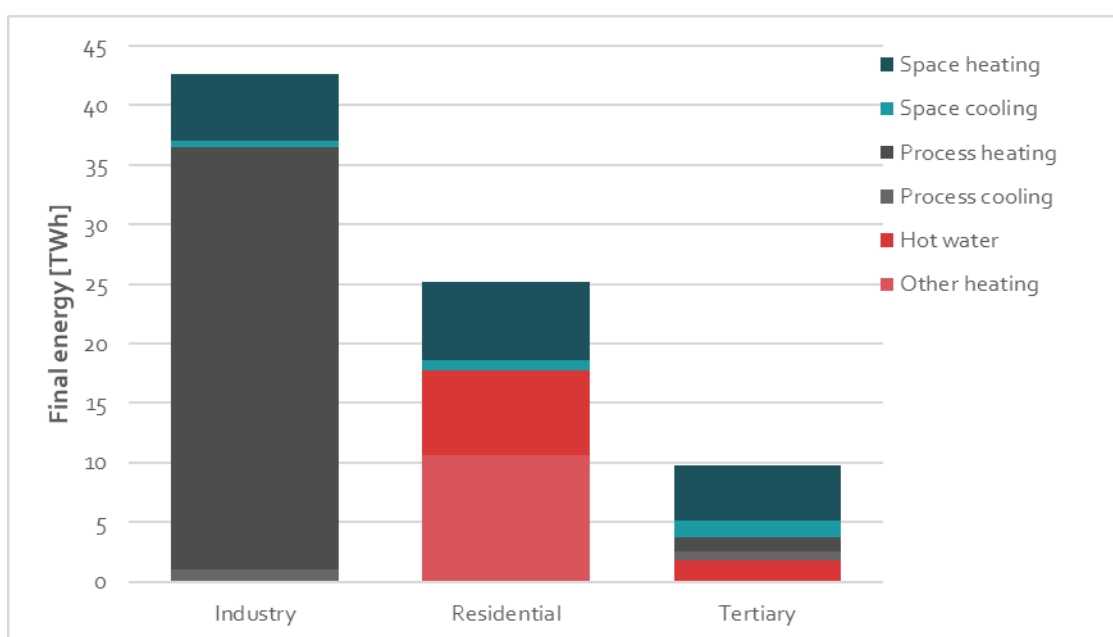


Figure 25: Shares of energy carriers in heating and cooling demand by sector, Portugal [3]

## Heating and cooling supply

Gas is the main energy carrier in supplying all three sectors, see Figure 26. Electricity and biomass also contribute with larger shares.

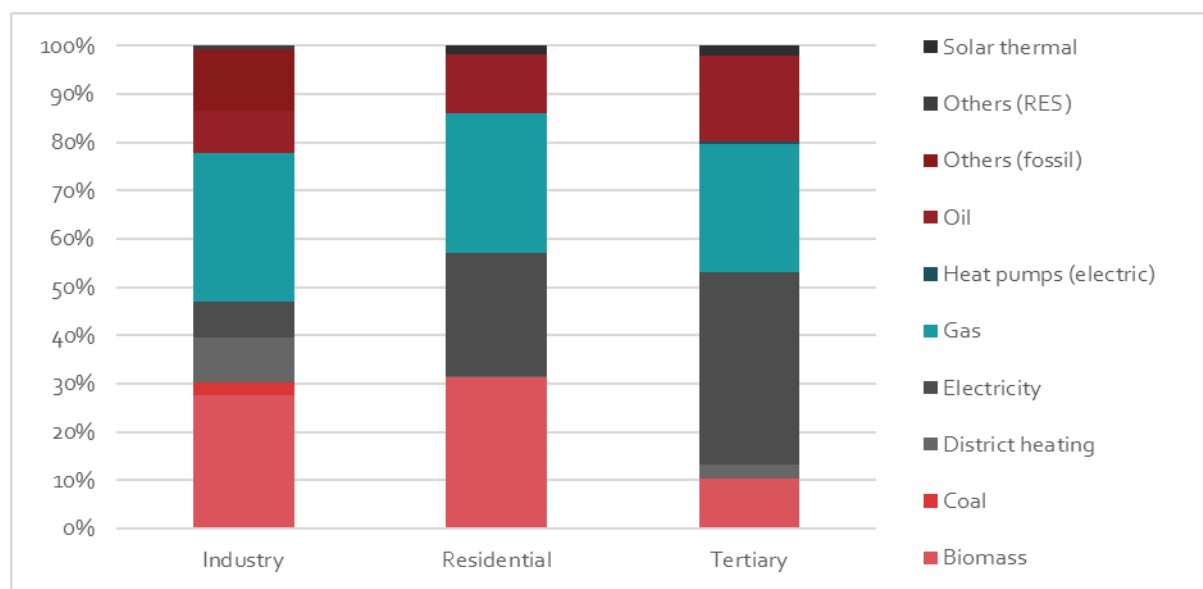


Figure 26: Shares of energy carriers in heating and cooling demand by sector, Portugal [3]

In 2017, the share of RES in heating and cooling was 34 % [16].

## Incentives for waste thermal energy recovery

N/A

### V.III. Social

N/A

## Public concern

N/A

## Health and safety concerns

N/A

### V.IV. Technological

Portugal has a large RES potential, especially heat from cogeneration with renewable origin and biomass could contribute to the heating sector. The share of district heating is very low, and the potential is also low due to low demand. There is some potential for waste heat and cold recovery, mainly from industrial sites and thermal plants.

## Renewable energy sources potential

According to the NECP [36] Portugal has a vast potential for a decarbonized electricity supply, due to the availability of renewable resources such as water, wind, sun, biomass and geothermal power, but also due to a reliable and secure electricity system that has the capability to deal with variability.

In 2016 the share of renewables in the heating and cooling sector was 35.1 %. The estimated trajectory for the increase of RES in heating and cooling (by gross final energy consumption) is 34 % by 2020, 36 % by 2025 and 38 % by 2030. Today solid biomass is the major renewable fuel in heating and cooling. Biomass together with heat from cogeneration with renewable origin are estimated to contribute the most to the renewable share in heating and cooling in the coming years (see Table 14).

*Table 14: Total effective contribution (Final Energy Consumption) of each renewable energy technology in Portugal in the Heating and Cooling sector (ktoe) for the 2030 horizon [36]*

	<b>2020</b>	<b>2025</b>	<b>2030</b>
Solar thermal	88	86	83
Biomass	952	956	937
Biomethane	0	20	80
Heat pumps	175	200	215
Heat from cogeneration (renewable origin)	715	670	626
Hydrogen (renewable origin)	0	4	11
<b>TOTAL</b>	<b>1 930</b>	<b>1 936</b>	<b>1 952</b>

## District heating and cooling network availability

Portugal has assessed the potential for the application of cogeneration and district heating and cooling. The report identifies that there is insufficient demand for district heating in the residential sector, and the same applies to the service sector. The cooling need is always greater than the demand for heating in most buildings in Portugal [36].

According to the respondent of the questionnaire, the only public district heating and cooling network in Portugal, Climaespaço, is located northeast of Lisbon. It is using a trigeneration system and has a total heating capacity of 29 MW<sub>t</sub>, a cooling capacity of 35 MW<sub>t</sub> and an electrical capacity of 5 MW<sub>e</sub> [39].

## Waste heat and cold potential

Portugal has assessed the potential for the application of cogeneration and district heating and cooling. The main findings were that the most production processes in the industry need or produce heat. Hence, large amount of consumption used in producing this heat could be replaced by cogeneration. This especially applies to the following areas: foodstuffs, beverages and tobacco, textiles, paper and paper items, chemicals and plastics, wood and wood-based products and rubber [36]. The STRATEGO project estimates the excess heat potential to around 40 TWh in Portugal, most of it coming from 14 thermal heat facilities and 24 industrial sites [34].

## V.V. Legal

**Buildings codes are pushing for solar thermal for heating domestic water.**

## Regulations related to heating and cooling

Building regulations in Portugal is pushing for solar thermal, as well as biomass and heat pumps (IEA, 2016b). For example, there is an obligation to use solar thermal collectors for heating water in new buildings and for large renovations (Jimeno, 2019).

## V.VI. Environmental

The energy sector is one of the main contributors to GHG emissions.

### Environmental concerns

According to the NECP [36] Portugal has seen an increase in GHG emissions by 13.1% between 1990 to 2016, but a reduction of 22% between 2016 and 2005. The trend with a decarbonization of the economy started before the latest financial crisis and the main drivers of the reduction has been the more extensive use of less polluting sources such as gas, more efficient power production, energy efficiency measures in transport and housing as well as a larger share of renewables [36].

Emissions from public electricity and heat production, i.e. electricity generation, combined heat and power generation, and heat plants, were 24 % of the national total (including international aviation) in 2017 [20].



## VI Romania

### VI.I. Political

There is an existing state aid program giving incentives to investments in efficient cogeneration from residual industrial process heat. Investments in district heating and cooling is identified as one way to reach energy efficiency objectives.

#### National Energy and Climate Plan (NECP)

Main objectives for 2030 in the NECP draft are the following [40]:

- Reduce ETS emissions by 43.9 % compared with 2005
- Reduce non-ETS emissions by 2 % compared to 2005
- A total share of 27.9 % renewable energy in final gross energy consumption (and 31.3 % renewables in the heating and cooling sector)
- A 37.5 % improvement in energy efficiency compared to PRIMES 2007

#### Policies related to heating and cooling

The NECP identifies that there is no clear set of policies and measures for the assessment of the necessity to build new infrastructure for district heating and cooling produced from renewable sources. However, it also mentions that investments in high-efficiency cogeneration (CHP) and district heating and cooling is a way to reach the energy efficiency objective [40].

On national level there is a bonus type support scheme for efficient cogeneration giving the producers a fixed amount of money for each unit of electricity produced through highly efficient cogeneration. The bonus is linked to the demand from the district heating system and runs until 2023. There is also a state aid program for investments in high efficiency cogeneration from natural gas, biomass and residual heat from industrial processes. This program runs until 2020 and applies to production units of maximum 8 MW<sub>e</sub>. Industry societies or administrators of industrial parks can be granted money [41].

#### Policies related to renewable energy sources

Support for renewables in heating and cooling is provided by subsidy programs by national and European funds. There is a recommendation considering the use of renewable sources in new building with a surface more than 1000 m<sup>2</sup> [42].

Between 2017 and 2020 there is a state aid program supporting investment in energy generation from less exploited RES sources such as biomass, biogas and geothermal energy [41].

#### Energy Efficiency Directive (EED) Article 14.5 implementation

There is no information available about the transposition of article 14.

### VI.II. Economic

District heating has historically been a large part of the thermal supply in Romania but is in decline due to several reasons and competes with individual heating solutions, mainly with natural gas as the energy carrier.

## Heating and cooling demand

In 2015 heating and cooling comprised 63 % of Romania's final energy demand, one of the highest shares in Europe [43]. Most of this energy, 43 %, is for space heating with process heating being the second largest end-use with 38 % (Figure 27). Cooling was around 3 % of the final energy demand, including both process cooling and space cooling.

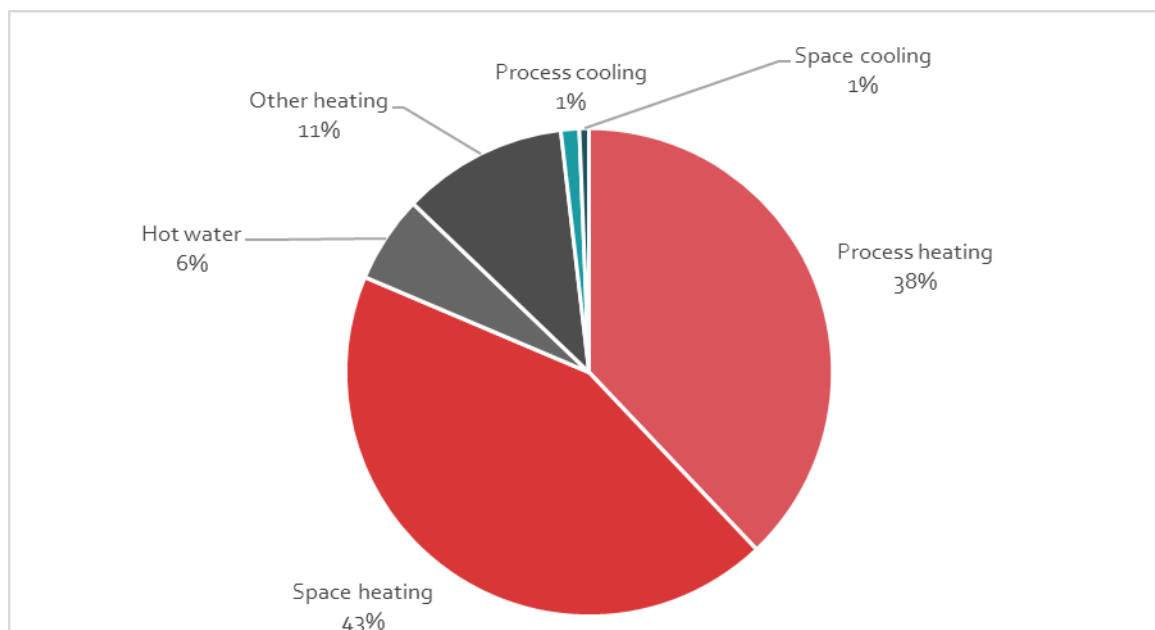


Figure 27: Shares of the different types of final heating/cooling, Romania [3]

The industry end-use is mainly process heating, while space heating contributes to a major part of the residential and tertiary sectors (see Figure 28).

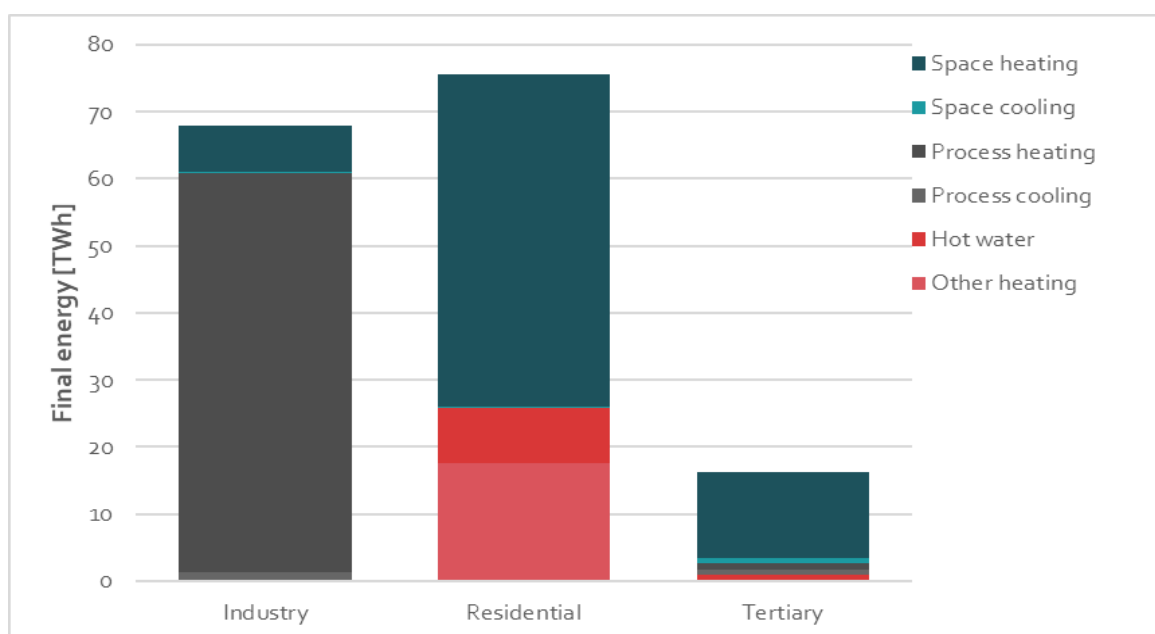


Figure 28: Shares of type of heat in final heating and cooling by sector, Romania [3]



The total heating and cooling demand is expected to increase by 8% between 2015 and 2050 [43]. Space heating will remain the largest demand even though it will decrease somewhat if both EU and national policies targeting space heating in buildings are implemented. Cooling is the fastest growing part of the thermal sector and will increase to 17 % of the total heating and cooling demand in 2050. Most of the increase is due to increases in space cooling in the service sector and in residential buildings.

## Heating and cooling supply

Out of the installed capacity for heating in 2015, 69 % came from individual boilers and the rest from district heating. In the cooling segment as much as 100 % came from individual cooling solutions [15].

Gas is a large supplier of heating and cooling for all three sectors (see Figure 29). However, biomass and district heating are together contributing to a larger share of the demand than the gas for residential heating.

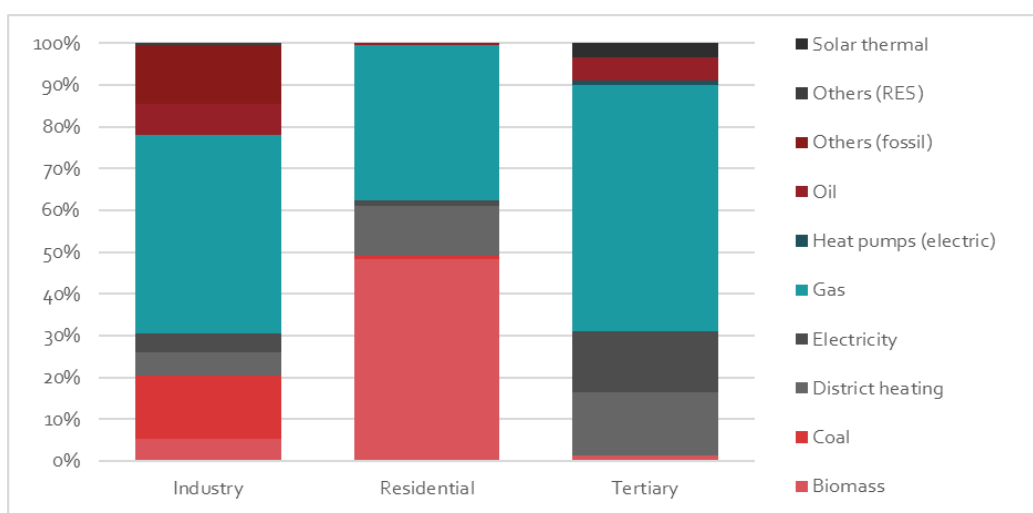


Figure 29: Shares of energy carriers in heating and cooling demand by sector, Romania [3]

Romania is developing a dependency on natural gas [44]. Currently most of the natural gas is from Romania, but it is expected to deplete in the coming decades, hence Romania risk a dependency on gas imports.

In 2017, the share of RES in heating and cooling was 27 % [16].

## Incentives for waste thermal energy recovery

Romania has, thanks to its communist regime legacy, a relatively extensive district heating system but after the Revolution in 1989 district heating was largely neglected by the authorities [45]. Today, the Romanian district heating business model is seen as unsustainable due to many disconnections, inefficient and old infrastructure mainly developed in the 1970's, and with subsidies for individual heating (e.g. gas boilers) which has led to high production costs as well as low revenues for the district heating operators.

### VI.III. Social

**Fuel poverty as well as health and safety risks associated with the widespread individual heating solutions are among the greatest Romanian social concerns linked to the thermal sector.**

#### Public concern

The heating sector in Romania has had challenges with fuel poverty for many decades, and subsidies is helping a large share of the population to pay their heating bills [46]. According to Eurostat data summarized in the draft NECP [40], Romania had the sixth lowest average EU electricity price for household consumers in 2017. However, the country also has a low purchasing power, and the energy poverty is a great concern in the country. 18 % of the Romanian households had registered delayed payments on utility bills in 2016. This can be compared with 8.1 % which was the EU average in the same year. The inability to ensure household heating at a satisfactory level is also high. In 2016 13.8 % was unable to warm their homes to the right level, the corresponding number for the EU average was 8.7 %.

#### Health and safety concerns

A local environmental issue, creating health and safety concerns, is the use individual boilers which has been spreading along with the disconnection from the district heating system [47]. The gases burned in individual boilers are exhausted through smaller chimneys, located below the rooftops, and next to windows, balconies and other inlets of buildings where it can easily enter inside buildings. The concentration of harmful substances may thus be higher than above the international values. The chimneys where the gasses are exhausted are often also not built for this purpose and hence it creates fire dangers. In addition to this there are risks of intoxication created by indoor connections to the natural gas infrastructure.

### VI.IV. Technological

**The excess heat potential is considerable and combined with RES, mainly firewood and agricultural waste, it could heat a large share of the population. However, the district heating system, which is currently in decline, needs to be developed to make use of the potential.**

#### Renewable energy sources potential

In 2016 Romania had a 25 % share of renewables in the gross final consumption of energy [40]. The share has increased somewhat during the past years, mainly due to the development of wind and solar technologies, and especially onshore wind, that have contributed to a larger share of renewable electricity. Before 2010, 100 % of the renewable electricity came from hydro power. As for renewables in heating and cooling it is mainly fire wood and agricultural waste that contributed to the 27 % share of renewables in the thermal sector in 2016. The improvements in the heating and cooling sector has been low the past years, and the NECP highlights that this area has room for developing policy. The future predictions for renewables in heating and cooling put the faith in renewable sources (mainly fire wood and agricultural waste), renewable sources derived from heat and heat pumps. No residual heating or cooling were considered in the NECP.

#### District heating and cooling network availability

As a result of the number of disconnections and lack of investments the system is suffering from heat losses which in turn has led to the decommissioning of several heat production units, especially

cogeneration, and escalating costs for end customers [45]. As of 2015 only 70 municipalities out of 315 still had functional district heating systems [48].

In 2015 Romania the district heating production amounted to roughly 22 TWh/year. More than 70 % came from CHP plants, while the rest came from fuel boilers [15]. An estimated 23 % of the population was served by district heating during the same year [31].

### Waste heat and cold potential

The potential for cogeneration and district heating and cooling has been assessed [40]. The total efficient heating and cooling potential was assessed in 2015 at 24 TWh, mainly from reconnecting to the centralized heating system and from new buildings connecting.

The potential for waste heat has been analyzed in the Stratego project [49]. The findings were that there is a very high potential thanks to large amounts of waste energy from thermal and industrial plants. It was indicated that combining the waste heat with renewable energy sources could contribute with heating three times of the required levels of district heating in Romania. However, it is necessary to develop the district heating networks to make use of this potential.

The availability of excess heat has also been analyzed In the Heat Roadmap Europe project [50]. Calculated from the 49 largest facilities, at least 58 TWh of excess heat could be identified and that would be able to cover 72 % of the Romanian demand for space heating and hot water. The largest heat sources are in the Eastern and the Southwestern areas of Romania.

## VI.V. Legal

**There is no regulation directly targeting waste heat and cold recovery, but the existing legal framework could be applied to a certain point. No specific barrier has been found.**

### Regulations related to heating and cooling

Among the regulatory instruments that effect the thermal sectors could be mentioned building regulations for NZEB solutions, energy audit obligations, energy program obligations for municipalities and building measures on local level for energy upgrading [41].

The existing legal framework does not explicitly address heat recovery, but the general legal framework could be applied to a certain point. The permits and licensing of the thermal energy sector is not specifically addressing heat recovery either [17].

## VI.VI. Environmental

**The energy sector is the main contributor to GHG emissions which is the only environmental impact found.**

### Environmental concerns

The energy sector is currently contributing the most to the GHG emissions in Romania. Emissions from public electricity and heat production, i.e. electricity generation, combined heat and power generation, and heat plants, were 17 % of the national total (including international aviation) in 2017 [20]. To reduce this contribution the focus is on modernization of fossil fuel power plants and electricity distribution grids. The program "District heating 2006-2020 heat and comfort" is also looking into improvements in the production, transmission and distribution of heat, mainly related to the central heating systems of the cities [40].

## VII Spain

### VII.I. Political

Electrification and RES in the thermal sector (mainly solar, but in reality, heat pumps) are considered key for decarbonization and pushed for while residual heat and cold is mentioned but not explicitly pushed for. Support schemes exist for district heating and cooling on national, regional and local level.

#### National Energy and Climate Plan (NECP)

The draft National Energy and Climate Plan (NECP) was published in February 2019 [51]. The following targets have been set for 2030 in the NECP:

- 21 % reduction in GHG emissions compared to 1990;
- 42 % of energy end-use from renewables;
- 39.6 % improvement in energy efficiency;

In 2050 the objective is also to achieve climate neutrality, by reducing the GHG emissions by at least 90 %, and achieve a 100 % renewable electricity system [51].

#### Policies related to heating and cooling

As a result of the 2030 commitments the Spanish government approved the first draft of the “National Programme to Control Atmospheric Pollution” (PNCCA) on September 27, 2019. This draft has been sent to the European Commission and the European Environment Agency. Seven measures (EE11-EE17) in the draft is aiming to improve the energy efficiency in residential and non-residential buildings and to increase the integration of thermal renewables in the building sector [52].

The National Energy Efficiency Plan 2011-2020 supports the deployment of district heating and cooling systems and there are both national and EU funds available for projects. Energy labelling considers the energy and GHG savings gained through DHC and is an additional incentive to connect to these networks [53].

Local and regional authorities are also playing an important role in promoting district heating and cooling. In Catalonia the authorities are strongly supporting DHC projects as part of its urban and energy strategies and other regions are looking into replicating some of their projects, such as the district cooling network in Barcelona [53].

CHP electricity production, as well as electricity from renewables, is supported through a premium tariff granted on top of the spot price. The premium tariff was introduced by the Spanish Government in 2014 and it substituted the previous feed-in tariff which was more generous for these technologies [53].

As for waste heat recovered from industries there is no specific regulation. However, according to the respondents of the questionnaire, the national regulation is allowing waste heat to substitute the required renewable contribution to the domestic hot water. More about this regulation in the next section of this report.

## Policies related to renewable energy sources

The contribution of the renewables to consumption of heating and cooling was 16.8 % in 2015. To achieve the objective of the NECP this share needs to double by 2030, reaching around 34 %. The plan identifies electrification and growth of the use of thermal renewables as the way forward to decarbonize the heating and cooling sector. It also mentions that improvements in buildings are needed to facilitate the deployment of heat and cold generation systems and the use of renewables in urban heating and cooling networks. Some specific measures for the development of renewable thermal energies includes measures that:

- Aim to guarantee a minimum quota for renewable energies in the thermal uses sector with a certificate/guarantee of origin mechanism
- Are related to the building sector, such as integration of thermal renewable energies in buildings and aid programs with loans and subsidies (with focus on solar thermal, biomass and geothermal).
- Promote heating and cooling networks by evaluating the potential for using renewables and residual heat and cold in heating and cooling networks [51].

Since 2006, the Spanish building code, that applies to all new residential and tertiary buildings are required to meet a certain share (in the range of 30-70 % depending on climate conditions and current building demand) of the domestic hot water with solar thermal energy [54]. The solar thermal contribution could also be replaced by any other renewable, cogeneration system or waste heat from outside the building [55]. According to the response received in the questionnaire, the regulation has boosted the installation of biomass (wood pellets and chips) boilers since solar thermal systems are considered more expensive.

The Spanish technical requirements on heat pumps to be considered as renewable energy sources, and hence could replace solar thermal, was fixed by Spanish regulation in 2014. The regulation stipulates a certain threshold value for the COP (Coefficient of Performance) of the heat pump. According to the respondents of the questionnaire, the new regulation has boosted the installation of aerothermal heat pumps in new buildings, especially in the warmest areas of Spain where the required minimum COP is lower and the heat pump hence cheaper than in colder parts of the country.

## Energy Efficiency Directive (EED) Article 14.5 implementation

Article 14 was transposed in national law in 2016 [13]. According to the respondent of the questionnaire, the Spanish Royal Decree 56/2016 (of 12th February 2016) transposed the European Directive 2012/27/EU (of 25th October 2012). The EU directive article 14.5 Promotion of efficiency in heating and cooling, and more specifically requirements of cost-benefit analysis on waste heat for certain projects, was also included in the Royal Decree. The Decree said that IDEA, the Spanish government national entity for energy efficiency, was responsible for publishing a methodological guide for the implementation of the cost-benefit analysis. The guide was published by IDEA on July 2019 [56].

## VII.II. Economic

**The main competitor to waste heat is gas, mainly used in individual solutions. Investment costs in heat and cold recovery are high and the incentives are low today, especially for industries that does not have a CHP plant already.**

## Heating and cooling demand

Currently, heating and cooling are together comprising 41% of Spain's final energy demand. Unlike most EU countries, process heating represents the largest demand with 40 % of the final energy demand in heating and cooling (see Figure 30). Space heating, usually the largest end-use, is around a third of the energy used in the thermal sector. Cooling, both process and space heating, is less than 10 % of the heating and cooling demand, on the higher end of other EU countries but still a small part of the demand [57].

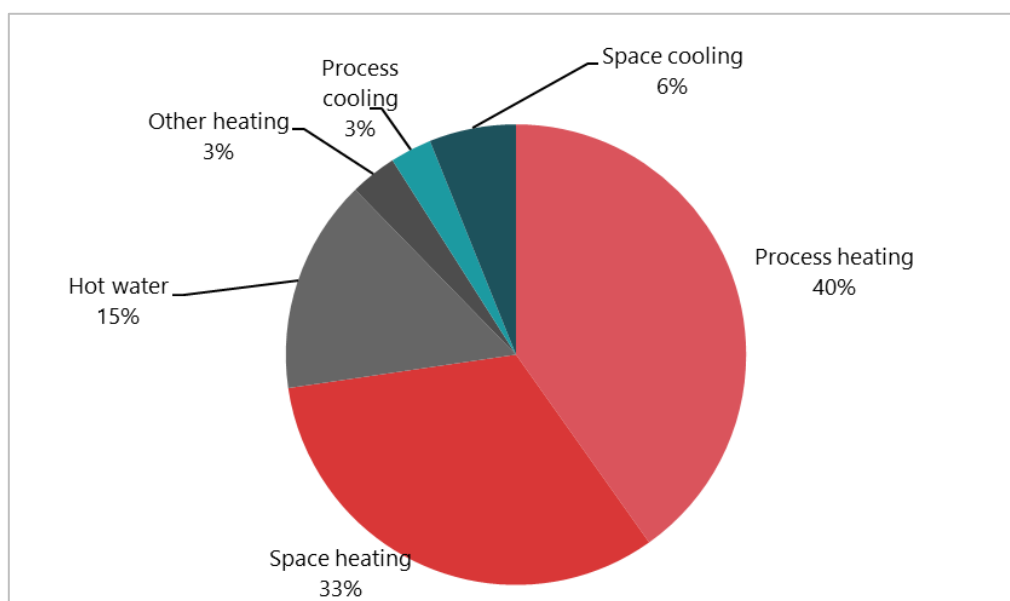


Figure 30: Shares of the different types of final heating/cooling, Spain [3]

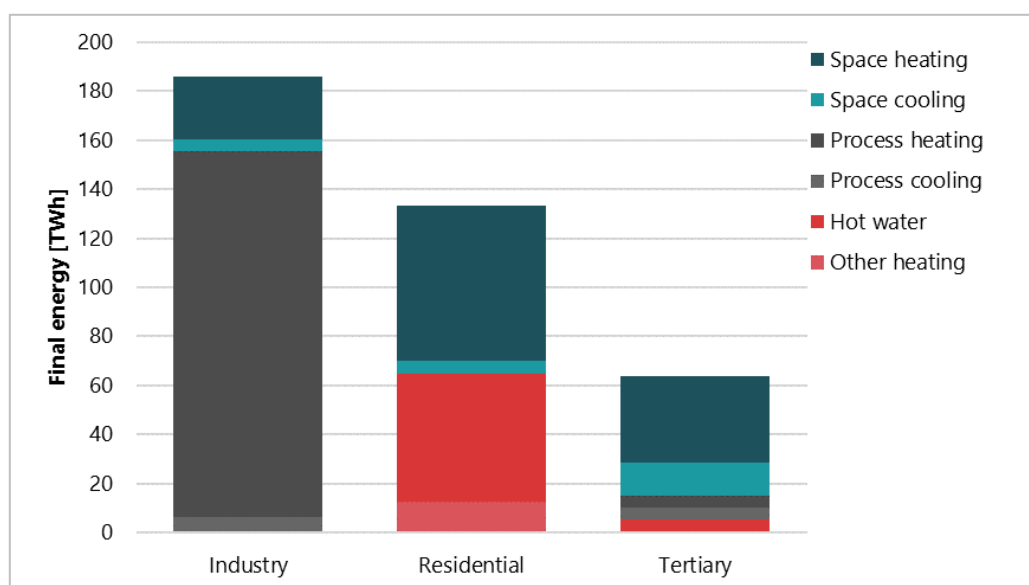


Figure 31: Shares of type of heat in final heating and cooling by sector, Spain [3]

In 2050 the demand for heating and cooling is expected to increase by 18 % given the current policies. Cooling is projected to increase to 40 % of the heating and cooling sector the same year [57].

## Heating and cooling supply

Out of the installed capacity for heating in 2015, 93 % came from individual boilers and heat pumps. The rest was district heating. In the cooling segment as much as 100 % came from individual cooling solutions [15].

Gas contributes to a large portion of the heating and cooling demand in the industry and residential sectors, while electricity is the largest supplying energy carrier in the service sector (see Figure 32).

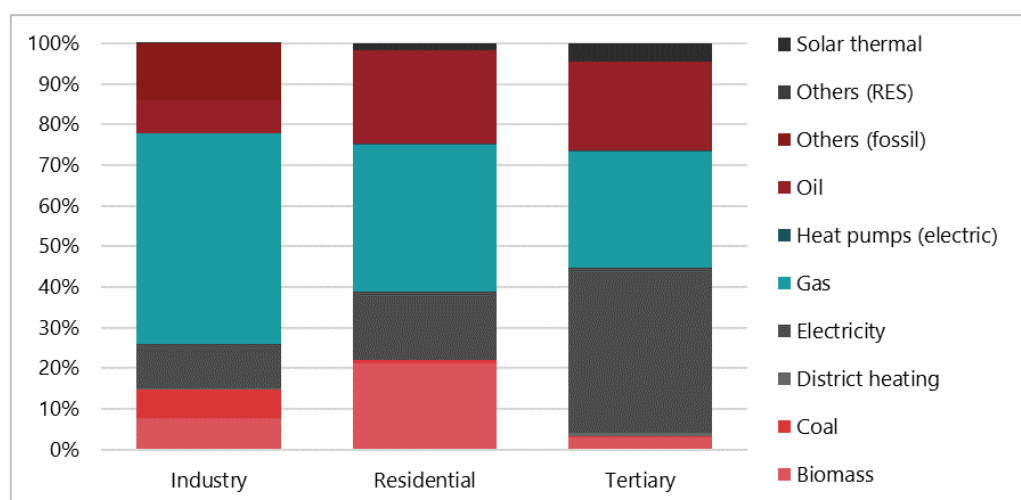


Figure 32: Shares of energy carriers in heating and cooling demand by sector, Spain [3]

Heating oil boilers are still used in rural areas where no gas infrastructure is available, according to the respondents of the questionnaire, but are gradually being replaced by biomass boilers and propane boilers with external propane storage tanks. For space heating and domestic hot water for the residential and tertiary sector it is mainly biomass (wood pellets and wood chips) and aerothermal electric heat pumps. Biomass is being used in most of the new district heating networks, regardless of the presence of cogeneration or not. It is also used in tertiary buildings as well as in larger residential buildings where there is space available for large biomass boilers. Biomass for thermal applications has grown in the past years when the oil price has been high but declined during years when the price of natural gas has decreased. Aerothermal heat pumps are installed mainly in the southern parts of the country where winters are mild but summers hot and hence the heat pumps can cover both heating and cooling needs.

According to the respondents of the questionnaire, there are currently three possible options for the heating system of new buildings:

1. Natural gas boilers supporter with solar thermal capable of proving between 30-70 % of the domestic hot water.
2. Biomass boilers, typically wood pellets boilers for smaller buildings and wood chips for larger boilers in larger buildings.



3. Aerothermal heat pumps, where the selected heat pump fulfills the required COP. The investment cost for geothermal and hydrothermal heat pumps are clearly higher even though they require a lower COP.

### Incentives for waste thermal energy recovery

A district heating company interviewed in ReuseHeat, a Horizon 2020 project looking into urban excess heat recovery, pointed out that investments in waste heat recovery in high temperature is not feasible because of high investment costs. Production costs for the production already in place in heating is so low that a change of configuration of the installation, i.e. adding waste heat to the mix, does not lead to a profit. If the energy price would have been higher, the opportunity to generate a profit would have been higher. Existing white and green certificates are not enough to pay the waste heat recovery projects. For the existing district heating there is a need for a dedicated business model for waste heat projects; the heat sales need to be planned at a fixed fare per kWh and updated according to the inflation [17].

According to the respondents of the questionnaire, selling energy is not the core business of the industries that does not already have a CHP system so for these companies there must be some financial benefit of investing in heat or cold recovery systems. However, those industries that already sell energy from their CHP facility could be more receptive to the idea of selling their energy to district heating companies or similar.

As for the economic challenges associated with an increased use of waste heat and cold, the respondents of the questionnaire mention that waste heat and cold recovery projects usually are very site specific with the distance between the heat or cold donor (e.g. an industry) and the receptor (e.g. district heating company or another industry) as a critical parameter. There are also high initial investments and without subsidies the payback periods are usually outside the acceptable range. A payback period of 10 years is not uncommon for heat recovery projects, and it could be reduced to 4-7 years when some possible subsidies and incentives are considered. The payback period is also highly dependent on variations in the energy prices, mainly the gas price, and financial managers usually do not approve investments with large uncertainties in the return of investment figures.

## VII.III. Social

**Public concerns mainly focus on energy price and comfort levels. Energy poverty affecting the populations ability to keep warm during the winter, CO poisoning and issues with excessive temperatures are some of the health and safety issues associated with the current thermal energy system.**

### Public concern

A survey published in 2018 evaluated the concerns about cooling systems. The main concern the respondents had for residential building was the price of the energy sources (83 %) and secondly was about not reaching the expected comfort levels (mainly in multifamily dwellings) [58]. For non-residential buildings the main concern was about not reaching the expected comfort levels (51 %), and the second one was about the price of the energy sources (40 %) [59].

### Health and safety concerns

Energy poverty could be considered one of the largest concerns when it comes to the current heating and cooling system. A 10 % of the population say that they cannot maintain an acceptable



temperature in their houses during the winter. 2% of the population even say that they have suffered the lack of heating supply during the last 12 months, meaning that they could not pay their gas or electricity bills and hence the utilities cut their energy supply [60].

Carbon monoxide (CO) poisoning is another concern linked to the current energy system. Every year 5,000 to 10,000 people suffer from CO poisoning, and an average 125 deaths occur every year. The issues are the largest in the winters due to the use of furnaces, gas stoves, heaters and fireplaces that work poorly or that are used in poorly ventilated spaces [61].

Related to cooling, there is an issue with excessive temperatures inside school buildings in south of Spain during the last month before the summer holiday. The regional government of Andalucía has recently started the legislation process of new legal regulation for the environmental and thermal conditions of the schools in order to tackle this issue [62].

## VII.IV. Technological

**Individual solutions still dominate the thermal sector. District heating is getting more and more attention but represents a very small share. The lack of DHC infrastructure, in combination with the seasonality of demand, pose technical challenges to make use of the large waste heat potential.**

### Renewable energy sources potential

In 2017, the share of RES in heating and cooling was 18 % (Eurostat, 2019). The use of renewable energy, in terms of biomass, for heating in industry is already competitive but new potential for using biomass for residential heating is relatively small. In the residential sector, Spain has a natural advantage in solar heating [54].

The national energy and climate plan projects that the share of renewables in heating and cooling could increase to around 22 % in 2030 in the baseline scenario, and as much as 34 % in a target scenario. The target scenario includes the measures of the plan; e.g. more promotion of renewables such as biomass, biogas and solar thermal energy as well as heat pumps for air conditioning [51].

Except for biomass and solar thermal, there is some potential for geothermal in Spain. According to several studies the potential of usable low temperature heat stored in Spain is equaling an installed capacity of 57 000 MW<sub>th</sub>. Low temperature heat could for example be used in HVAC systems and in different industrial processes as well as for space ventilation, heating and cooling systems and/or in processes with or without the use of a heat pump [63].

### District heating and cooling network availability

The heating and cooling markets in Spain are dominated by individual solutions based primarily on gas and electricity. District heating represents a very small share of the installed capacity, only 1% in 2015. The main reasons are a low heating demand, lack of awareness and experience among urban planners as well as the extensive use of natural gas and fossil fuels for heating. However, district heating and cooling is gaining more and more interest, particularly from industries and tertiary buildings with large cooling needs [53].

The Spanish Association of District Heating and Cooling Companies (ADHAC) has been updating statistics about the district heating and cooling in the country since 2012. The registered number of district heating and cooling networks have been growing steadily since the start. In 2018 there were 402 registered district heating and cooling networks, compared to 139 in 2013. These represent 1056

MW of the total installed thermal heating power and 392 MW of cooling thermal power. There is almost no district network used exclusively for cooling purposes. Out of the 402-district heating and cooling networks only four (1 %) were cold only, 35 (9 %) were heat and cold combined and the overwhelming majority with 363 (90 %) of the networks were heat only. However, the installed power is the largest for the combined networks. A rough estimate is that the district heating provides around 6-7 TWh of heating energy per year [64].

## Waste heat and cold potential

Heat Roadmap Europe [65] estimates that there are at least 174 TWh of excess heat from the 204 largest facilities around Spain, most of them located in the Northern regions. The excess energy would cover 94 % of Spain's final energy demand for space heating and hot water.

In 2016 the Spanish government, through IDAE, assessed the potential for waste heat and found five main contributors [66]:

1. Non recovered, or imperfectly recovered, waste heat from large industries that consume high temperature heat, e.g. cement or metallurgy factories. This potential has been evaluated to 5,280 GWh/year.
2. Waste heat in urban waste incineration plants. This waste heat can be recovered and generate electricity with low efficiency (25-30 %) or can be recovered into heat for district heating systems with efficiency values of around 90 %. This potential has been evaluated to 6,309 GWh/year.
3. Municipality sewage treatment plants with biogas production potential that later could be used for heat, CHP or even refining into methane to be injected in the gas network. This potential has been evaluated to 6,673 GWh/year.
4. Renewable energy available as residual biomass from agricultural or industrial activities, geothermal recovered heat and solar heat usable for space heating. This potential has been evaluated to 77,971 GWh/year.
5. Finally, the set of thermal power (electricity generation) plants provide an estimated potential of 76,732 GWh/year of waste heat.

Regarding the possibility to recover waste cold the most common donor is liquid natural gas gasification plants. There are examples of projects in Spain, including the Ecoenergies Barcelona [53].

One of the technical challenges mentioned by the respondents of the questionnaire is the seasonality of the heat demand. During late spring, summer and early autumn, the demand in the district heating system, that could potentially accept waste heat, would possibly drop to very low values. There are also variations in the demand from industries that work in a batch-like way, while the energy production usually works in a more continuous way. Both challenges would require technical adaptations or solutions, e.g. thermal storage systems or alternating between heat and electricity production from the waste heat.

## VII.V. Legal

**New regulations are expected to boost a shift from gas heating to electric heat pumps. There are also European regulations mentioned that could possibly affect the waste heat recovery by restricting the use of the heat pumps using fluorinated greenhouse gases.**

### Regulations related to heating and cooling

In 2019 the Spanish Council of Ministers approved the Royal Decree-Law 15/2018 under which the administrative, technical and economic conditions for energy self-consumption will be regulated. Previously prosumers were only compensated if they were legally authorized energy producers, but with the new decree smaller producers will also be remunerated. According to the respondents of the questionnaire, this regulation is expected to boost a shift from gas heating to electric heat pumps in those buildings where solar electricity could provide part of the required energy.

The respondents of the questionnaire mentioned that there are European regulations that could possibly affect the recovery of waste heat, namely the EC 842/2006 regulation on certain fluorinated greenhouse gases. This regulation could have an impact on the use of fluorinated gases in high temperature heat pumps widely used in waste heat recovery systems. Fluorinated gases have been introduced instead of ozone depleting substance in thermal applications, but these are instead potent greenhouse gases effecting the climate.

## VII.VI. Environmental

**GHG emissions are the most commonly mentioned environmental impact from the Spanish energy system. However, the energy sector is the main contributor to several types of emissions, among them SO<sub>x</sub> and PM<sub>2.5</sub>. With the increased recovery of waste heat there is a risk of a more extensive use of fluorinated gases which may exist in the heat pumps used.**

### Environmental concerns

According to the NECP [51], Spain's GHG emissions was 18 % higher in 2017 than 1990, however the emissions had been reduced by 25 % between 2007, the highest levels recorded, and 2017.

Emissions from public electricity and heat production, i.e. electricity generation, CHP generation, and heat plants, were 19 % of the national total (including international aviation) in 2017 [20].

According to the 2019 Spanish Informative Inventory Report (IIR), public electricity and heat production is one of the main contributors to most of the covered emissions. The sector is responsible for a 40-90% share of NO<sub>x</sub>, SO<sub>x</sub>, PM<sub>2.5</sub>, PM<sub>10</sub>, TSP, BC, CO, Pb, Cd, Hg and HCB emissions nationally. NO<sub>x</sub> emissions from public power and heat have decreased by 59% since 1990 thanks to the introduction of abatement techniques in thermal power plants and the shift to combined cycle gas plants. In 2007 one of the main brown coal mines in Spain and the thermal plant in the vicinity had to be retrofitted. This led to a drastic drop by 38% between 2007 and 2008. During the same periods the SO<sub>x</sub> emissions were reduced out of the same reasons. For the small particulate matter (PM<sub>2.5</sub>) small stationary combustion, i.e. residential stationary combustion accounts for roughly half of the emissions [67].

Environmental concerns with an increased use of waste heating and cooling could possibly be the more extensive use of fluorinated gases which, as mentioned earlier in this report, are powerful greenhouse gases. These gases are widely used in heat pumps used in waste heat recovery systems, according to the respondents of the questionnaire.

## VIII Sweden

### VIII.I. Political

Swedish policy is pushing for a decarbonization of the energy sector, e.g. with CO<sub>2</sub> taxation and a renewable electricity certificate scheme. In parts thanks to the taxation on heating oil, individual oil boilers in single family houses have been substituted by heat pumps and biofuels to a large extent. Energy Efficiency Directive (EED) Article 14.5 has been implemented for plants larger than 20 MW.

### National Energy and Climate Plan (NECP)

Final National Energy and Climate Plan was submitted to the EU in the beginning of 2020. The main objectives of the NCEP are [68]:

- Sweden will have net zero emissions by 2045 compared to 1990
- Emission reduction of 40 % by 2020, 63 % by 2030 and 75 % by 2040 from sectors outside EU ETS compared to 1990
- Emission reduction of 70 % in domestic transport by 2030 compared to 2010
- Renewable energy share in gross final energy consumption will be 50 % by 2020
- By year 2040 renewable electricity production will be 100 % by 2040 (This target is unrelated to decisions on nuclear power plants)
- Energy use will be 50% more efficient than 2005 by 2030.

### Policies related to heating and cooling

There are several policies that are affecting the heating/cooling sector [69]. Briefly, sector is affected favorably by Renewable Electricity Certificate (REC) scheme and CHP tax. CO<sub>2</sub> and energy taxation and EU-ETS are affecting the sector negatively.

The district heating development has been ongoing since the 1950ies and expansion has been driven first by a need of additional energy supply to the hydro power and later by a need to shift from fossil fuels due the oil crises in the 1970s [70]. The role of district heating is larger in multifamily houses, but for single family houses biofuels and electricity are dominant [71]. In Sweden the use of oil is heavily taxed, while use of biofuels are promoted with the adopted national Climate Policy Framework in 2017. Therefore, the oil boilers were substituted by heat pumps and biofuels alternatives between 2015-2020.

There is a fuel taxation that supports the use of renewable energy sources over fossil fuels [68]. Energy and CO<sub>2</sub> taxes are paid when liquid/ gaseous heating fuels, coal and coking coal used in the plants for production of heat. If sustainable biofuels are not affected by the energy tax. Additionally, because of EU-ETS, plants need to buy emission allowances to use fossil fuels [71]. As mentioned above, renewable fuel use in the CHP plants in Sweden have been supported but REC scheme and also they are paying 11 % less CO<sub>2</sub> tax from 2018 with EU-ETS [68, 71]. Other heating plants, besides CHP are paying 100 % of energy tax as of 2018 [68].

## Policies related to renewable energy sources

In 2016, Swedish parliament adopted 16 environmental quality objectives [72]. The climate change action is addressed with Reduced Climate Impact goal, which is related to the objective of keeping the global average temperature increase below 2°C above pre-industrial levels and push for keeping it below 1.5°C. In addition, Energy Agreement in 2016 set the target for net zero emissions by 2045 compared to 1990 [72]. To achieve this, one of the targets is 100% share of renewables in electricity generation by 2040.

Several policies were adopted with the January agreement in 2019 in Sweden [72]. These were about increasing environmental taxation, increasing the share of biofuels in transport sector, including aviation. Moreover, to support the fossil free charging of vehicles increasing investment in production and distribution of biogas and other infrastructure.

## Energy Efficiency Directive (EED) Article 14.5 implementation

Certain cost benefit analyses (CBA) in the energy sector has been adopted by the law (2014:268), which states that CBA has to be conducted for new plants and if adjustments are made which make the current plants categorized in the following: thermal power production plants with a capacity higher than 20 MW, industrial plants with a capacity higher than 20 MW that generates waste heat, DHC grids, and energy production plants with a capacity higher than 20MW that are connected to the existing DHC grid. These CBAs are required for the permit applications according to Environmental code, CBA is required [13].

### VIII.II. Economic

**A large share of the thermal energy is used for space heating, especially in the residential sector. Electricity and district heating contribute to major share of the heating and cooling in the residential and tertiary sectors, while biomass is the largest source for heating and cooling in the industrial sector. Fossil fuels have almost been phased out.**

## Heating and cooling demand

The final gross consumption for heating and cooling is around 76 TWh, which is equivalent to almost 50 % of the final overall energy consumption [73]. Around 53 % of the energy used for heating and cooling is spent on space heating, and next is process heating (see Figure 33).

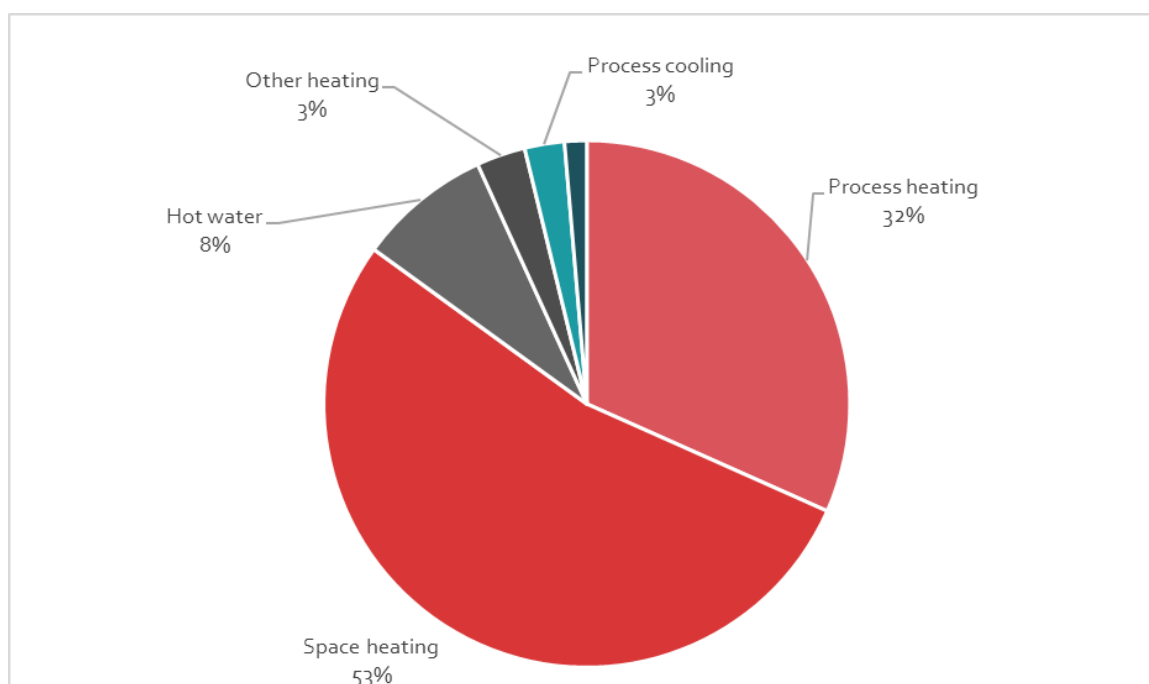


Figure 33: Shares of different types of final heating/cooling, Sweden [3]

The residential sector contributes to the largest demand, followed by the industrial sector (see Figure 34). The end use of these two sectors differ quite a bit. The major part of the residential sector uses the thermal energy mainly for space heating while the final energy demand in the industry sector is process heating.

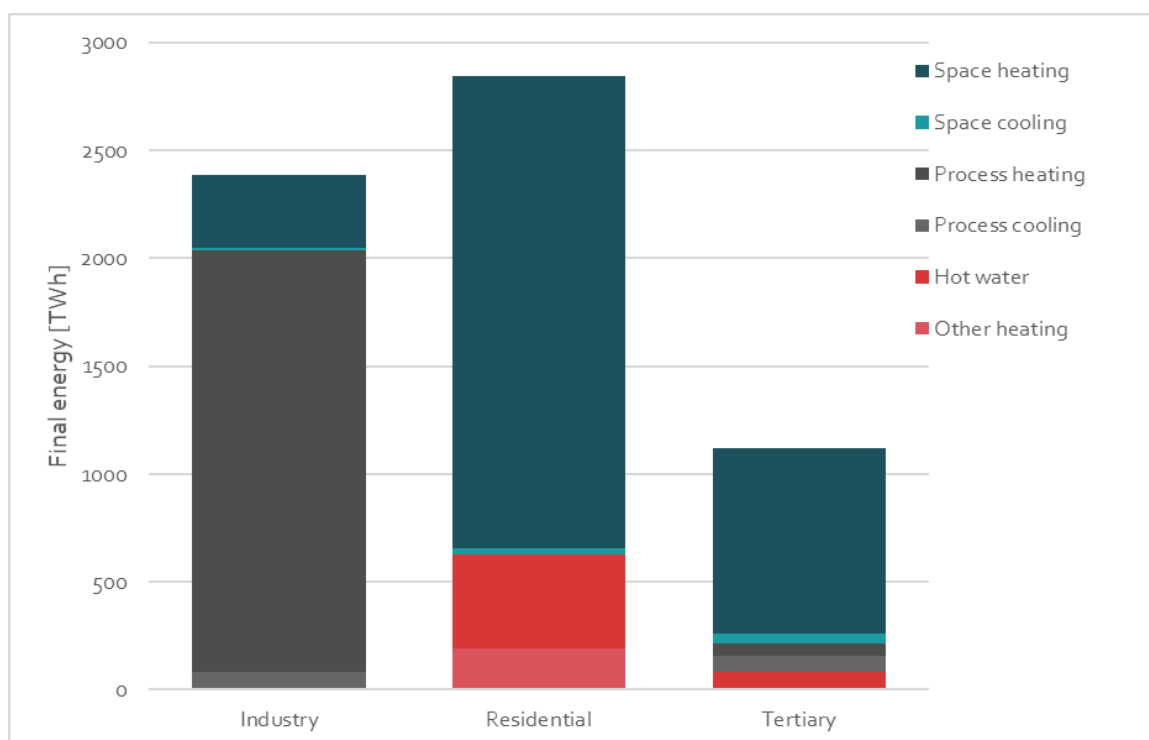


Figure 34: Shares of type of heat in final heating and cooling by sector, Sweden [3]

The Heat Roadmap project estimates that the total energy demand for heating and cooling will increase by 1 % from 2015 to 2050, including the effects of existing policies [74]. Space heating and process heating are predicted to remain the largest demand in the heating and cooling sector. Demand in hot water and process heating is expected to rise by almost 10 %. Cooling is the fastest growing part of the thermal sector and is also expected to increase and may contribute to 17 % of the heating and cooling sector in Sweden in 2050.

### Heating and cooling supply

Out of the installed capacity for heating in 2015, 85 % came from combined heat and power plants as fuel boilers [15]. The rest is primarily from heat pumps. In the cooling segment, 100 % came from individual cooling solutions.

Fossil fuel use for heating has almost been phased out in Sweden. Main fuel mix consists of biofuels, municipal waste and waste heat [75]. The dominant energy carrier supplying the Swedish industry with heating and cooling is biomass, see Figure 35. In residential and tertiary sectors this is changed to district heating and electricity.

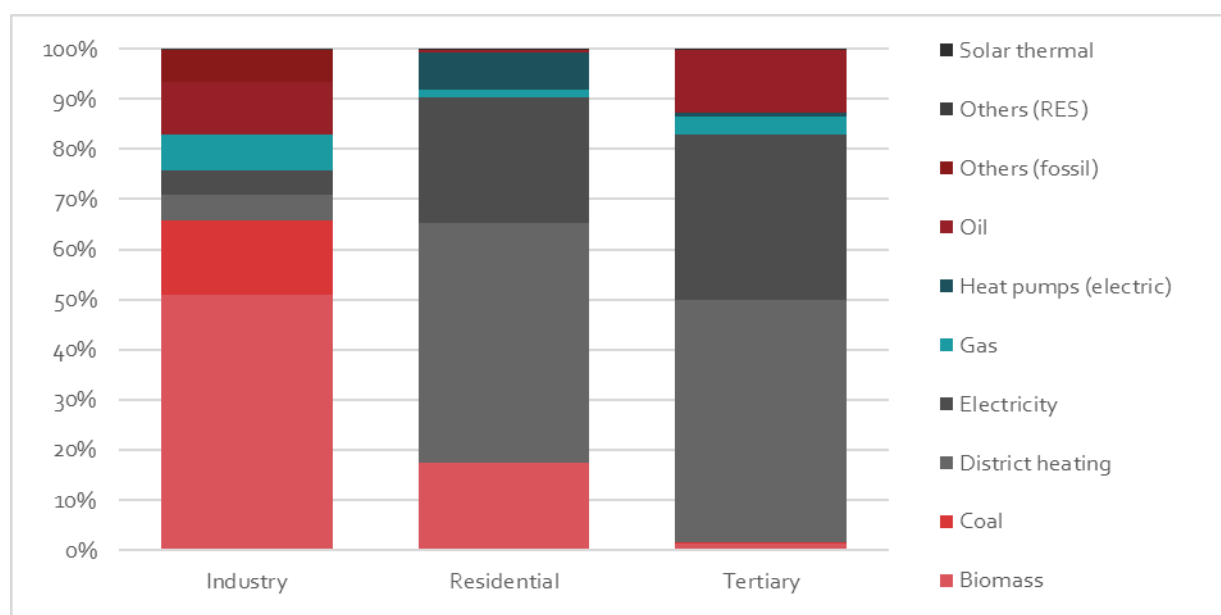


Figure 35: Shares of energy carriers in heating and cooling demand by sector, Sweden [3]

## VIII.III. Social

Social concerns include risks for heating customers with a dependence on a single supplier and the absence of price regulation. Health and safety concerns include anticipated effects from climate change, such as the increased heat-related mortality and spread of infectious diseases.

### Public concern

The absence of strong price regulation and dependence of a single supplier in the district energy sector creates risks for heat customers [75].



## Health and safety concerns

Due to climate change, Sweden is expected to warmer winters with high precipitation rate and drier and warmer summers in the future [76]. These in turn may affect the mortality related to heat waves and the spread of infectious diseases. Health risks also include effects of flooding, such as the contamination of water, diseases spreading in the water as well as mold in buildings and on infrastructure. The actions taken for the energy transition in Sweden is expected to have positive effects on the concerns, e.g. with better air quality.

## VIII.IV. Technological

**The Swedish district heating is dependent on renewables such as biomass and waste and focus for future technological development is increased system efficiency. The availability of district heating is widespread, and there are also some district cooling networks. Excess heat is 7 % of the total district heating supply, mainly from pulp and paper, steel and chemical industries.**

### Renewable energy sources potential

The share of use of renewable sources in heating and cooling in Sweden is around 65% according to Eurostat, 2018 [77]. In Sweden the district heating industry is almost fossil free, so the main challenge diverting the focus to introduce new technologies to increase system efficiency [75]. Currently the system supports 3<sup>rd</sup> generation DH technology [70] but there is a need of technological development for using low temperature heat [75].

Currently, DH sector in Sweden is dependent on biomass and waste. Heat supply resources will be challenged in the future. Firstly, for waste, recycling preference will result in decrease of available waste for incineration [70]. Secondly, according to Börjesson et.al. [78], in chemical and petrochemical industry, the demand for forest-based biomass used for energy production is likely to increase. Even though, the biomass production is expected to increase from agriculture and forestry, the resource will be less available as the demand will increase in competitive sectors [70].

### District heating and cooling network availability

Sweden has a high utilization of district heating and all major cities and towns in Sweden have district heating systems [70]. Currently around 500 district heating systems, including small district heating systems, are listed in statistics. The systems mainly supply multi-family residential houses. During 2014, 93 % of all the multi-family residential houses had a connection to a district heating grid.

In the future, district heating companies will be challenged regarding heating demand, supply resource, technology and business models [75]. Near zero energy requirements that came in with European energy performance directive will result in lower heat demand in the future [79]. This can affect the cost of DH, but the expected increase in population in urban areas will result in lower distribution cost. Thus, the total DH cost might not be affected significantly.

District cooling was introduced in Sweden with the first district cooling system taken into operation in 1992 in Västerås [70]. Larger DC systems now exist in Stockholm, Göteborg, Linköping, Solna-Sundbyberg, Lund and Uppsala. In 2014, 40 urban areas had district cooling systems. The size of the district cooling supply is much smaller than that of district heating, but it is expanding. Cooling will be an important element for the future system as the demand will increase because of warmer climate and increase in the frequency of the heat waves [71]. Thus, district cooling is expected to grow in



Sweden, but the customers are not aware of district energy systems. In addition, there is a need of business models to be developed and transparent pricing should be discussed [75].

### Waste heat and cold potential

Waste heat recovery from industries have already been introduced in several locations. The first was introduced in Helsingborg already in 1974 [70]. In 2014, 9% of the total DH supply came from industrial waste heat, mainly from pulp and paper, steel and chemical industries [71]. For example, the city of Gävle's collaboration with the pulp and paper industry and in the city of Borlänge the waste heat is of SSAB's steel plant has been used [69]. In Gothenburg, 30% of the DH is supplied by industrial waste heat, mainly from waste incineration and oil refineries [71] [70].

### VIII.V. Legal

**The District Heating Act forces the district heating companies to investigate the economic viability of waste heat recoveries whenever such are possible. If the recovery is not deemed economically viable the investment is not a legal requirement.**

#### Regulations related to heating and cooling

The District Heating Act was introduced in 2008 and updated in 2009, and covers the transparency in pricing by forcing the DH companies to publish their annual profits and losses in on the Energy Markets Inspectorate website [70]. Also, a District Heating Board is established to regulate negotiations between the DH companies and the customers about pricing [70]. The District Heating Act forces the district heating companies to investigate the economic viability of waste heat recoveries whenever such are possible. If the recovery is not deemed economically viable the investment is not a legal requirement.

### VIII.VI. Environmental

**The introduction of district heating has reduced the local emissions in cities caused by solid fuel combustion. Regulations have also forced DH companies to reduce the nitrogen dioxide emissions and the use of fossil fuels. Climate change is now the focus rather than clean air.**

#### Environmental concerns

The expansion of district heating has lowering the dust and Sulphur problem in the cities caused by solid fuel combustion [70]. In addition, the fee introduced for the nitrogen dioxide emissions forced the DH companies to improve technology on reduction of nitrogen dioxide emission up to 65% since 1990 [70]. The introduction of the national carbon dioxide tax forced the sector to use less and less fossil fuel in the mix and has taken the industry into the current situation [70]. That is high share of renewables in the sector but the national goal is abandoning fossil fuels for 100% in domestic heat supply [80]. Climate change has replaced clean air as the dominating environmental issue associated with the thermal sector [70].

## IX United Kingdom

### I.I. Political

The UK policies mainly focus on supporting energy efficiency improvements and low-carbon technologies, such as heat pumps, biomass boilers and solar thermal, for heating of homes and businesses. There is also support for new heat networks to be built. Article 14.5 of EED has been transposed and a cost-and-benefit assessment of waste heat recovery used for cogeneration or connection to a district energy network is now required for being granted an environmental permit.

### National Energy and Climate Plan (NECP)

In line with the EU binding targets for 2020 and 2030 the United Kingdom are obliged to the following targets:

- Reduction of the GHG emissions by 37% in 2030 compared with the 2005 levels for all non-ETS sectors [81].
- 15% of the gross final energy consumption from renewable energy by 2020, with non-binding sub targets of 30 % RES in the electricity sector and 12% in the heating sector [82].
- A maximum 177.6 Mtoe in primary energy consumption by 2020, equivalent to a 20% reduction from 2007 levels [82]. There is also an ambition to reduce business energy use by 20 % by 2030.

To achieve the abovementioned, the National Energy and Climate Plan (NECP) describes some of the measures. It was submitted to the EU in the end of 2018. UK's main climate target stated in the NCEP was to reduce the emissions by at least 80 % to 2050, compared to 1990 [81]. In June 2019 the UK Government amended the original target under the Climate Change Act and the legally binding target is now a "net zero" target for 2050 [83]. The target is associated with legally binding five-year caps on emission, i.e. carbon budgets [82]. The UK has confirmed that leaving the EU will not change the state's commitment to reduce their emissions.

In addition to the UK state wide targets, there is a Scottish target of 50 % renewables of all heat, transport and electricity consumption in 2030 [81]. Scotland has also introduced a target for the reduction of GHG emissions by 90 % to 2050 and has recently pledged to a net zero target by 2045 [82]. The Welsh targets are a 80 % reduction in GHG emissions by 2050 [82] and 70 % RES in the electricity consumption and 1 GW of renewable capacity to be locally owned in 2030 [81]. Northern Ireland has set a target to reduce their emissions by 35 % to 2025 compared to the 1990 level [82].

### Policies related to heating and cooling

There are a number of national policies affecting the heating and cooling segments. In addition to the UK wide policies stated below, there are number of country specific measures i.e. in Scotland and Wales.

Renewable Heat Incentive (RHI) is a principal support program for low-carbon heat technologies in homes and businesses, among them heat pumps, biomass boilers and solar water heater (only eligible for water heating). Eligible non-domestic installations receive payments for 20 years depending on the heat generated, while domestic installations may receive payments for 7 years. The

UK government has planned to spend £4.5 billion between 2016 and 2021 for this support program [81]. So far, the scheme has not proven as effective as the government had initially expected. There are additional barriers that challenge renewable investments, such as strong competition from the extensive natural gas network [82].

Heat Networks Investment Project (HNIP) is aiming to cover up to 200 projects between 2019 and 2020 with £320m to support more heat networks to be built and to help create a financially sustainable heat market [81]. Projects that use a minimum of 50% renewable or waste heat, or 75% co-generated heat are eligible for funding. The first round of applications was only open to local authorities and public sector bodies, but the scope of eligible applicants is expected to be broadened in the following rounds [82].

The IEA has assessed the British policies in the heating sector and highlights that the UK lacks some of the most effective policies: there is no obligation to install renewable heating in new buildings, no carbon or energy taxes for residential consumers and taxes on natural gas a relatively low compared to other countries [82]. There are however some policies trying to target the state's building stock and residential sector.

The Green Deal Framework was introduced in 2013 with the aim to improve the country's building stock in terms of energy efficiency, with special focus on homes. The scheme enables energy consumers to take out loans to pay for energy efficiency improvements in their properties and make the repayments through their energy bills. The repayments are made after the improvement has been made, the consumer begins to save money, their energy bills have been lowered compared to before the improvement, and the savings made could be used to repay the loan [84].

Energy Company Obligation (ECO) is an energy efficiency scheme that requires obligated energy suppliers to deliver energy efficiency and heating measures to British homes. The ECO was introduced in 2013 and has been amended over the length of time [85]. It is planned to run until at least 2022 and the 2018-2022 scheme will be focused entirely on low income and vulnerable households [81].

The Warm Home Discount scheme is one of the support schemes targeting 2 million low income and vulnerable households. Since 2011 it has helped to reduce the energy bills of a large number of energy consumers [86]. During the Winter of 2019 to 2020 those eligible could get £140 off the electricity bill between September and March. The discount could be given to both gas and electricity bills. In addition to this support there is also a Cold Weather Payment and a Winter Fuel Payment scheme [87].

In addition to the above mentioned, the Climate Change Levy (CCL) is also impacting the energy sector [88]. The CCL is an environmental tax charged that businesses have to pay on their use of electricity, gas and solid fuel (e.g. coal, coke, lignite or petroleum coke). The energy supplier is responsible for charging the CCL. In order to pay a reduced tax, businesses have to enter into a Climate Change Agreement (CCA) with the Environment Agency [89]. The CCA is a voluntary agreement to reduce energy use and carbon dioxide emissions.

The Clean Growth Strategy is the main UK strategy combining decarbonization and industrial development [90]. There are a number of key policies and proposals in the strategy, effecting the heating and cooling sector. The UK aims to have established the first net-zero carbon industrial

cluster by 2040, and at least one low carbon cluster by 2030. A phase out of high carbon fossil fuels in new and existing homes off the gas grid during the 2020s. A reformation of the Renewable Heat Initiative to support investments in low carbon heating for homes and businesses. Innovation support scheme to develop new energy efficiency and heating technologies.

The respondent of the questionnaire emphasizes that very few schemes serve the city or regional level but are rather for specific developments such as one housing estate, a hospital, a few blocks of flats etc.

### Policies related to renewable energy sources

The three main support schemes for renewable electricity generation has been the renewables obligation (RO), the feed-in-tariffs (FIT) and the Contracts for Difference (CfD) [82]. The RO was replaced by the CfDs in 2017 [81] and the FIT scheme stopped accepting applications after March 31 2019 and has been replaced by a Smart Export Guarantee [82].

The Contracts for Difference (CfD) is now the country's main scheme for supporting low-carbon electricity generation. The CfDs provide support to developers of RES projects that have high upfront costs and long lifetimes. The low-carbon electricity generator enter into a private law contracts with a government-owned company (Low Carbon Contracts Company, LCCC) and are paid a flat (indexed) rate for the electricity they produce during a 15 year period [91]. The CfD scheme is planned to run at least until 2035. In 2018 the CfDs supported 42 renewable electricity projects [81]. The IEA has assessed the UK energy and climate policies and state that the CfDs are one of the key reasons that the UK is now one of the leaders in emissions reduction by capturing the low-hanging fruit especially in the electricity supply [82].

### Energy Efficiency Directive (EED) Article 14.5 implementation

Article 14.5 has been transposed through the Environmental Permitting, for England and Wales [13]. The Environmental Permitting of England and Wales [92] states that to be granted an environmental permit for an installation that is generating waste heat at a useful temperature, a cost-benefit analysis is required, and it must include an assessment of the cost and benefits of utilizing the waste heat to satisfy economically justified demand, including through cogeneration; and the connection of that installation to a district heating and cooling network. There is separate legislation in Scotland and Northern Ireland for the implementation of 14.5 [13].

## I.II.Economic

**Natural gas is the main competitor to an increased waste energy recovery in the thermal sector. Other economic barriers to waste energy recovery are lack of CAPEX funds for smaller companies and relatively long payback periods compared to other investments. The lack of confidence in heat recovery technologies is affecting the pay-back calculations negatively. Companies also gives energy efficiency measures a lower priority.**

### Heating and cooling demand

The final gross consumption for heating and cooling in 2015 was 44 % of the final overall energy consumption [93].

As much as 60 % of the energy used for heating and cooling is spent on space heating (see Figure 36). Cooling, the total of both space and process cooling, contributes to less than 2% of the demand.

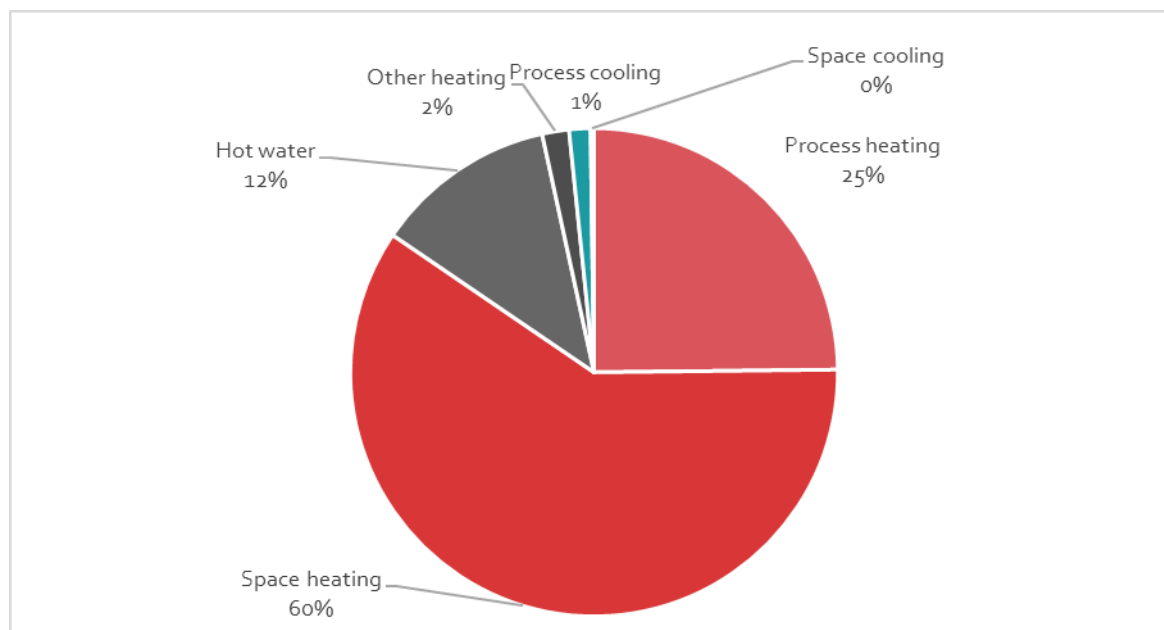


Figure 36: Shares of different types of final heating/cooling, United Kingdom [3]

The residential sector contributes to the largest demand, followed by industry (see Figure 37). The end use of these two sectors differ quite a bit. The major part of the industry final energy demand is process heating, while the residential sector uses the thermal energy mainly for space heating and hot water.

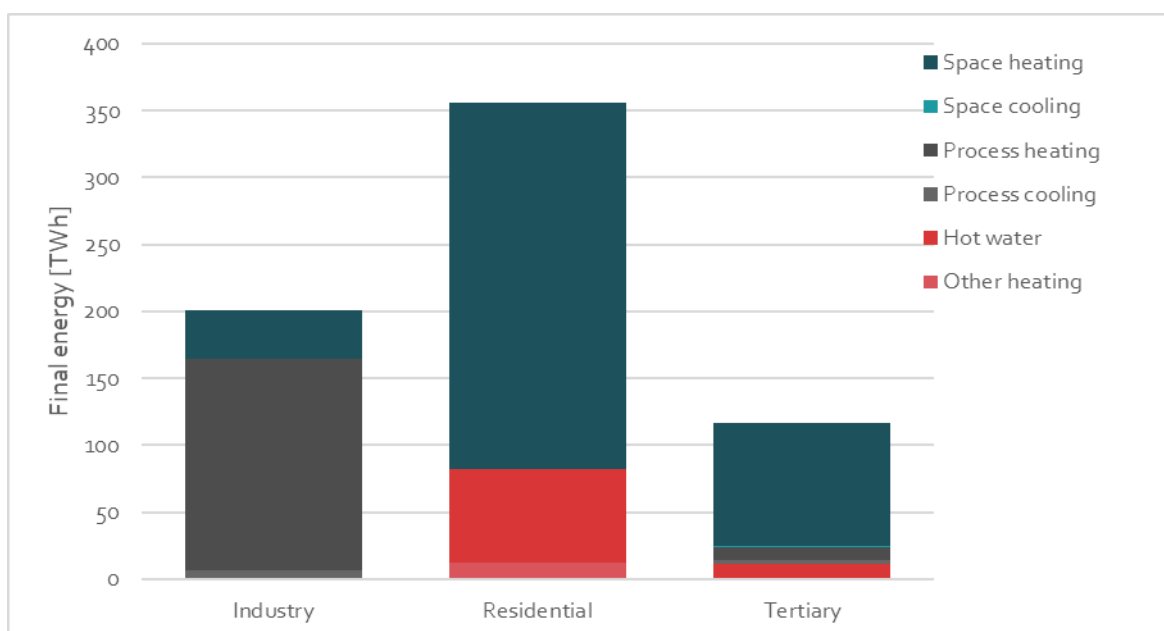


Figure 37: Shares of type of heat in final heating and cooling by sector, United Kingdom [3]

The Heat Roadmap project estimates that the total energy demand for heating and cooling will decrease by 9 % from 2015 to 2050, including the effects of existing policies. Space heating is predicted to remain the largest demand in the heating and cooling sector. Demand in hot water and process heating is expected to rise by almost 2 %. Cooling is the fastest growing part of the thermal sector and is also expected to increase and may contribute to 13 % of the heating and cooling sector in 2050 [14].

## Heating and cooling supply

Out of the installed capacity for heating in 2015, 90% came from individual solutions such as boilers or heat pumps. The rest was primarily CHP. In the cooling segment, 100% came from individual cooling solutions [15].

The dominant energy carrier supplying the UK industry with heating and cooling is gas, see Figure 38. The same applies to the residential and tertiary sectors. In addition to gas, UK industry has a substantial share of fossil energy with oil, coal and other fossil-based fuels. The share of district heating is the largest in the industry segment, with 12% of the demand.

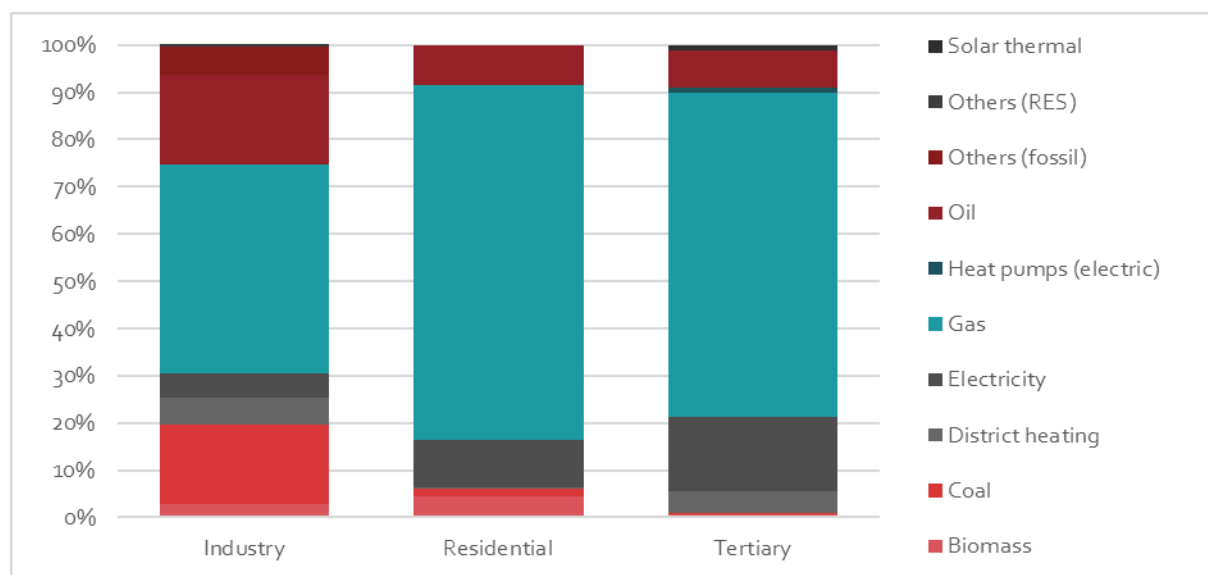


Figure 38: Shares of energy carriers in heating and cooling demand by sector, United Kingdom [3]

In 2016, 85 % of dwellings had gas central heating and one third of the boilers are less than three years old. The large share of gas boilers in British households reflects the housing stock (low density single-family housing), extensive gas networks and low gas prices [82].

The total energy production in the UK has decreased by 57 % since the production peak in 1999 due to a decline in oil and gas production, meanwhile renewable energy production has tripled. The large drop in domestic energy production has led to an increased UK dependency on imports. In 2017 the overall import dependency was 38 %. This is however lower than the dependency level in the 1970s [82].

## Incentives for waste thermal energy recovery

A study from 2016, looking at 33 energy intensive companies in the UK, identified some of the main factors effecting companies' experiences of heat recovery. Some of the commercial factors were the availability of CAPEX funds for smaller companies and long pay-back periods (over 3 years) that do not meet the companies' typical required return on investment or do not compete well with other investments. There is also a lack of confidence in the heat recovery technologies, and as a result also in the payback calculations. In addition to this the companies put a low importance on energy efficiency measures, to which heat recovery is perceived to be part of [94].

The Industrial Heat Recovery Support (IHRS) program aims to support investment in heat recovery technologies in England and Wales. The program will run until March 2022. Funding from a total pot of £18 million is distributed through a competitive process. Grants could be received for feasibility studies, preliminary engineering, detailed design and capital delivery. Eligible for the grant are manufacturing companies and data centers, and third parties acting on behalf of these sites [95].

One of the respondents of the questionnaire mean that one of the main economic barriers to using more waste heat and cold is the low price of natural gas.

### I.III. Social

**Raising energy bills are high on the political agenda and a concern of the public. Heat network customers are in general more positive about the price they pay than non-heat network customers. Air pollution from the burning of fossil fuels and biomass is of a health concern as this could be attributed to premature deaths, especially in the larger UK cities.**

#### Public concern

England, Wales, Northern Ireland and Scotland all have different policies to fight energy poverty, or fuel poverty. Most of them focus on improving the energy performance of fuel poor homes [81]. Rising energy bills are high on the political agenda [82]. To protect customers from energy companies taking advantage of those not actively choosing energy supplier, there is a price cap per kWh electricity and gas [96].

In 2018, 5.4 % of the population stated that they were unable to keep their homes warm, lower than the EU average for the same year that was 7.4 % [26]. The same year, 5.4 % of the population had arrears on utility bills (compared to 6.6 % in the EU) [27].

In 2017 the Heat Networks Consumer Survey surveyed the heat networks consumers' attitudes to heat networks [97]. The survey asked 5,000 consumers (3,000 on the heat network and 2,000 on another heating system) about their satisfaction level with their current heating system, price and transparency of billing, and customer service. The three main findings of the study were:

- I. The level of customer satisfaction was similar for customers of heat networks and non-heat networks. Satisfaction were somewhat higher when the heat networks were operated by housing associations than by a private organization or a local authority.
- II. The heat network customers experienced a lower level of control over their heating system than non-heat network customers. They were more likely to report over-heating; customers with homes built before 1960 could not control their heating while customers in buildings from 2000 onwards were more likely to blame poor ventilation.



- III. Findings from price and information billing suggests that heat network consumers paid an average £100 less per year for their heat than consumers with individual gas boilers, even when excluding the cost of the gas boiler. In general, heat network customers were more positive about the price they pay than the non-heat network customers.

### Health and safety concerns

In 2013 the five most populated cities of the United Kingdom had annual mean PM<sub>2,5</sub> levels that were above the WHO guideline value [98]. Short lived climate pollutants, such as black carbon, methane and ground level ozone, are released through inefficient use and burning of biomass and fossil fuels and are also of a concern to the UK. These are also responsible for both global warming, deaths and diseases. It has been estimated that the reduction of these in the United Kingdom could prevent 1,800 premature deaths from 2030 and onwards. There have also been studies showing that the air pollution overall is responsible for health costs even larger than the costs of obesity.

### I.IV. Technological

**Progress with more renewables in the heating sector has been more challenging than in the electricity sector where the UK has large potential especially in wind. Possible low carbon technologies in the thermal sector are heat pumps, hydrogen, biogas, industrial excess heat and energy from waste. There is potential for more waste heat and cold recovery. District energy networks available are mainly supplying a single building.**

### Renewable energy sources potential

The UK is part of the wider North Seas region, which has a large renewable energy potential and already a world-leading offshore wind sector [81]. The UK is the largest market for offshore wind [82]. Wind is the main source of renewable electricity and the wind generation is expected to increase [2]. Renewables in general are rapidly increasing in the UK, especially when it comes to biofuels and waste, solar photovoltaics (PV) and wind power. The energy production from renewables tripled between 2007 and 2017 [82]. The overall renewable share in 2017 was 10.2 %, with 28.1 % in electricity and 7.5 % in heating and cooling [16]. Out of the total final energy consumption, solid biofuels and renewable waste is the major contributor to the renewable share [29]. In 2030 the electric RES share is projected to reach 55.4 % and in the thermal sector it is estimated to reach 33.1% [81].

In the heating sector progress with more renewables have been more challenging than in the electricity sector [82]. Policy measures, such as the RHI, has not been so effective in stimulating consumers to change to renewable heating. The strong competition from the extensive natural gas network makes it hard for RES in heating to compete, so residential investments have mainly happened in off-grid areas.

Alternative sources of low carbon heat presented in the Clean Growth Strategy are low carbon electricity powering heat pumps, hydrogen to replace natural gas, biogas to use in existing gas grids and waste-heat and energy-from-waste to supply heat networks [90].

### District heating and cooling network availability

As of 2017 there were 17,000 heat networks in the UK, out of which 5,500 are district heat networks (supplying at least two buildings and one customer) and 11,500 are communal heat networks (supplying at one building occupied by more than one customer) [97]. These heating grids supply



12 TWh of heat annually [97], equivalent to 2 % of the UK heat demand [97] [82]. The heat in the heating networks is primarily coming from gas (56 %) and gas CHP (32 %), but there is also an increasing share of biomass (10 %) as well as energy from waste and large-scale heat pumps [97]. Around 500,000 customers were connected to the heat networks in 2016, the large majority of them domestic customers and mainly small flats and duplexes. Among the non-domestic loads on the heat networks are the military, universities and colleges and art, leisure and community sectors.

The district energy grids supply 0.2 TWh of cooling annually [81]. For example, Southampton has district heating and cooling scheme currently rated at 40 GWh heat, 26 GWh electricity and 7 GWh cooling annually from geothermal and CHP. This grid supplies a shopping center, hospital, university and an office [99]. There are also a few trigeneration schemes around; most for individual hospitals and supplied by gas fired CHP engines [100].

The Clean Growth Strategy has presented a 2050 scenario in which heat networks could meet 17 % of the heat demand in homes and up to 24 % of the heat demand in business and public-sector buildings [90]. The Committee on Climate Change suggested that around 18 % of heat in buildings may need to be supplied by heat networks in 2050 to meet carbon budgets.

## Waste heat and cold potential

The HRE<sub>4</sub> project estimated that there is a potential for at least 1.13 GWh excess heat, calculated from the 192 largest facilities (including thermal power plants) in the UK mainly located in the central region of the UK and around metropolitan London. If it would be recovered it could cover 65 % of the final energy demand for space heating and hot water [101]. The same project estimated that excess heat recovery could cover at least 29 % of the district heat production in the UK [93]. According to the Department for Business, Energy and Industrial Strategy industrial waste heat is estimated to about 50 TWh annually [102].

According to one of the respondents of the questionnaire, there is significant waste recuperation and generation from excess heat carried out in industries and waste thermal energy is also shared between industries. In Middlesbrough industrial waste heat recovery has also been announced as part of a feasibility study for a district heating system development project [103].

The UK has three terminals for liquefied natural gas (LNG) where the LNG at -160°C is re-gasified before entering the national gas network [104]. These terminals either use sea water or burn gas to supply the heat necessary to re-gasify the imported LNG. In [104] it was estimated that about 20 TWh/year of cold are wasted due to this in 2015. By 2030, based on projected LNG imports, it is estimated that the amount of waste cold could reach 80 TWh/year – equivalent to 2015's UK cooling demand.

## I.V. Legal

**There are suggestions for regulations on low carbon heating in homes. New legislation is also pushing for more efficient boilers in homes.**

## Regulations related to heating and cooling

It is likely that natural gas boilers will not be permitted in new build homes from 2025 as part of the Future Homes Standard. The Future Homes Standard will require new build homes to be "future proofed with low carbon heating and world leading levels of energy efficiency", with an estimated up

to 80 % lower level of carbon dioxide emissions. Consultations of new energy efficiency standards were currently ongoing in 2020 [105].

In 2018 new legislation (Boiler Plus) on energy efficiency of heating systems in UK homes was implemented [106]. All boilers must now have an efficiency of at least 92 % as well as time and temperature controls.

## I.VI. Environmental

**GHG emissions from the energy sector as well as leakages of the global warming potent F-gases from refrigerants are some of the environmental concerns associated with the energy sector.**

### Environmental concerns

The contribution of energy supply to the total national GHG emissions has decreased since 1990 mainly due to a switch from coal to gas and renewables as well as energy efficiency improvements [81]. There has been a 35 % reduction in energy related emissions between 2017 and 1990. Oil, mainly from transport, and natural gas, mainly from electricity generation, are now the main sources of CO<sub>2</sub> emissions in the energy sector [82]. Out of the total GHG emissions (incl. international aviation, but without LULUCF) power and heat generation contributed to a 22.5 % share in 2017 [20].

Refrigerant use in air conditioning systems is a major environmental concern due to the mainly due to the climatic impact. Hydrofluorocarbons (HFCs) account for 95 % of the F-gas emissions are mainly used as refrigerants in refrigeration, air conditioning and heat pump applications. Fluorinated gases (F-gases) such as HFC are currently released in small amount through leakages in appliances but are may still have a large contribution to global warming since they are potent GHGs. The HFCs have a global warming potential (GWP) of up to 14,800 times the potential of CO<sub>2</sub>, the most widely used HCFs are however usually between 1,000 and 4,000 GWP. In the UK F-gases accounted for 3 % of the overall GHG emissions in 2015, and there is an increasing demand for their use in air conditioning and refrigeration [107].



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## Appendix C: Questionnaire

### Belgium

#### Political and Legal

- How are the national 2030 commitments (reduction of GHG emissions by 35%, 18.3% RES and 12% in final energy savings) affecting the heating and cooling supply and demand policies?
- Except for low taxes and subsidies for heating oil as well as support for solar thermal, heat pumps and CHP, are there any other policies or regulations related to the supply and demand of heating and cooling?
- What policies and regulations exist related, specifically, to the use of industrial, as well as industrial WH/C combined with RES?
- Are there any policies or regulations (federal, regional, industry, environmental, health & safety) affecting the industries possibility to recover WH/C?

#### Economical

- Except for natural gas boilers and oil heating, is there any other H/C supply that would compete with an increased industrial WH/C supply?
- What would be the main incentive for the industry to supply WH/C?
- What are the major economic challenges associated with the increased use of WH/C?
- How is the economic “wellbeing” of the industry sector that would be potential WH/C suppliers? E.g. are industries shutting down, moving abroad etc.?

#### Technological

- Where in the country is district heating available, and for what sectors?
- Are there any district cooling networks and if yes, which sector is using these?
- Is electricity the only energy resource used for cooling (processes and space cooling)?
- The RES potential is estimated to be low in Belgium, but what would be the RES used for heating and cooling? How large is that potential?
- To what extent is WH/C used today?
- What are the major technical challenges associated with an increased use of WH/C?

#### Environmental

- Oil leakage from oil tanks and GHG emissions have been identified as two of the impacts of H/C, what other environmental impacts are associated with the current H/C?
- What could be the major environmental impacts associated with an increased use of WH/C?

#### Social

- What are the main public concerns with the current H/C?
- What are the main public concerns with an increased use of WH/C?
- What are the main health and safety concerns associated with the current H/C?

## Italy

### Political and Legal

- How are the national 2030 commitments (reduction of GHG emissions by 33%, 30% RES and 43% in final energy savings) affecting the heating and cooling supply and demand policies?
- Except for tax deductions for energy-efficient retrofitting, "Conto termico", White Certificates system, subsidies for co-generation and a guarantee fund for district heating investments, are there any other policies or regulations related to the supply and demand of heating and cooling?
- What policies and regulations exist related, specifically, to the use of industrial, as well as industrial WH/C combined with RES?
- Are there any policies or regulations (federal, regional, industry, environmental, health & safety) affecting the industries possibility to recover WH/C?
- How has the Energy Efficiency Directive (EED) Article 14.5 been implemented in Italy?

### Economical

- Except for biomass and heat pumps, is there any other H/C supply that would compete with an increased industrial WH/C supply?
- What would be the main incentive for the industry to supply WH/C?
- What are the major economic challenges associated with the increased use of WH/C?

### Technological

- Are there any district cooling networks and if yes, which sector is using these?
- What are the main energy resources used for cooling?
- To what extent is WH/C used today?
- What are the major technical challenges associated with an increased use of WH/C?

### Environmental

- Other than emissions from biomass-fired heating systems, what would be the main environmental concerns with the current heating and cooling systems?
- What could be the major environmental impacts associated with an increased use of WH/C?

### Social

- What are the main public concerns with the current H/C?
- What are the main health and safety concerns associated with the current H/C?
- What are the main public and health & safety concerns with an increased use of WH/C?



## Portugal

### Political and Legal

- How are the national 2030 commitments (reduction of GHG emissions by 17%, 47% RES and 35% in primary energy savings) affecting the heating and cooling supply and demand policies?
- The RCN2050 (*Roteiro para a Neutralidade Carbónica*) identifies electrification and biomass as key for de carbonization of heating and cooling in the industry. But are there any policies or regulations targeting these or other types of H/C?
- What policies and regulations exist related, specifically, to the use of industrial, as well as industrial WH/C combined with RES?
- Are there any policies or regulations (federal, regional, industry, environmental, health & safety) affecting the industries possibility to recover WH/C?

### Economical

- Except for gas and biomass, is there any other H/C supply that would compete with an increased industrial WH/C supply?
- What would be the main incentive for the industry to supply WH/C?
- What are the major economic challenges associated with the increased use of WH/C?
- How is the economic “wellbeing” of the industry sector that would be potential WH/C suppliers? E.g. are industries shutting down, moving abroad etc.?

### Technological

- How is the heating and cooling demand by industries, household and services met today? Are there any statistics available?
- District heating seems to be used solely by the industry due to small heating demand by the residential sector. Are there any plans to increase these networks to include even more industries?
- Are there any district cooling networks and if yes, which sector is using these?
- Biomass and renewable CHP has been identified as potential RES in H/C, are there any other RES resources that could be used for H/C?
- What is the estimated WH/C potential? To which extent is this potential utilized today?
- Which types of industries could potentially recover WH/C?
- What are the major technical challenges associated with an increased use of WH/C?

### Environmental

- Except for GHG emissions, what are the main environmental impacts associated with the current H/C?
- What are the main environmental impacts associated with an increased use of WH/C?

### Social

- What are the main public concerns with the current H/C?
- What are the main public concerns with an increased use of WH/C?
- What are the main health and safety concerns associated with the current H/C?

## Romania

### Political and Legal

- How are the national 2030 commitments (reduction of GHG emissions by 43.9%, 27.9% RES and 37.5% in energy savings) affecting the heating and cooling supply and demand policies?
- What policies and regulations exist related to the supply and demand of heating and cooling?
- What policies and regulations exist related, specifically, to the use of WH/C from industries, as well as WH/C combined with RES?
- Are there any policies or regulations (federal, regional, industry, environmental, health & safety) affecting the industries possibility to recover WH/C?

### Economical

- Except for gas and biomass, is there any other H/C supply that would compete with an increased industrial WH/C supply?
- What would be the main incentive for the industry to supply WH/C?
- What are the major economic challenges associated with the increased use of WH/C?
- How is the economic “wellbeing” of the industry sector that would be potential WH/C suppliers? E.g. are industries shutting down, moving abroad etc.?

### Technological

- Except for biomass such as firewood and agricultural waste, what other RES potential is there for heating and cooling?
- Are there any district cooling networks and if yes, which sector is using these?
- To what extent is WH/C used today from thermal and industrial plants?
- Which type of industry has the potential to supply WH/C?
- What are the major technical challenges, except for development needs in district heating networks, associated with an increased use of WH/C?

### Environmental

- Except for GHG emissions and local toxic emissions from individual boilers, what are the main environmental impacts associated with the current H/C?
- What are the main environmental impacts associated with an increased use of WH/C?

### Social

- What would be the main incentives for Romanian households to move away from individual heating and choose more centralized options?
- Fuel poverty has been identified as one of the major issues with the current H/C system, are there other public concerns?
- Are there any other health and safety concerns, except for the fire dangers and harmful emissions from individual boilers, associate with the current H/C?

## Spain

### Political and Legal

- How are the national 2030 commitments (reduction of GHG emissions by 21%, 42% RES and 39.6% in energy savings) affecting the heating and cooling supply and demand policies?
- Except for the support of solar thermal, what policies and regulations exist related to the supply and demand of heating and cooling?
- What policies and regulations exist related, specifically, to the use of WH/C from industries, as well as WH/C combined with RES?
- Are there any policies or regulations (federal, regional, industry, environmental, health & safety) affecting the industries possibility to recover WH/C?

### Economical

- Except for gas, is there any other H/C supply that would compete with an increased industrial WH/C supply?
- What would be the main incentive for the industry to supply WH/C?
- What are the major economic challenges associated with the increased use of WH/C?
- How is the economic “wellbeing” of the industry sector that would be potential WH/C suppliers? E.g. are industries shutting down, moving abroad etc.?

### Technological

- Is district heating and/or district cooling available in the country, and to what extent?
- Are there any district cooling networks and if yes, which sector is using these?
- Except for biomass and solar thermal, what other RES potential is there for heating and cooling?
- What is the estimated WH/C potential? To which extent is this potential utilized today?
- Which type of industry has the potential to supply WH/C?
- What are the major technical challenges associated with an increased use of WH/C?

### Environmental

- Except for GHG emissions, what are the main environmental impacts associated with the current H/C?
- What are the main environmental impacts associated with an increased use of WH/C?

### Social

- What are the main public concerns with the current H/C?
- What are the main public concerns with an increased use of WH/C?
- What are the main health and safety concerns associated with the current H/C?

## United Kingdom

### Political and Legal

- How are the national 2030 commitments of a reduction of GHG emissions by 37%, affecting the heating and cooling supply and demand policies?
- Except for the policy instruments described in the PESTLE document this far, are there any other policies or regulations related to the supply and demand of heating and cooling?
- What policies and regulations exist related, specifically, to the use of industrial WH/C combined with RES?
- Are there any policies or regulations (federal, regional, industry, environmental, health & safety) affecting the industries possibility to recover WH/C?

### Economical

- Except for natural gas, what other H/C supply would compete with an increased industrial WH/C supply?
- What would be the main incentive for the industry to supply WH/C?
- What are the major economic challenges associated with the increased use of WH/C?

### Technological

- Are there any district cooling networks and if yes, which sector is using these?
- What are the main energy resources used for cooling?
- To what extent is WH/C used today?
- What are the major technical challenges associated with an increased use of WH/C?

### Environmental

- Other than emissions from natural gas and other fossil heat supply, what would be the main environmental concerns with the current heating and cooling systems?
- What could be the major environmental impacts associated with an increased use of WH/C?

### Social

- What are the main public concerns with the current H/C?
- What are the main health and safety concerns associated with the current H/C?
- What are the main public and health & safety concerns with an increased use of WH/C?