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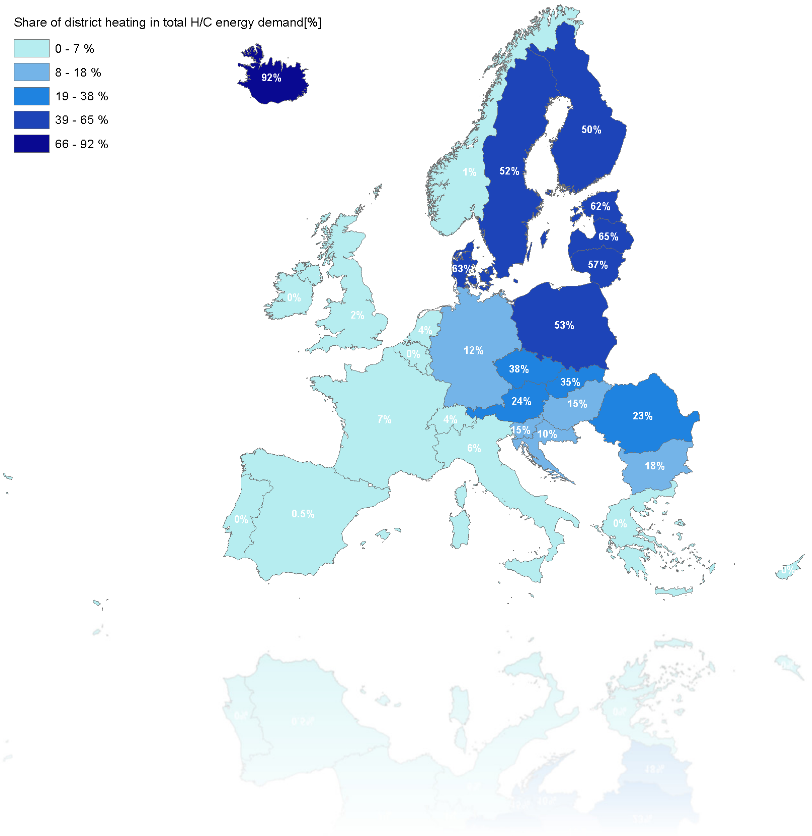
Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables)



Work package 5: Barriers, Best Practices and Policy Recommendations

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1 Background, objective and approach

1.1 Objective

In this work package, an analysis of barriers and bottlenecks that prevent the use of renewable energy sources (RES) for heating and cooling (H/C) purposes is conducted. The role of successful best practices is also documented in this work package, highlighting the ideal policies for the reduction of barriers and bottlenecks.

Barriers are analysed for the following energy efficient and RES H/C technologies, as mapped in work packages 1 and 2:

- **Heat pumps**: A strong focus of the analysis is on heat pumps, being one of the most widespread renewable technologies in Europe. While air source heat pumps account for approximately 90% of the annual European market sales, more efficient ground source applications only make up 10 %. The use of heat pumps is widespread in Italy, France, Switzerland and Sweden.
- **Biomass boilers**: Biomass boilers fired with wood pellets, logs or chips are primarily designed for space heating, process heating and hot water. Biomass is the leading renewable energy carrier for final energy consumption in Europe. Biomass applications are also the most widely spread and heavily used renewable technologies in the residential sector.
- **Solar thermal systems**: While flat plate collectors are the most common type of solar thermal system in Europe, the main countries using solar thermal systems, such as Germany, France and Greece, usually use vacuum collectors.
- **Combined heat and power (CHP)**: Combined heat and power generation can substantially contribute to meeting greenhouse gas reduction targets, especially when fuelled with biomass (e.g. biogas, waste wood) and in fields were other RES technologies such as heat pumps are less appropriate or cost-effective (e.g. non-retrofitted buildings, industry).
- **Solar thermal cooling systems**: Solar thermal driven cooling is seen as the most common RES cooling application. However, while the estimated European air-conditioning market size was 5.2 Million sold units in 2012 (Jakob, 2013), the number of solar cooling installations in Europe is still limited, at about 800 installed units in 2012 (Mauthner et al., 2015), focused in the Mediterranean countries.

The scope of the project and the scenario definition emphasise that barriers and policy recommendations should focus on H/C supply technologies. While energy efficient measures that reduce useful energy demand (e.g. through building insulation) are also considered, they are less important in this report.

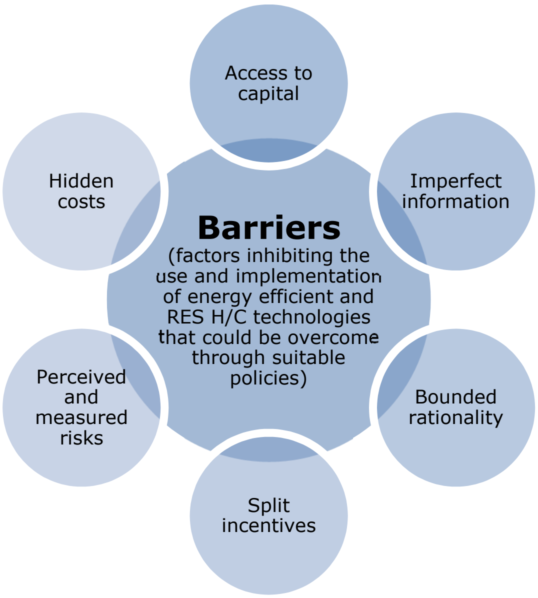
1.2 Approach

The central questions of the task deal with the identification of the factors and bottlenecks, such as economic aspects, behavioural issues, and decision making routines, as well as financing conditions and subsidy programs among different types of actors, which influence the diffusion of RES H/C technologies and might be overcome with suitable policies. These factors are assembled through a literature review and interviews with representatives of H/C associations and selected technology experts across the sectors.

For the purpose of our study, *barriers are defined as factors inhibiting the use and the implementation of energy efficient and RES H/C technologies that could be overcome through suitable policies.*

Existing studies on barriers emphasise that there are many current mechanisms across the complete technology product cycle. This means that the elimination of a single barrier is likely to be ineffective unless the same or additional measures affect other existing barriers. Consequently a coherent bundle of measures is needed to perform a successful and comprehensive energy efficiency policy. Within this work package, barriers are classified according to the following proposal based on Sorrell et al. (2011)[1] (see Figure 1).

Figure 1: Categories of barriers for energy efficient and RES H/C technologies:



Source: own illustration based on Sorrel et al. 2004

These barriers are defined as follows.

- **Access to capital:** Barriers concerning the provision and management of financial resources including internal funds and external borrowing.
- **Imperfect information:** Barriers concerning asymmetries of information between different actors and a lack of adequate information on the advantages of energy efficient or RES H/C technologies.
- **Bounded rationality:** Barriers concerning different decision behaviour of individuals and organisations to that assumed by economic models. This in-

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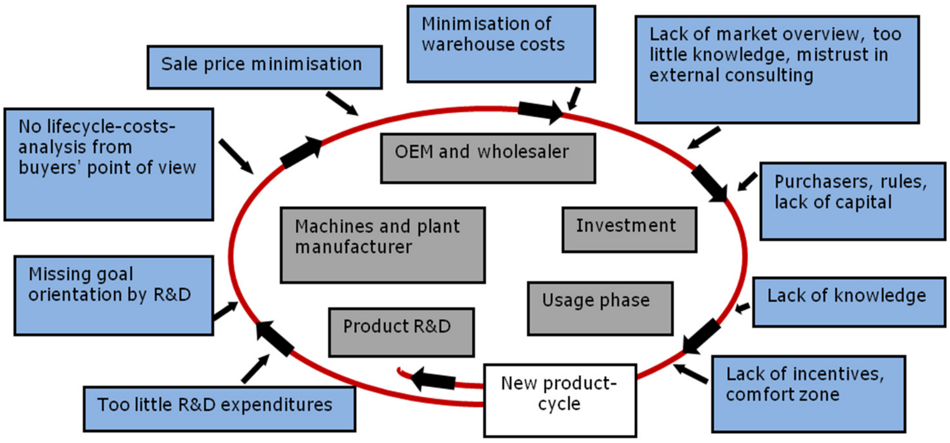
[1] The literature review indicates multiple and overlapping classifications of barriers for energy efficient and RES heating and cooling technologies. The complex nature of barriers can lead to a definition concept via financial factors, information deficits, psycho-social factors as well as administrative, legal or technical aspects (Palm (2009), Sorrell et al. (2011)). Other sources classify them as economic, behavioral and organizational barriers or into market and non-market failure barriers

cludes personal attitudes, rule-of-thumb-approaches and preferences.

- **Split incentives:** Split incentives and variations between the interests of different actor groups.
- **Perceived and measured risks:** Barriers concerning administrative, legal, organisational and technical risks which may occur when investing in H/C technologies.
- **Hidden costs:** Barriers concerning the overestimation of H/C technology potentials such as the underestimation of costs for industrial production disruption, additional maintenance, training or gathering information.

Barriers and bottlenecks to the use of RES in H/C technologies can also be analysed along the product cycle. A particular focus is given to RES technologies with high deployment potential (see Figure 2 below).

Figure 2: Examples of barriers along the product cycle for efficient or RES H/C across different types of stakeholders[2]



Source: Lösch et al. (2015a)

The best practices address the learning and success factors of policies to reduce bottlenecks, serve as proof of concept for next generation technologies and highlight the reasons for their success.

The policy recommendations include both overall policy recommendations and sector and technology specific recommendations at EU level. Recommendations of policy measures will address economic and non-economic barriers at different levels. This includes cross-sectoral policies, sector specific (e.g. industry) and technology specific policies. The aim of the recommendations is to provide incentives to use RES or more efficient H/C technologies.

Barriers, best practice examples and policy recommendations are structured according to the main H/C sectors as follows:

- Space heating and cooling in residential and non-residential buildings

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[2] OEM – Original Equipment manufacturer

- Process heating and cooling in industry and tertiary sectors
- District heating and cooling

2 Barriers to energy efficient and RES H/C technologies

This chapter assesses barriers to space heating and cooling in residential and non-residential buildings as well as to process heating and cooling in industry and tertiary sectors and district heating.

2.1 Space heating and cooling

A preliminary consideration of potentials for energy efficient and RES H/C is essential for the analysis of barriers to the use of RES for space heating and cooling in the residential and non-residential building sectors. An understanding of the current building stock and the relevant actors in this sector is also necessary. Both of these are discussed in the following section where selected results of WP1 are also summarised. The importance of individual barriers is discussed alongside the different types of barriers before they are then summarised in an overview at the end of the section.

2.1.1 Sector structure

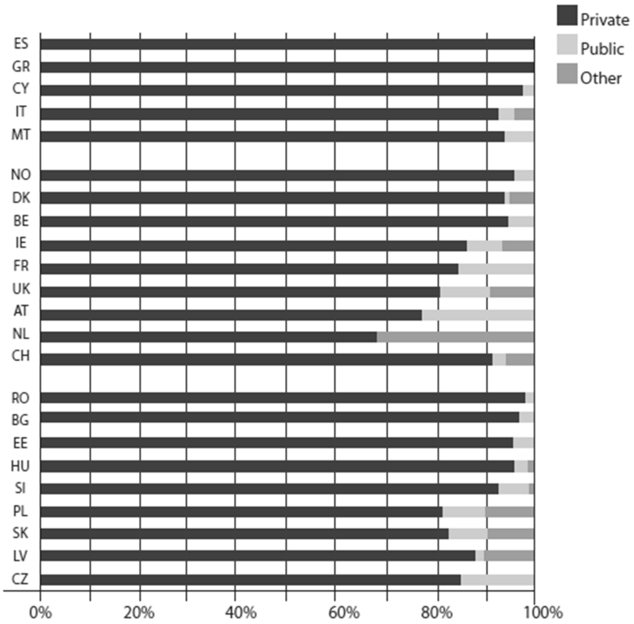
In Europe's residential buildings, space heating is the major end-use and accounts for 68% of the total final energy demand. Only 12% of the final energy demand is used for non-heating and space cooling purposes and the remainder is taken up by water heating (14%) and cooking applications (6%).

In the tertiary sector, representing non-residential buildings, 61% of total final energy demand is used for space heating. When water heating is included the share increases to 75%. In the tertiary sector, the final energy demand for H/C purposes varies across the different sub-sectors. Wholesale and retail is the dominant sub-sector and covers 25% of the total demand. Space heating is the dominant end-use in wholesale and retail as well as in the educational sub-sector. Space cooling and process cooling are also relevant for wholesale and retail.

Significant differences in the perception of barriers across building type (e.g. owner-occupied single family house, public rented social housing building or large shopping centre) are observed.

In Europe, residential buildings account for 75% of the total building stock. The ownership structure and distribution across EU member states are important for the barriers identified. The country-specific ownership of residential buildings in Europe is shown in Figure 3. The largest proportion of residential buildings in European countries is held by private owners while only 20% of the buildings are publically owned (Economidou et al., 2011a). Differences in the share of public ownership are often connected to the structure of social housing in the different European countries. While, for example, in Austria, social housing is mainly owned by public bodies, in The Netherlands these buildings are fully owned by housing associations (private bodies).

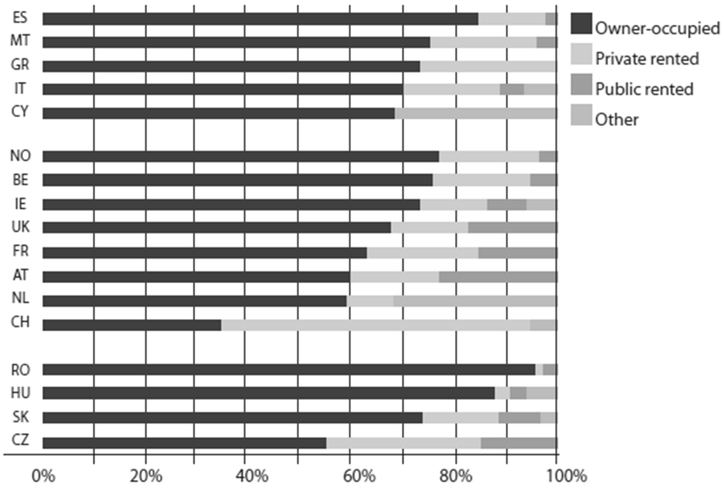
Figure 3: Ownership of residential buildings in Europe



Source: Economidou et al. (2011)

A high proportion of residential buildings are occupied by the owners in almost all countries as shown in Figure 4. There are significant proportions of private tenants in Switzerland, Greece and the Czech Republic while shares of public rented buildings are highest in Austria, the UK and France.

Figure 4: Tenure of residential buildings in Europe



Source: Economidou et al. (2011)

The tenure and ownership structure guides many factors associated with investments in new technologies. These include the access to finance, the perception of the usefulness of renovations or new energy technologies, split incentives or how information and awareness plays a role for owners of buildings including their behaviour and preferences.

2.1.2 Access to capital

The high initial costs of energy efficient and RES H/C technologies, relative to conventional alternatives (e.g. ground source heat pump versus natural gas boiler), are a significant barrier to the uptake of these systems. Regarding specific investment in technologies, previous research has shown that CHP units are up to 3 times more expensive than fossil fuel condensing boilers. A similar cost relationship can be identified for biomass and solar thermal applications compared to fossil boilers (see Table 1). High costs are observed in fuel cells and stirling CHP plants when compared to average electricity prices for the EU.

Table 1: Specific investment costs of different energy efficient and RES H/C technologies in Europe (2012)

Technology	Average specific investment costs [€/kW]	Minimum specific investment costs [€/kW]	Maximum specific investment costs [€/kW]
condensing gas boiler	387	196	645
condensing oil boiler	457	232	762
combined heat and power (internal combustion)	1451	737	2 424
combined heat and power (Stirling)	7 202	3 651	12 000
combined heat and power (fuel cell)	10 005	5 071	16 670
air source heat pump	1 130	n.a.	n.a.
ground source heat pump	1 675	n.a.	n.a.
biomass	974	n.a.	n.a.
solar thermal	773	n.a.	n.a.
solar thermal cooling	4 500	n.a.	n.a.

Source: see work package 2

According to recent survey results of the FROnT Project (Ortega Izquierdo, 2016), the high investment costs for RES technologies in the residential and industrial sectors are a common argument for not investing. This is based on the analysis of over 4,585 interviews conducted in 6 European countries in the residential and industrial sectors.

Besides high initial costs of energy efficient and RES H/C systems, financial uncertainties regarding the investors play a major role in the investment in these technologies. There can be uncertainties in the overall cost-effectiveness of investments, the financial situation of the investor (e.g. access to internal or external capital) or future energy price trends. Thus, uncertainties of private investors about their financial future can hinder investments especially when a loan is needed. Commercial investors have to face similar challenges in addition to handling their corporate image (Fette et al., 2012b).

Public buildings are associated with separate budget lines for investments and running costs when energy efficient and RES H/C technologies are taken into account. However owners of office buildings are often economically aware which forces energy efficient and RES H/C applications to compete with other uses of investment capital (Fette et al., 2012b; Heiskanen et al., 2014).

2.1.3 Imperfect information

The lack of information and poor awareness of energy efficient and RES H/C technologies are important barriers to the pursuit of such investments. As most energy efficient and RES H/C technologies are currently not mainstream technology, and the access to information is limited for most customers, the possibilities and benefits of these technologies are limited (Doble and Bullard, 2008).

High perceived difficulties of getting used to the systems (e.g. operability of manual biomass feeding systems) and a functional misunderstanding of the technologies (e.g. the belief that heat pumps are complex technologies) cause fundamental information deficits for customers (Michelsen and Madlener, 2013). This leads to a state of inertia which inhibits the utilisation of the technologies (Doble and Bullard, 2008).

On the technology supply side, a lack of qualified and trained experts (e.g. installers, energy consultants) is identified as an obstacle. Many of these experts rely on conventional H/C technologies as they are more familiar with these proven systems (Doble and Bullard, 2008; Heiskanen et al., 2014).

In addition, the misunderstanding of the benefits of energy efficient and RES H/C technologies by financial institutions can reduce the credit rating of buildings, affecting the award of additional loans.

A lack of information on these technologies by the city council or the local administration can be responsible for administrative burdens that make the diffusion of energy efficient and RES H/C technologies even more complicated.

Poor energy efficiency of buildings is rarely recognized by small private building owners. They often have only restricted knowledge of energy consumption and the cost reduction potential of their buildings. The energy status of buildings is often positively rated by such individuals as long as no functional defects appear. In many cases this information deficit is related to an inadequate knowledge about funding and consulting opportunities (Fette et al., 2012b).

2.1.4 Bounded rationality (attitudes and preferences)

When costs are high, the diffusion of innovative energy efficient and RES H/C technologies is hindered, especially when customers are looking for short-term investments that offer a quick payback (Frontier Economics Ltd., 2013; IEA-ETSAP and International Renewable Energy Agency, 2013; Heiskanen et al., 2014; Asztemborski et al., 2016).

Uncertainties surrounding the performance of energy efficient and RES H/C systems result in a lack of confidence among customers (Doble and Bullard, 2008; Frontier Economics Ltd., 2013). This barrier is caused by the fact that, in the past, energy efficient and RES H/C technologies in real applications have performed below theoretical specifications of the manufacturers. These uncertainties and negative application examples in the social environment (e.g. family, friends, neighbours) of customers lead to a low expected reliability of energy efficient and RES H/C technologies (Michelsen and Madlener, 2013).

Investment decisions by owners of residential buildings are not only rationally-based but include a mix of emotional desires, objective criteria and subjective decision preferences. In addition a life cycle analysis is not commonly considered for these investment decisions - also in view of uncertainty in profits (Stieß et al., 2009).

The degree of professionalism in the private sector is rather low, thus influencing the barriers for implementing these types of investments. This is particularly the case for standard apartments and household owners. However, an increased know-how and economic optimisation for these types of investments in homeowners associations can often be assumed. This higher degree of professionalism by home owners' administrations can also negatively influence the investments in RES and energy efficiency for H/C technologies because these technologies cannot compete with conventional technologies in economically feasible terms. Housing societies also show a high degree of professionalism when analysing investments. For non-residential buildings, commercial housing companies' financial investors have a special role. The retention or increase in property value is not of primary importance but the expected investment yields leads to the consideration of measures with very low amortisation. The actual profitability of the measures is, in many cases, neglected (Fette et al., 2012b).

In residential buildings, investments in energy efficient and RES H/C technologies often compete with other modernization measures to improve the living quality or comfort (e.g. new bathroom) which cannot be valued in economic terms. In these cases, home owners mostly tend to choose the more aesthetic and visible measure. This could be problematic for the diffusion of energy efficient and RES H/C technologies, especially when the low external perception of these systems is taken into account (Fette et al., 2012b).

Elderly home owners tend to have a lower risk tolerance, causing an aversion to new technologies, and borrowing regarding investments in energy efficient and RES H/C technologies. This behaviour can be identified in nearly all socio-demographic groups and is seen as a fundamental attitude of many building owners (Heiskanen et al., 2012; Fette et al., 2012b). Additionally, older building owners often transfer renovation measures to their children making them financially accountable for the realisation of such projects and bearing the inconveniences during the implementation.

2.1.5 Split incentives

A mismatch of incentives (e.g. landlord-tenant split) can be identified as a barrier in the residential and non-residential sectors. If the investor in a new energy efficient and RES H/C system is not the beneficiary, it can jeopardise the whole investment. Such a scenario can be found in almost every landlord-tenant relationship in residential buildings (Heiskanen et al., 2012; Fette et al., 2012b; Frontier Economics Ltd., 2013). According to the tenure structure of the buildings in Europe, 40% or fewer of the buildings are occupied by the owners, so that a significant share of buildings (especially in Western rather than Eastern European countries) face this investment challenge as previously highlighted.

In addition large utility companies tend to fight against changes in the supply market as they want to preserve their traditional role as a central provider of energy. This lobbyism can broadly influence the diffusion of energy efficient and RES H/C systems in the residential sector (Fette et al., 2012b).

2.1.6 Perceived and measured risks (legal, technical and administrative risks)

In some cases a barrier to the diffusion of energy efficient and RES H/C technologies seems to be a dysfunctional market mechanism particularly concerning the pricing of fossil energy. Subsidies for fossil fuels make such energy carriers artificially cheap which makes it nearly impossible for energy efficient and RES H/C technologies to compete with them (Barany and Grigonytė, 2015; Asztemborski et al., 2016; Lucha et al., 2016).

Heat pumps:

There are a few technical obstacles which can act as barriers to the uptake of the two types of heat pumps examined (air source and ground source).

First of all, the noise pollution of air source heat pumps can be a significant barrier, especially in densely populated areas (Frontier Economics Ltd., 2013). The noise generated by the external fan and compressor unit of an air source heat pump can affect the building occupants as well as their neighbours. A study by the Edinburgh Napier University Building Performance Centre determined that the noise level of different air source heat pump installations is in the range of 50 to 60 dB at one metre from the unit. At the same time the upper noise level was required to not exceed 42 dB at one metre from the unit. This means that the majority of the observed air source heat pumps need to be located 10 to 20 metres away from neighbouring buildings to achieve the required 42 dB level, making utilisation quite difficult in areas of high housing density. In addition, the size of the outdoor unit of air source heat pumps can be perceived as an obstacle to the uptake of this technology, both in terms of visual aspects and space constraints.

The utilisation of air source heat pumps is very cost-effective in areas where space heating and cooling are required throughout the year. However, ground source heat pumps can also be used as effective applications for space cooling and heating, as in most regions the temperature of the ground remains stable throughout the year (IEA-ETSAP and International Renewable Energy Agency, 2013). For ground source heat pumps, the need for a ground loop represents the biggest technical barrier. The required ground loop could be associated with site-specific design considerations, complex evaluations of the geological conditions or difficulties during the installation (Goetzler et al., 2009). All of these aspects are uncertainties that can influence the decision to investment in this technology. For example the location of the building could be an obstacle when the prevailing soil conditions are unsuitable for the installation of the ground loop (Michelsen and Madlener, 2013). Besides these type-specific barriers, the operating costs of both technologies generally depend on the current electricity price. This dependency can significantly affect investment in heat pumps.

Space constraints in urban areas or environmental regulations (e.g. restricted re-injection of ground water for ground source heat pumps) might hinder the installation of heat pumps as well as risks (e.g. potential for glycol leaks of ground source heat pumps) that are connected to the operation of these technologies (Goetzler et al., 2009).

Biomass boilers:

A number of technical barriers can be identified that hinder the diffusion of biomass boilers into the residential sector. First of all, the logistics needed for the broad utilisation of biomass boilers are quite complicated (Asztemborski et al., 2016). There are different types of biomass used (e.g. wood pellets, chips, and logs) which all have to be transported and stored. This either requires multiple decentralised storage units with a lot of space in individual residential buildings which can be problematic, or huge centralised depots requiring the fuel to be transported over long distances (Michelsen and Madlener, 2013).

The demand for biomass is especially high during heating seasons (e.g. winter) leading to weekly or monthly fuel deliveries. Besides this, the overall quality of the biomass has decreased during recent years. Biomass is a very heterogeneous fuel and the quality varies substantially over the seasons and different suppliers. In addition there are doubts about the assumption that the biomass price will continue to be low in the future. These uncertainties of the fuel supply inhibit the uptake of biomass boilers (Doble and Bullard, 2008).

Furthermore, the lack of suitable equipment as well as its sometimes observed low quality can be seen as barriers. This also includes the absence of equipment for biomass harvesting, collection and transport, as well as sufficient multi-fuel biomass boilers that could otherwise lower the dependency on special fuel types (Asztemborski et al., 2016).

Weak legislative framework conditions and long bureaucratic processes (Asztemborski et al., 2016) as well as regulatory constraints (e.g. emission standards) are perceived to negatively influence the market penetration of biomass boilers (Doble and Bullard, 2008; Michelsen and Madlener, 2013).

Another barrier for biomass boilers is related to the perception of biomass sustainability (e.g. biodiversity). There is a general public debate about the further expansion of the use of land for energetic biomass rather than for food crops or the utilisation for material purposes. Thereby the production of biomass for energy is not always discussed favourably (Asztemborski et al., 2016).

Solar thermal systems:

It might be difficult to integrate the required technical equipment for solar thermal systems into existing buildings. Obstacles can either occur concerning the requirements for retrofitting the new heating system or concerning practical considerations (e.g. lack of space for water tank) (Philibert, 2006).

Customer's investment decisions can also be influenced by the perceived dependency of solar thermal systems on solar radiation; they expect this technology to be less reliable. This perception becomes even more important when taking into account that the potential of the sun is greater in the summer when the demand is low, while an increased need for heat occurs when the potential is lower in the winter (Philibert, 2006).

Permission regulations for ground or roof mounted installations can act as barriers at a local or national level. In addition solar thermal systems have to compete for roof space with PV applications(International Renewable Energy Agency, 2015).

Combined heat and power (CHP):

For an economically optimal operation the power generated by CHP plants has to be consumed centrally (Mühlbach, 2014). This could be a problem when the tenants in a residential building are not contractually bound to purchase the power that is cogenerated by their CHP heating system. Such uncertainties can hinder the investment in CHP plants.

Besides this, the performance of certain CHP plants can be seen as a barrier. Some systems trip up under part-load operation which leads to weak electrical efficiencies. Alternatively they operate at power-to-heat ratios which do not fit the load profiles of residential buildings (Boehnke, 2007). Furthermore, the high noise and vibration levels of several CHP units can make this technology quite unattractive for residential applications (Boehnke, 2007).

Solar thermal cooling systems:

An important barrier to the diffusion of solar thermal cooling systems is the fact that non-standardised components can create difficulties during the selection or operation phase. Suppliers usually lack the required equipment and complete “package” solutions (e.g. solar flat plates are available, but absorption systems are hard to find) for solar thermal cooling applications, as components from different sources have to be connected (ESTIF, 2006a; Oppelt et al., 2013). Improper design, resulting from missing guidelines for dimensioning and energy management, as well as non-optimal control or insufficient maintenance of the solar thermal cooling applications, can affect the efficiency of these systems. This leads to lower energy savings (Solar Heating & Cooling Programme, 2015).

Furthermore, the utilisation of auxiliary equipment or co-firing might increase the energy consumption of the systems while further lowering the energy saving potentials (Oppelt et al., 2013). As already mentioned for solar thermal systems, limitations in available rooftop size can hinder the realisation of solar cooling projects. An additional obstacle to the market penetration of solar thermal cooling technologies seems to be a lack of units with small capacities. These could compete with conventional cooling applications (ESTIF, 2006a).

The limited number of demonstration plants, and investments costs which have been identified to be 2 to 5 times higher than for conventional state-of-the-art systems, hinder the uptake of solar thermal cooling systems (Coroyannakis et al; Oppelt et al., 2013; Solar Heating & Cooling Programme, 2015).

2.1.7 Hidden costs

Time taken to research the technologies and the hassle associated with the installation of the systems are seen as non-monetary costs that can limit the uptake of energy efficient and RES H/C technologies. Increased operating costs caused by poor performance are identified as monetary barriers (Doble and Bullard, 2008).

Besides the above mentioned barriers, experts often tend to advise against energy efficient and RES H/C technologies in existing buildings because of the energy retrofitting of the buildings or adjustments to the heating infrastructure (e.g. low flow temperature of the heating system) that are usually required (Doble and Bullard, 2008; Michelsen and Madlener, 2013). This behaviour prevents the implementation of energy efficient and RES H/C technologies in older buildings.

There are also inconveniences associated with refurbishment works such as a loss of space due to hot-water cylinder installation or ground works in the garden for the ground loop for heat pumps (Frontier Economics Ltd., 2013). These measures represent “hassle costs” which can be perceived as barriers.

The implementation of energy efficient and RES H/C technologies might require additional information, time or attention, for financing or gaining permission, caused by a lack of awareness or familiarity with these systems. Thus, the transaction costs, on a capacity basis, are often larger than conventional applications, making energy efficient and RES H/C technologies more expensive than common alternatives (Beck and Martinot, 2004).

2.1.8 Overview of barriers for different user groups

There is a different group of barriers for each type of building owner across Europe. A common problem is the perceived payback times for the investments; the opportunity to benefit from the profitability of such long-term investments is missed. A lack of confidence and trust in new technologies is also a common barrier across all groups, additionally influenced by negative examples. The priorities of the different owner types are influenced by the type of renovations (e.g. heating system vs. visible interventions); the preference is usually to invest in visible measures which affect comfort and aesthetics, displacing the importance of energy efficiency or RES supply.

Table 2: Barriers to energy efficient and RES H/C technologies in residential buildings for different owner types

	Barriers	Owner-occupied	Private rental housing	Owner community	Housing company
	access to capital				
I	uncertainties about own financial future	++	++	++	-
II	lack of internal capital	++	++	++	-
III	lack of external capital	+	+	+	-
	imperfect information				
IV	insufficient rating of energy status	++	++	++	-
V	lack of knowledge about energy demand	+	+	+	-
VI	lack of knowledge about energy cost reduction	++	++	+	-
VII	lack of knowledge about funding and consulting opportunities	++	++	+	-
	bounded rationality				
VIII	payback time too long	+	+	+	+
IX	lack of confidence in new technology	-	-	-	-
X	influence of negative examples	-	-	-	-
XI	inconveniences during retrofitting	-	+	+	+
XII	preference for visible measures (image)	+	+	+	+
XIII	concerns about borrowing	++	++	++	-
XIV	perceived low ratio between efforts and benefits	++	++	++	-

Legend code: very important (++), important (+), less important (-)

Source: Fette et al. (2012)

In the residential sector, organisational difficulties of reaching agreement on the need to invest in energy efficient and RES H/C technologies, and on the system to be utilised, are widespread obstacles for owner-occupied multi-family buildings (Heiskanen et al., 2012).

The investor-user dilemma is also an important differentiation for non-residential buildings (services sector), as with the owner occupied and rented housing sections of the residential buildings sector. Furthermore, the public sector (embedded within the services sector) provides an example for private investments to invest in RES H/C and energy efficiency buildings renovations.

The service and industrial sectors are more heterogeneous; selected findings from the non-residential buildings sector can be transferred to the analysis of this sector. For instance the professional investment calculations by non-residential building owners and administrators can be easily transferred. For very small service establishments, barriers and investment behaviours are similar to those of private individuals. In addition, it is important to consider that in the area of non-residential buildings, renting is largely through professional companies with only a limited amount taking place through private individuals. This might, however, vary across European Union member states.

The economic approach for investment calculations is more frequently used in the non-residential than in the residential building sector. If investments are to be pursued with external financing (borrowing), decisions are based mainly on the calculated profitability of the measure; the only underlying obstacles to external financing for the private sector are particular conditions of individual EU countries (Herkel, 2011; Neumann, 2011). This can be a supportive factor for RES and energy efficiency (and H/C) investment decisions, however due to the very short amortization expectations, this also acts as a barrier. Furthermore, this trend is also influenced by the fact that corporate loans are given a shorter maturity than loans for individuals.

In the service and industrial sector, a barrier appears to be to prioritise the business activity over the energy management related aspects of the building. The focus for companies in services and industry is the maintenance of the production or the services provided around their business activities. The cost structure is dominated by personnel costs and inputs costs and since energy management is not a priority for company leaders it is accordingly often neglected, particularly in small companies. Very often energy management is removed from the corporate agenda. It can also result in recommended actions being missed or a distrust of proposed recommendations with increasing transaction costs (Herkel, 2011).

Within the non-residential buildings sector, investments are attractive if they lead towards an increase of labour productivity, an improvement of the working environment, or increased marketing activities and motivation (Herkel, 2011; Fette et al., 2012b). These need to be considered as a promotion factor when planning and consultancy of such projects are conducted. For countries with building certification schemes, the public benefit of such a certificate seems to be a promotional factor for non-residential building users (Neumann, 2011; Heiskanen et al., 2012; Fette et al., 2012b).

The public sector within the service sector, being non-residential buildings, plays a special role, On the one hand it provides economic opportunities for local actors through the energetic renovation or RES H/C investments, while on the other hand it sets an example for other sectors to follow. The isolated assessment and observation of single buildings of the public sector leads to investor-user dilemmas and if partially observed, might not take into account the needs of future users of the buildings (e.g. schools). This lack of consideration can distort the intentions of efficient and RES H/C production (Tepper, 2011; Heiskanen et al., 2012; Fette et al., 2012b).

The public sector (i.e. cities administrations), and associated energy management measures, can be financed through local budgets and external financing. This is specific for this sector, meaning that the allocation of credits for individual measures is not really feasible and is more dependent on the balances of accounts of these, often highly indebted, communities. This particular situation represents a barrier to these very reasonable measures.

2.2 Process heating and cooling

This section summarises barriers for energy efficient and RES H/C technologies in process heating and cooling in industry but also in the tertiary sector. It begins with a brief summary of the sector’s structure with regard to RES H/C potentials. In the main part the importance of individual barriers is discussed within the classes of defined barriers. Finally, a summary of the main barriers identified is provided, distinguished by different company sizes.

2.2.1 Sector structure

Referring to WP 1 the total final energy demand of all member states of the European Union in 2012 in the industrial sector was 3,200 TWh while 74% (~ 2,365 TWh) was used for H/C purposes alone. With 60% of the total final energy demand, process heating is the major end-use, split almost equally into heat demands above and below 500 °C. With a share of 11%, space heating is also a relevant end-use while process cooling accounts for about 3%.

The utilisation of RES H/C technologies is much less developed in industrial applications due to the significant demand of high temperature steam and heat in this sector. The majority of the RES H/C systems, which are commercially available today, are not able to deliver steam and heat in the required quality, particularly in the basic materials industries including cement, steel or glass manufacturing.

In niche applications, heat pumps, biomass boilers and solar thermal units are already supplying process heat at low and medium temperature levels. About 21% of industrial final energy in the EU28 consisted of low and medium temperature heat below 200°C in 2012. Even though industrial RES H/C technologies are currently accessible and successfully tested, their market share is still low.

Besides temperature levels, H/C use also varies by sub-sector. Process heat demand with high potential for RES H/C (i.e. below 200°C) is used in the pulp and paper, food, and chemical industries as well as in the ‘other industry’ sub-sector. High temperature process heating is mainly used in the iron and steel, chemical and non-metallic and minerals (cement and glass) sub-sectors while non-ferrous metals (aluminium) has lower demand in total numbers. Process cooling is mainly used in the chemicals industry (mostly for air-fractioning) and in the food industry.

2.2.2 Access to capital

A major barrier for energy efficient and RES H/C technologies is the high investment needed (IEA, 2014; IEA-ETSAP and International Renewable Energy Agency, 2015; Larive International, 2015). Even if energy efficient and RES heating technologies save conventional energies throughout their operation, the initial financial effort often inhibits the broader market penetration of these systems in the industrial sector.

While investment decisions of large enterprises are mainly influenced by the payback time of energy efficient and RES H/C technologies, financial restrictions (e.g. access to internal or external capital) play a more important role for SMEs. The competition between energy efficient and RES H/C technologies and other investments is more evident in SMEs, whereas large enterprises are often inhibited by short-term planning horizons.

The availability of internal capital is relatively poor for many SMEs in Europe. Banks are more cautious in financing SMEs than larger companies. This means that some SMEs would need to finance energy efficiency and RES H/C from internal cash flow (as long as this is available).

These financing restrictions could prevent investment in RES H/C and efficiency, even though a portion of such investment would be very profitable. Enhancing support factors (such as visibility of RES for marketing) could help prioritise these investments.

2.2.3 Imperfect information

Missing information about energy efficient and RES H/C technologies and a lack of knowledge about H/C demands is often connected to the absence of internal experts in SMEs. This barrier appears to be less important for larger enterprises due to their more diverse employment structure. Otherwise, concerns regarding negative product properties and process qualities caused by investments in new energy efficient and RES H/C technologies are identified as major obstacles in SMEs as well as in large enterprises. SMEs are almost unaffected by barriers related to internal information flow and the complex decision making of large enterprises (Fette et al., 2012b; Lösch et al., 2015b).

Many companies do not understand the demand for H/C in their processes. To overcome this lack of awareness of heat consumption, companies need expensive and time consuming measurements to determine savings opportunities (IEA, 2014). The substantial effort required for this hinders the diffusion of energy efficient and RES H/C technologies in this sector.

Besides the awareness of heat consumption, the integration of energy efficient and RES H/C systems in industrial processes requires detailed knowledge of the capabilities of such technologies as well as expertise of the associated process. The combined know-how of these two aspects is rarely found in all the experts (e.g. installers, decision-makers) in the industry which makes a suitable integration of energy efficient and RES H/C technologies quite difficult (Wolf et al., 2012).

This lack of understanding concerning bio-energy and climate technologies causes mistakes in feasibility studies, poor quality of engineered solutions, and thus a lower than planned performance of energy efficient and RES H/C systems (Larive International, 2015).

2.2.4 Bounded rationality (attitudes and preferences)

Customer concerns are identified as an important barrier to the diffusion of energy efficient and RES H/C technologies in the industrial sector. Decision-makers tend to choose well proven conventional technologies, as process heat supply is often a critical factor for production (Wolf et al., 2012). This attitude is mainly caused by a lack of information about successfully realised practice examples. The resulting lack of experience leads to a low acceptance of energy efficient and RES H/C technologies in the industrial market. This affects operators and industrial partners as well as the supply and consulting chains of these technologies.

Furthermore, investments in energy efficient and RES H/C technologies are often not permitted by decision-makers, as in most companies such efforts are not directly part of the core business (Vesterinen et al., 2010).

Inadequate routines are observed for SMEs with respect to purchasing and the determination of profitability. There are no clear specifications for the purchasing of technical equipment (RES H/C) or machines (efficiency). It is likely that the investments in H/C technologies would be assessed in SMEs by means of total investment amounts and not necessarily through the analysis of lifecycle costs. A similar situation is observed with respect to profitability of investments. It is likely that SMEs would use payback times for their decisions, neglecting high profitabilities calculated by means of IRR and net present value (Schröter et al., 2009).

2.2.5 Perceived and measured risks (legal, technical and administrative risks)

As in the buildings sector, a dysfunctional market mechanism concerning the pricing of fossil energy is identified as an important barrier for energy efficient and RES H/C technologies in industry. The cheap prices of fossil fuels do not compensate for the environmental damage that is caused by their use. Subsidies make these energy carriers artificially cheap making it almost impossible for energy efficient and RES H/C technologies to compete (Asztemborski et al., 2016; Lucha et al., 2016).

Furthermore, enterprises generally tend to avoid risks connected to their production processes. This includes the implementation of energy efficient or RES H/C technologies as well as changes in the current process parameters. This barrier is more closely examined in chapter 2.2.6.

Heat pumps:

A technical barrier of industrial heat pumps is the feasible heat sink temperature of the system. Many heat pump applications only realise heat sink temperatures below 65 °C whereas higher process temperatures are required in the industry. Energy efficient heat pumps need to be developed to increase the heat sink temperatures up to 100 °C and higher, IEA (2014).

Biomass boilers:

Uncertainties about the biomass market are a major barrier to the uptake of industrial biomass boilers. A lack of reliable suppliers of biomass can be identified as an obstacle which hinders the realisation of long-term supply contracts. Furthermore, the quality of the fuel can be a problem as consistent properties of this biomass cannot be guaranteed by the suppliers (Larive International, 2015).

Several kinds of biomass are classified as waste, leading to a quite restrictive legislation for usage (e.g. emission standards) (Vesterinen et al., 2010).

Solar thermal systems:

The high temperatures required for the operation of industrial processes can appear to be a technical barrier for solar thermal systems. If such a system is not able to meet the required process conditions, it is a natural obstacle for the diffusion of this technology. Additionally, solar thermal can only be used in combination with a redundancy system for energy supply that provides most of the heat demand and does not depend on solar radiation.

On the administrative side a lack of suitable planning guidelines and tools can be identified as barriers that need to be addressed (IEA-ETSAP and International Renewable Energy Agency, 2015). Only a few experts (e.g. engineering offices, research institutes) have a reputation concerning large scale industrial solar thermal systems, while the tools and guidelines needed are often missing.

Combined heat and power (CHP):

Requirements needed to connect a CHP unit to the electricity grid can be complicated or expensive, which discourages companies from investing in this technology. Where established interconnection standards exist, technical requirements for the grid interconnection, and requirements for paperwork (e.g. timelines for approvals, insurance requirements) have to be met. Standby rates are often paid by CHP operators to local utilities to provide backup electrical grid service for when the CHP unit is offline (e.g. maintenance, unexpected shutdowns). This guaranteed backup service is also useful when the demand exceeds the generation of the CHP system. Standby rates are usually calculated based on unlikely scenarios where CHP units go offline at periods of peak demand. This leads to overestimated costs compared to real applications (Simchak and Davis, 2013; U.S. Department of Energy, 2015).

Furthermore, the structure of pollution regulations might inhibit the diffusion of industrial CHP systems. CHP generation is not generally recognized as a net emissions and energy saving technology. The higher amount of useful energy which is produced by a CHP unit compared to a conventional boiler is often ignored, especially when emissions regulations are related to the concentration of pollutants in the exhaust gas. Such an approach does not take into account the environmental benefits of CHP systems and misses the fact that the overall emissions of CHP units are lower than the separated generation of heat and power (Simchak and Davis, 2013).

The common business model of utility companies can also hinder investments in CHP technology. Traditionally such companies try to recover their fixed costs of building new power plants or distribution infrastructure, by selling energy. Thus, a reduction of energy sales due to energy efficiency measures, such as the diffusion of CHP units, might reduce the revenues of the utility companies. Such a business model could create a disincentive for these companies to support such energy efficiency measures (U.S. Department of Energy, 2015).

Solar thermal cooling systems:

The large number of different applications and technologies associated with solar thermal cooling leads to a variety of relevant barriers. Thus, a process specific analysis of inhibiting factors is necessary to identify existing barriers for solar thermal cooling systems, considering, for example, general factors and system concepts as well as ad- and absorption refrigerants (sustainable cooling supply ...).

2.2.6 Hidden costs

The effort needed for funding applications and approvals of energy efficient and RES H/C technologies is seen to be an important barrier for both types of companies, dominated by the importance of uncertainties concerning framework and planning conditions.

The technical managers of SMEs companies often do not have the time, due to high workloads and wide working fields, to handle energy flows and consider alternative ways for producing heat or electricity from RES or making demand more efficient. The focus of their work is primarily on the technical production and the quality of the products, safety and environmental concerns (due to inspections). It is seldom that the reduction of energy costs by means of renewable technologies or increased energy efficiency can be considered.

In addition, energy costs are generally allocated to the costs of production but they are not usually allocated to specific processes due to a lack of measuring systems. In this way they remain unnoticed. This means that the substitution potentials of both RES H/C and energy efficiency measures are underestimated and normally downgraded. The potential for substitution of fossil energy carriers by means of RES H/C and energy efficiency potentials are high in SMEs (Mielicke et al., 2012).

Significant barriers to energy efficient and RES H/C technologies in the industrial sector are concerns and uncertainties about product properties and process qualities that might arise with the implementation of the new system. Industrial companies tend to avoid production interruptions to stay competitive in terms of cost efficiency (ESTIF, 2006b).

As previously mentioned, the implementation of energy efficient and RES H/C technologies often requires additional information, and the application of time or attention to obtaining finance or gaining permissions. This is exacerbated by a lack of awareness or familiarity with the systems. Thus, the transaction costs of these technologies are usually larger than those of conventional applications, making energy efficient and RES H/C technologies more expensive than common alternatives (Beck and Martinot, 2004).

2.2.7 Overview of barriers for different user groups

Table 3 provides a summary of important barriers observed in the use of energy efficient technologies and RES for process H/C. The relevance of the individual barriers is indicated for different company sizes, because investment decisions are taken differently in small and large enterprises. Restrictions that decision-makers face are also different. While there are certainly more company characteristics affecting the intensity of individual barriers, the company size is the factor that is most researched and can therefore be included in the table. Other factors include the share of energy cost as well as the capital ownership and the position in the value chain (i.e. the closeness to the final consumers). These cannot, however, be included in this summary for all barriers, due to a lack of empirical research.

SMEs exhibit particular barriers with respect to the risks related for financing and external capital to finance RES H/C and energy efficiency. These are due to liquidity concerns as well as good business performance. Energy savings can be provided as further guarantees (see Table 3). The lacks of knowledge with respect to the potentials available, to the energy expertise of the company or the technological RES H/C possibilities are a latent hurdle for the market entry.

Table 3: Barriers to energy efficient and RES H/C technologies within different types of companies

Barriers	Small size enterprises (SMEs)	Medium size enterprises	Large size enterprises
Access to capital			
Access to internal and external capital	++	+	-
Competition with other investments	+	++	-
Imperfect information			
Information deficits concerning RES H/C technologies	++	+	-
Absence of energy experts	++	+	-
Lack of knowledge about energy demand	++	+	-
Lack of process specific knowledge	++	+	-
Perceived and measured risks			
Concerns about negative product properties and process quality	++	++	++
Short-term planning horizon	-	+	++
Uncertainties about framework and planning conditions	++	++	++
Bounded rationality and split incentives			
Internal information flow	-	+	++
Complex decision making	--	-	++
Payback time too long	+	+	++
Hidden costs			
High effort for funding applications and approvals	+	+	+

Legend code: very important (++), important (+), less important (-), insignificant (--)

Source: Fette et al. (2012)

The following promotion/support factors are often neglected by SMEs (Lösch et al., 2015b):

- Investment decisions can be completed quickly; there can be direct contact between management and energy managers.
- Motivation of employees can be achieved rapidly through close contact with management; there can be distinction of innovative employees.
- Marketing and the image of the company can be improved.
- Participation in energy efficiency and RES competitions.
- Improvement of waste heat by means of active contractors and energy service companies (ESCOs).
- Special financial incentives, marketing and standards open up possibilities for RES H/C and other H/C technologies.

2.3 District heating and cooling

A brief summary of district heating and cooling in the EU is provided in this section, based on the results of WP1 and WP2. The individual barriers for both the use of RES in district heating as well as the extension of district heating to new consumers are then discussed.

2.3.1 Sector structure

Poland, Germany, Sweden and Finland are the countries with the highest heat sales from district heating, representing nearly half of total district heat sales in all countries considered. District heat is mainly used in the residential sector (45%) as well as the tertiary sector (24%), while only 11% is associated with the industry sector.

Approximately 20% of the final consumption is used in non-specified sectors. Otherwise, district cooling is still not a widespread technology and many countries lack these systems. The highest district cooling sales were registered in Sweden and France in 2012 (see WP1).

The energy supply mix of district heating is very country-specific as the development of the supply system has followed country specific paths. In 2012 fossil fuels accounted for the major share of energy supply for district heating in Eastern European countries (Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia) while a large proportion of biomass was used in Sweden, Austria and Estonia. Solar thermal and heat pumps play only a minor role with regard to this heat production (see WP1).

2.3.2 Access to capital

A fundamental barrier to the uptake of district heating and cooling networks is the need for internal and external financial resources to meet the development and implementation costs. The high capital costs of this technology are associated with the construction of plant, networks and connections (Pöyry Energy Ltd, 2009; IEA-ETSAP, 2013). Compared to conventional natural gas supply the initial costs of district heating networks are higher, leading to longer payback times and weaker cost competitiveness of investments.

2.3.3 Imperfect information

A general lack of knowledge and experience is identified as an obstacle to the diffusion of district heating and cooling systems. This kind of information deficit, in the form of a lack of local expertise and established supply chains, hinder the decision-making of developers and investors in favour of this technology. Besides this, customers and the public sector lack familiarity with district heating and cooling technology (Pöyry Energy Ltd, 2009). This poor awareness about district heating and cooling applications and their benefits inhibits the market penetration of this technology (Frontier Economics Ltd., 2015).

2.3.4 Bounded rationality (attitudes and preferences)

As far as the long-term potential of district heating and cooling systems is concerned, developers and investors worry about the competitiveness of the technology compared to alternative technologies (e.g. heating from de-carbonized electricity). These actors often perceive other technologies to be less risky than district heating and cooling networks (Pöyry Energy Ltd, 2009).

Furthermore, many consumers (e.g. owners, tenants or stakeholders) do not trust district heating and cooling networks due to the high perceived hassle of connecting to existing networks (e.g. connection and utilisation costs) and perceptions of poor quality of supply (e.g. poor performance and service level). Further concerns include the pricing and the transparency of billing (Frontier Economics Ltd., 2015).

2.3.5 Perceived and measured risks (legal, technical and administrative risks)

District heating and cooling networks are natural monopolies leading to a strong dependency between customers and the local developers. The limited competition of these monopolies due to the high fixed costs of the systems may lead to disadvantages for the customers causing reputational damage to this technology and hindering the further diffusion (Frontier Economics Ltd., 2015).

Demand uncertainties can hinder investment in district heating and cooling as these systems are highly sensitive to the number of customers connected to the local network. Energy efficient refurbishment can have an additional negative impact on energy demand which, in the case of district heating, leads to reduced cost effectiveness. Ambitious energy performance standards of buildings, causing a low heat demand, might be a problem for the diffusion of district heating networks. This obstacle requires detailed analysis, and significant effort is needed to evaluate this during the planning process. Otherwise, uncertainties concerning the integration of reliable heat sources can inhibit the uptake of district heating (Frontier Economics Ltd., 2015).

Administrative barriers, with respect to strategic planning and long-term decision-making, are coordination problems caused by the simultaneous development of heat sources, distribution networks and end-user connections as well as a lack of standardisation in contract structures for developers and heat suppliers of district heating and cooling networks. External heat suppliers are influenced by the temperature level of district heating networks. High temperature levels often deny the grid access to low temperature sources (e.g. solar thermal heat, low temperature waste heat). Furthermore, the local mix of the housing stock might play an important role for the cost effectiveness of district heating and cooling networks. A high proportion of flats and apartments increase the heat density in a specific area while decreasing the unit cost for building the network. This compares favourably to locations with a higher proportion of single family houses (Pöyry Energy Ltd, 2009). Construction restrictions, related to a lack of space arising from existing natural gas or water pipes, might affect the extension of district heating and cooling networks.

3 Best practices examples

There were two criteria for selecting the following best practice examples: i) how best practices address different type of barriers for different involved actors with an innovative approach, ii) to formulate policy recommendations for RES H/C and energy efficiency.

These examples need to be understood as a selection of possibilities; they do not intend to address all aspects related to all identified barriers. One criteria chosen was that the lessons learned from these examples should be innovative (either as a technological solution, policy instrument or business model) and another factor should be that they cover different geographical regions in the EU. Success factors are highlighted for the diffusion of RES and efficiency technologies in the sectors studied (chapters 2.1, 2.2 and 2.3).

An overview of the technological scopes and sectors are presented below.

Table 4: Overview of selected best practice examples in different EU member states

Category / Sector	Chapter	Best practice example	Country	Page
Space heating in residential and non-residential buildings	3.1	Heat Pump City: Etten-Leur	Netherlands	23
	3.1.2	In-house biomass boiler in the kindergarten Elhitsa	Bulgaria	24
	3.1.3	Innovative business models for solar thermal systems	Spain	25
	3.1.4	A web tool for energy efficient renovations	Slovakia	25
	3.1.5	Long-term support for heat pumps	Sweden, Switzerland	26
	3.1.6	Industrial-scale energy renovations	Netherlands	27
Process heating in industry and tertiary sector	3.2.1	Integration and utilisation of waste heat in industry	Germany, Austria, Sweden	28
	3.2.2	Biomass heating in a potato processing factory	Netherlands	30
	3.2.3	Brewery as a pioneer in terms of sustainability	Austria	30
	3.2.4	Promotion of market penetration of trigeneration	Countries across Europe	31
	3.2.5	Biomass heating – clean, efficient, fully automated	Austria	31
	3.2.6	Innovative combined concepts for industrial production	Switzerland	33
	3.2.7	Learning Energy Efficiency Networks (LEEN)	Germany, Switzerland, Austria	34
District heating	3.3.1	Successful integration of renewables in district heating	Denmark	35
	3.3.2	LowEx district heating	Finland, Denmark, Germany	36

3.1 Space heating and cooling

3.1.1 Heat Pump City: Etten-Leur

Location: Etten-Leur, the Netherlands

Framework conditions: The municipality Etten-Leur has a high level of ambition with respect to the use of RES. The municipality introduced their first policy on sustainable building and energy savings in 1980 and commenced their first heat pump project in 2002. The long-term policy of Etten-Leur is to achieve the energy-neutral building of new developments by 2020. The municipality was the winner of the EHPA's Heat Pump City of the Year award in 2012.

Project data: The initial demonstration project from 2002 included 20 dwellings and a school which were connected to ground source heat pumps. To date, around 1,000 dwellings have either been constructed or are currently under construction, and most are served with individual closed loop ground source heat pumps. Furthermore, the new city hall, a cultural centre and a school building have been included. The total installed heat pump capacity is between 4 and 5 MW. In 2011 over 25 observation wells were installed to monitor ground and groundwater temperatures, providing insight into the effects on the soil temperature of this very large scale application. For the future, further residential housing and municipal buildings are planned, and all of this development is taking place in the context of a "no gas" and "zero-energy" neighbourhood infrastructure.

Lessons learnt: A number of quite unique challenges occurred during the project, mainly because of its scale and density, as it is one of the largest of its kind in the world. A close coordination of different architects, contractors, installers and heat pump manufacturers was necessary through the several phases of the project. A large part of the system has been in operation now for at least five years and the system has performed well, standing the test of a prolonged cold winter. The success story of Etten-Leur illustrates the benefits of heat pumps in meeting the demanding H/C needs of large urban centres and contributing to a greener and even more energy efficient future.

Source: Witte, H. J. L. et al; The European Heat Pump Association EEIG and Delta Energy & Environment Ltd. (2013)

3.1.2 In-house biomass boiler in the Elhitsa kindergarten

Location: Elhitsa kindergarten in Chepelare, Bulgaria

Framework conditions: The kindergarten building is a brick construction with a total surface area of 1,299 m² and a heated volume of 3,637 m³. The heating was supplied by a heavy-oil-fuelled boiler located in the ground floor of the kindergarten. Experiencing high energy costs, the management of the kindergarten decided to install an energy efficient heating solution.

Project data: A biomass boiler (model Marine CSA 230, D'ALESSANDRO-TERMOMECCANICA), with a capacity of 230 kWth, replaced the old boiler. The biomass boiler and the ancillary equipment are located in a 20-feet metal container with thermal insulation. The boiler is supplied by an automated fuel feeding device and equipped with a fire safety system. To achieve a higher level of energy efficiency a system for automated regulation of the heat supply has been introduced. Furthermore, the water pipe network has been thermally insulated. The wood pellet suppliers are chosen after a public procurement procedure while the duration of the biomass supply contract is for five years. The load capacity of the storage facility is equivalent to 30 operational days of biomass needs. The company implementing the project was ERATO Holding (energy audits, design, supply, installation, start-up and adjustment of the automated hot water boiler) while the financing was provided by the municipality.

Lessons learnt: Municipal buildings have substantial potential for energy savings and for the implementation of energy efficient investments. The public procurement procedure is identified as an economic and ecological contractual form providing benefits to the municipalities. A highly efficient and environmentally-friendly project has been realised by switching the fuel from heavy oil to biomass, improving the overall quality of life. This project is analysed to be profitable with a very good return on investment, as biomass as a fuel guarantees significant energy and cost savings.

Source: ARBIO, Bioenergy4Business (2015)

3.1.3 Innovative business models for solar thermal systems

Location: Solar thermal installation companies in Andalusia, Spain

Framework conditions: Regional incentive programs have been the main drivers for the slight growth of the Spanish solar thermal market during the last three years. Examples of these programs are Prosol or the Programa de Impulso a la Construcción Sostenible (Stimulus Program for Sustainable Building) located in Andalusia. By directly subsidising solar thermal systems in such a way, the Andalusian market contributed nearly 33% to the newly installed capacity in Spain in 2014. Nevertheless, these incentives have become less reliable and the approval of such credit lines is often connected to small budgets, tight deadlines and uncertainty. In order to reduce dependence on subsidies a few installers have started to offer their own innovative financing schemes for solar thermal systems to their customers.

Project data:

The Novasol model: Novasol is one such installer of solar thermal systems from Andalusia. The company provides a financing solution to their customers based on monthly instalments. The amount of each instalment is equal to the monthly energy bill the customer used to pay plus an additional discount. The customer does not have to pay upfront for the system, but it is usually paid back in 6 – 7 years. At this point the customer acquires full ownership of the unit and benefits from the energy savings.

The Sumersol model: Sumersol, another supplier, provides energy by means of an Energy Service Company (ESCO) under their motto "Solar energy starting at no cost". In this way, Sumersol invests in a solar thermal system, retaining ownership and signing an 18-year contract with the customer. The whole installation, operation and maintenance of the system are carried out by Sumersol throughout the entire contract period. While Sumersol receives the amount saved on the customer's energy bill minus 10 – 20% discount, there are no upfront costs for the customer.

Lessons learnt: Innovative and supply-side designed business models are a suitable protection against unreliable government subsidies while providing the installers with a steady income source over the entire contract period. Furthermore, such instruments foster the competitiveness of the companies involved due to increasing sales and rising market shares.

Source: http://www.solarthermalworld.org/print/68757

3.1.4 A web tool for energy efficient building renovations

Location: Slovak Innovation and Energy Agency (SIEA), Slovakia

Framework conditions: A lack of information on how to carry out energy efficient renovations or obtain an Energy Performance Certificate (EPC) caused the Slovak Innovation and Energy Agency to develop a web tool, providing necessary information in a clear, simple and easy to use way to householders, tenants and their representatives.

Project data: To develop the website, SIEA held a workshop with more than 30 experts with expertise in different stages of the renovation process. The information collected was used for the web tool. The website was divided into three sections: (i) general building renovation advice as step-by-step guides on how to carry out refurbishments, (ii) how to select contractors and ensure high quality, (iii) descriptions of energy efficient and renewable energy measures and explanations about the purpose and benefits of EPCs. The web tool was then tested and evaluated by SIEA and external energy experts. The tool was launched in May 2012 and has been promoted through the SIEA website and various articles and press releases. It is expected that the distribution and the impact of the web tool will continue to grow.

Lessons learned: The expert evaluation classified the tool as an interesting and well designed instrument that helps to make different phases of the refurbishment process much easier to understand while providing almost all the necessary information needed for certification procedures in terms of EPCs.

Source: Downy et al. (2012)

3.1.5 Long-term support for heat pumps

Location: Sweden and Switzerland

Framework conditions: As heat pumps have been seen as a suitable instrument to (i) improve energy efficiency in the heating sector, (ii) increase security of energy supply, (iii) reduce environmental pollution, and (iv) mitigate climate change, they have been supported by various countries since the 1970s. Within Europe, Sweden and Switzerland have played an essential role regarding the development and commercialisation of heat pumps. The number of installed heat pumps in Sweden and Switzerland has been growing continuously since the early 1970s. The characteristics of the energy systems have been discussed to be important underlying reasons for the development of heat pumps in these two countries; they both demonstrated a substantial need for electricity for heating in the 1970s and 1980s. Heat pumps have been seen as energy efficiency measures, and initial support of heat pumps in Sweden and Switzerland included multiple policy programs with subsidies, loans, training, information campaigns and testing activities. Over the years more and more incentives, programs and policies have been launched (even after the collapse of the heat pump market during the 1980s).

Project data:

Sweden: Sweden held its first seminar on heat pumps for a broad group of stakeholders (e.g. researchers, authorities, builders and real estate owners) in 1974. The first governmental supported energy research program for heat pumps was launched in 1975. Meanwhile, industrial and public funding promoted different demonstration projects. From 1977 to 1985 investment subsidies and loans were granted for households to promote heat pumps. The Energy Prototype and Demonstration Program were carried out from 1979 to 1985 providing energy guidance, training and dissemination of information by municipalities. Further research programs have been realised since 1990, supported by the government. Later on, a technology procurement program was launched that included investment subsidies and information campaigns for heat pumps. Furthermore, the first quality label (P-label) for ground source heat pumps was introduced during the late 1990s followed by the introduction of energy advisory offices in 1998. Additional government subsidy programs were created promoting the conversion from electric heating systems to other energy sources for residential houses and the Swan eco-label for heat pumps was introduced in 2006. The label was based on criteria development from 1998 with the involvement of multiple stakeholders.

Switzerland: In 1980 Switzerland held its first conference on heat pump technology. Additionally, a heat pump testing facility was established during the 1980s at the University of Lausanne. In 1981/82 initial heat pump field testing began, while a meeting on the simplification of the approval procedure took place in 1983. The Energy 2000 program was launched in 1990 aiming to increase the use of renewable energy and improve energy efficiency; heat pumps were a part of this. The program was complemented by a dedicated heat pump promotion program in 1992. From 1993 to 1995 subsidies were granted for heat pumps in existing buildings while handbooks for better heat pump installations were simultaneously designed. Further field testing was carried out in the 1990s increasing confidence in the technology while some electricity utility companies supported subsidies from 1997 to 1998. The Canton of Zurich introduced standards for new buildings in 1997 including a maximal share of 80% for heat and hot water covered by non-renewable energies. To support energy efficiency and renewable energy in residential buildings, the MINERGIE label was introduced. In 1998 the heat pump quality label DACH was created and introduced in Germany, Austria and Switzerland and the follow-up program of Energy 2000, Swiss Energy, was launched in 2000. A regular three day training program for installers was introduced in 2006.

Lessons learnt: A few important lessons can be learned from the development of the heat pump market in Sweden and Switzerland. Generally, long term and continuous support schemes are needed for energy technology (innovation and) development and deployment. The technology lifecycle, starting with the innovation and ending with widespread diffusion, takes time. Over this time the combination of policy instruments and measures may have to change. While initial policies may support testing of innovative technologies to ensure quality of service, later ones need to develop stable framework conditions to encourage long-term investment and product standardisation for the industry. Furthermore, policies need to address the technology development as well as the market formation and actors. Thus, actor networks might be a crucial factor in this context as they can facilitate feedback and spillover effects. Testing and certification processes are essential to support technical quality and legitimacy; by introducing a system for quality assurance, both countries created reliable products that meet a high level of public acceptance.

Source: Kiss et al. (2012)

3.1.6 Industrial-scale energy renovations

Location: The Netherlands

Framework conditions: Energiesprong is a new concept from the Netherlands that has been developed to define new standards in terms of energetic renovation. The concept was born as a result of a political decision in 2009; the Dutch government had been unable to generate enough incentive to initialise an adequate number of energy renovations and so they decided to transfer the responsibility for this project to an economic-thinking team. Within the project a zero energy standard was proposed for the buildings concerned.

Project data: The Energiesprong partners' consortium includes four construction companies and six housing associations. The consortium aims to renovate 11,000 houses in an industrial scale to a zero energy standard. Furthermore, 21 more housing associations have signed a framework agreement to request the renovation of an additional 100,000 dwellings if the initial renovations of the Energiesprong project meet the proposed costs. In total 111,000 dwellings might be covered by Energiesprong, making the project quite interesting for serial production.

The participating construction companies have already installed production lines for the roof panels, the new building technologies and the facades. The energetically optimised facades will be installed as a whole in front of the existing building walls. The renovation process was designed to be completed within ten days and the energy savings are granted by the construction companies for 30 years. The project includes no subsidies for the renovation process but the rent remains constant. While the landlords receive the same rent as before the renovation, the energy savings refinance the costs of the measures implemented. The pre-financing is provided by the Bank Nederlandse Gemeenten (BNG) which specialises in public and semi-public projects. Up to now 600 houses have been renovated by Energiesprong and an additional 6,000 houses are in a planning phase and should be finished by the end of 2016. This project has received funding from the European Union's Horizon 2020 research and innovation programme.

Lessons learnt: The binding energy saving guarantees to significantly influence the construction companies in providing perfect quality products and services to their customers. This helps define new standards for the entrepreneurial spirit in such companies, with terms such as customer satisfaction becoming more important for these actors.

The project provides an innovative business model concept for financing investments in energy efficiency measures within the residential building sector. The approach also offers great potential for the non-residential sector and could be transferred to other EU member states. Refinancing highly efficient renovation measures through guaranteed energy savings, while the pre-financing is conducted through a financial institution, is a beneficial way to overcome the challenges of split incentives (e.g. landlord-tenant dilemma) in this sector.

Source: http://www.energiesprong.eu

3.2 Process heating and cooling

3.2.1 Integration and utilisation of waste heat in industry

Location: Germany, Austria, Sweden

Framework conditions:

Waste heat is available from large power plants and from industrial processes in the form of exhaust gases that carry high temperatures and energy. Waste heat recovery is an economic measure to increase the efficiency of plants and industrial processes and is a way to reduce primary fuel demand. Waste heat utilisation is possible in different forms and uses at least one of the following possibilities:

- Integration and use of industrial waste heat in existing district heating networks or neighbouring production sites
- Electricity generation by means of Organic Ranking Cycles (ORC)
- Short-term heat storage and system integration

There are examples of these possible uses in Karlsruhe (Germany) and Graz (Austria) with the integration of industrial waste heat from a local refinery or local cement producer into an existing district heating network and other options include absorption cooling using district heating networks and waste heat. Best practices in steel producing plants include the generation of electricity from industrial waste heat by means of ORC plants as demonstrated at Riesa (Germany).

Industrial waste heat integration in district heating (e.g. Karlsruhe): A pre-feasibility research project was initially conducted to assess the economic possibility of using waste heat reaching 40 MW_{th} in both refinery plants. A pre-condition of the project was that the main refinery process would not be affected by the use of waste heat. There was no previous experience with the handling of waste heat so the initial stage was to use of waste heat from a single plant. The use of waste in the district heating network was possible through a 5 km long transport connection together with the design of a heat transfer connection within the heating plant of the city and the refinery (with seven heat sources). In 2010 the integration was possible at both sites with the refinery integration and build up of three heat exchangers at the thermal power plant. In 2011 a recooling system was completed and the heat supply in the north of the city was begun. In 2015 the second operational stage commenced.

EAF Steel producing plant and ORC: At the Italian-German electric arc furnace (EAF) steel factory (Elbe-Stahlwerke Feralpi) in Riesa (Germany) an ORC power system has been installed as a new heat recovery system forby the EAF offgas. The challenge is to keep a constant power production with rapidly changing EAF production conditions (batch system) and therefore changing offgas exhaust. High temperatures (>1600 °C) are required to melt scrap steel and form it into different products. The motivation behind the project was to increase productivity, energy efficiency (reduction of specific energy and CO_2 per unit produced) and environmental performance of the facilities. Feasibility studies for power production began in 2008. The option was designed to use the heat of exhaust gases, classified as waste heat and representing approximately 25% of the total energy input. The power generation concept could be applied in any of the EAF steel factories across Europe (i.e. Italy) where incentives (white certificates) where in place to increase efficiency. However, due to long amortisation times and electricity cost savings, the project was not expanded in Italy. An important decision factor for the project in Germany was the acquisition of a large proportion of the waste heat from a neighbouring tyre manufacturing company. The configuration of the best practice includes both the generation of electricity by means of ORC technology and a partial steam delivery for a neigbouring company. The first demonstration project (2011) was co-financed by the Life Program EU funds, which included a waste heat recovery system and fume treatment with evaporite cooling and saturated steam. The power generation unit fed with saturated steam is an approximately 2.7 MW ORC power plant. It was finalised in December 2013 and commissioned in June 2014. A buffer system guarantees steam delivery under changing EAF batch production for both the local utility company and for electricity production.

Lessons learnt:

Industrial waste heat integration in district heating (e.g. Karlsruhe): The challenge and requirements of the proposed project brought together different company approaches to address the investment decision. The project was successful because of the fair distribution of risks and chances between the refinery and the local utility. A very important aspect is the necessary existence of a common trust in these negotiations. The solution included a pre-financing of the investments by the energy utility company in Karlsruhe. The actual value of heat makes the refinancing structure possible with any risks being distributed among partners. A risk guarantee of some stranded investments from the refinery was agreed and helped to progress the project. The spread of this best practice is possible across Europe as waste heat and efficiency potentials are available. However, the main reasons why many of these projects do not start are the long payback time and lack of information available on the expected profitability of the investment. Lifetime costs should also be included in the investment decisions. The financing of such projects by means of local energy utility companies or contractors definitely increases the acceptance by covering capital costs, while O&M costs should be covered through the savings. For other projects in Europe the contracts should be longer than the return on investment and project partners should get a yearly payment after the solution has been commissioned.

EAF Steel producing plant and ORC: The volume of produced and required steam is relevant when considering power production by means of ORC. In the case-study the economic performance of the solution was improved through the additional purchase of saturated steam from a neighbouring company. The success of guaranteeing the constant supply of heat was at least partially due to having the local utility company as the official deliverer and contractor of the heat supply. This definitely hedges the risks of failing to deliver on clear contracts. Furthermore, the technical solution considered the build-up of a buffering system that stabilises interruptions in production flows of EAF steel. Additionally, changing the cooling system to an evaporite one extends the life of the offgas ducting system (i.e. prevention of acid corrosion and reduced thermal mechanical stress). This reduces O&M costs that increase the economic attractiveness of the solution.

Source: Bause et al. (2015)

3.2.2 Biomass heating in a potato processing factory

Location: Potato processing plant Peka Kroef, Netherlands

Framework conditions: As a GLOBALG.A.P. certified company (certification system for Good Agricultural Practice) Peka Kroef strives to conduct environmental-friendly entrepreneurship. To meet this internal policy, in 2015 Peka Kroef decided to make the production process more environmental-friendly by switching from a natural gas fired boiler to a biomass boiler for steam generation.

Project data: The biomass boiler installed (Attero Biomassa-energiecentrale Odiliapeel) is a steam boiler with a capacity of 8.2 MW and located next to the processing plant. The steam is produced through the combustion of wood shreds from garden waste, municipal green waste and forestry and is used to steam peel and blanch potatoes. The biomass is collected in a radius of 50 km from the biomass boiler. To guarantee the fuel supply for the boiler, a mixture of short and long term contracts with biomass suppliers was adopted. The biomass storage facility is sufficient for five days of demand. In case the biomass boiler is out of order for maintenance reasons an additional back-up steam supply has been installed. The investment and operation of the biomass plant is through the company Attero.

Lessons learnt: A crucial factor for the installation of biomass boilers in industrial applications is to secure long-term contracts for the supply of biomass. Furthermore, it is important that the heat demand profile of the industrial process suits the heat delivery profile of the biomass plant. For example a biomass plant can provide base load while alternative energy sources are needed in the case of peaks in demand. Complex and time-consuming procedures to acquire necessary permits have been identified as the main difficulties in the realisation of the project.

Source: ARBIO

3.2.3 Brewery as a pioneer in terms of sustainability

Location: Brewery Göss located in Leoben, Austria

Framework conditions: The Austrian brewery, Göss, decided to use renewable energies in all of their processes to reduce fossil fuel based CO_2 emissions during the brewery process to zero. As a member of the largest brewery company in Austria, Göss takes a responsible approach towards the community, customers, consumers and employees. They perceive beer to be a natural product consisting of raw materials that depend on the environment remaining intact. Following this philosophy, Göss pays special attention to environmental and climate protection.

Project data: Since October 2015 the Göss brewery has produced beer in an environmental friendly and completely CO_2 neutral way due to multiple initiatives in terms of energy supply. Around 40% of the heat demand of the brewery is covered by the waste heat of a wood processing company located in the neighbourhood. Approximately 90% of the waste heat generated during the brewery process is used for water heating. A new cooking system has been implemented enabling the demand for power and water to be reduced within the brewery process. A solar plant of nearly 1,500 m^2 provides environmental friendly energy to the brewery. In October 2015 a fermentation plant was added to the company, which uses spent grain as a substitute for natural gas. Energy produced by this plant is used for steam generation in the brewery while surplus gas is converted into power. By-products of the fermentation plant can be utilised as high quality fertilizer. Furthermore, Göss is proud to use only raw materials that are originally from Austria. In the recent past the brewery has received different awards such as the Energy Globe Austria 2016, the IEA SHC Solar Award 2016 and the EU Sustainable Energy Award 2016.

Lessons learnt: This project has proven the compatibility of renewable, as well as environmental friendly, energy supply with the simultaneous production of high quality products. The unique characteristics of the Göss example should enable it to become a lighthouse project for the whole industrial sector in terms of sustainability engagement.

Source: Straka and Ferk (2016)

3.2.4 Promotion of market penetration of trigeneration

Location: countries across Europe

Framework conditions: With total system efficiencies of 30% to 50% greater than "*cogeneration*," trigeneration is the simultaneous production of power/electricity, hot water and/or steam, and chilled water derived from one fuel. Also known as CCHP (cold combined heat and power), it is similar to CHP, but cooling energy is also generated for space temperature conditioning, refrigeration processes in industry or for food/drink storage application. CCHP systems can vary over a wide power range from 1 kW to 500 MW. Rated power of decentralised CCHP systems (trigeneration) ranges between less than 1 kW in residential facilities to more than 10 MW in public buildings, industry, hotels, etc.

In warm climates trigeneration or micro-trigeneration provides a more consistent requirement for heat, thus increasing the system utilisation time. Therefore trigeneration offers an interesting avenue for efficiently delivering power, heating and cooling to residential buildings, particularly in warmer climates.

Project data:

Tesco Colney Hatch, UK: The installed trigeneration system generates 800 kW of green electricity using a sustainable bio-fuel source for a large retailer in the UK. The system produces chilled water together with power air conditioning and refrigeration systems from waste heat. This is the first time an adsorption chiller has been used in the store as a greener alternative to the absorption chillers.

TRiMa, Germany: This project serves to promote climate protection projects in municipalities and holds considerable potential for achieving cost efficient and broadly effective emission reductions. An essential aim of the study was also the analysis of the economic policy framework for the implementation of cogeneration plants including existing funding policy.

Hypo Alpe Adria - Trigeneration plant: This trigeneration plant is located in Tavagnacco (UD) in the north-eastern part of Italy. The “Hypo Alpe Adria” plant includes a CHP motor engine with 1 MW of electrical and about 1.3 MW of heat capacity.

In addition, two heat boilers with 1.2 and 2.0 MW of heat capacity have been installed. The cooling plant includes two chillers with 1 MW of cooling capacity and an absorption chiller with 0.5 MW of cooling capacity.

Lessons learnt:

For investors, the risk lies in the uncertain trend in energy prices. Appropriate financing models can assist in the acquisition of the plant. The high efficiency of CHP, and the extraordinary level of plant utilisation, usually generate a very short payback period of perhaps four to five years. Introducing an absorption chiller into a cogeneration system means that the site is able to increase the operational hours of the plant with an increased utilisation of heat, particularly in summer periods. The electricity-intensive space cooling can also be covered with waste heat. Thereby the energy costs are significantly reduced and the carbon-dioxide emissions can be substantially lowered.

The market penetration of CHP plants in Europe is not very high. Information campaigns need to be carried out in order to convey the numerous technological and economic benefits of this technology to a wider audience.

Source: Stojkov et al. (2011), Borg (2012)

http://www.cogeneurope.eu/new-and-emerging-chp_273.html

http://www.trima-kwkk.de

3.2.5 Biomass heating – clean, efficient, fully automated

Location: Upper Austria

Framework conditions: Due to climate change (rising temperatures, environmental disaster) the people in Upper Austria have started to invest in numerous biomass heating systems. Other reasons for the motivation for 100% renewable targets were the loss of purchasing power, the negative impact of the competitiveness of companies in Upper Austria and social problems (such as energy poverty). This initiative was based equally on the creation of new jobs and improved prospects for the farming and forestry sector.

Project data: Biomass heating plays a huge role in Upper Austria. The region showcases a successful shift from fossil fuel based heat supply to renewable heat which has taken place due to a comprehensive sustainable energy strategy.

Biomass (wood chips) is produced within the region. A total biomass potential of 16 GWh (11 GWh of forest biomass) is attributed to Ansfelden. Since 1995 50,000 automatic individual biomass systems (26,000 pellet systems and 24,000 wood chip systems) have been installed. The range of the installed power is from less than 100 kW to more than 1 MW. The total capacity of these biomass heating systems amounts to about 2,600 MW. Furthermore 345 biomass district heating plants are in operation today.

The biomass heating strategy in Upper Austria stimulated the biomass demand through regulatory measures such as emission and efficiency standards, a renewable heating mandate and minimum requirements for H/C. At the same time there was promotional action through different policy packages (investment grant programs, contracting program, regional R&D program and pilot projects). The whole process was accompanied by a bundle of various informative measures (local energy action plans, training programs, publications, campaigns and competitions, energy advice, sustainable energy business networks).

Lessons learnt: The economic impact of the biomass heating is evident in:

- a total of 4,500 personnel employed in biomass heating,
- annual investments in biomass heating systems of 110 million Euro,
- annual revenue of biomass boilers and the stove industry (production, sales, installation) in Upper Austria of 530 million Euro,
- annual sales of biomass heating fuels of 190 million Euro and
- a share of biomass heating systems in private homes of about 35%.

The interviewees see further potential of biomass for private owners as well as larger installations in Upper Austria. However, in areas where a gas network already exists and gas prices are currently low, people are not so eager to change their energy source. For an individual installation, the investment costs associated with changing the heating systems in the building are an additional barrier. Therefore biomass use needs to be promoted, for example through subsidies, improvements of laws and regulations, awareness raising activities and information campaign measures, in order to achieve a greater effect.

Source: Amt der Oberösterreichischen Landesregierung, Bürger et al. (2011)

3.2.6 Innovative combined concepts for industrial production

Location: Zehnder Group AG in Gränichen, Switzerland

Framework conditions: In the framework of the "Green Alliance for Sustainable Production" the two companies Ritter Solar XL and Eisenmann have agreed to foster the diffusion of solar thermal systems in industrial processes. As a provider of large-scale solar thermal systems, Ritter Solar XL is responsible for the supply of process heat that is utilised by a painting line produced by Eisenmann. The innovative cooperation project was installed on the warehouse rooftop of the Zehnder Group AG in Switzerland. The Zehnder Group AG is a Swiss room air-conditioning specialist that aims to define new environmental and energy efficient standards for its products as well as for their production lines.

Project data: The "Green Alliance for Sustainable Production" has installed 80 vacuum tube collectors on the rooftop of the Swiss room air-conditioner company building. The whole collector field accounts for nearly 400 m² and consists of 16 modules each including five collectors. The collectors have been prefabricated to decrease the installation time to a minimum of one day. The solar thermal system is directly connected to the heating system of the Zehnder Group AG and predominantly supplies the painting line produced by Eisenmann. Approximately 30% of the energy demand is covered by the solar system. A share of 100% is feasible for ideal conditions during the summer. The solar thermal system generates a saving potential of 200 MWh per year which is equal to a reduction of 20,000 litres of heating oil. The solar thermal system is subsidised by the Swiss federal office for energy with a payback time of only four years, making the whole project profitable after a few years. The commissioning of the solar system took place in the July of 2012.

Lessons learnt: The cooperation project of the "Green Alliance for Sustainable Production" is, so far, only a pilot project. Ritter Solar XL has identified huge potential for the utilisation of solar thermal heat in the industrial sector although the awareness of these systems is quite low among relevant decision-makers. As energy costs usually only account for a small proportion of total production costs in the industrial sector, and prices for fossil-based fuels are currently low, investments in RES technologies are often ignored. Introducing minimal shares of RES for heat and energy supply in the industrial sector might be a useful tool to externally foster the diffusion of these technologies.

Source: Willige (2014)

http://ritter-xl-solar.com/anwendungen/prozesswaerme/zehnder-group-switzerland

3.2.7 Learning Energy Efficiency Networks (LEEN)

Location: Different cities in Germany, Switzerland and Austria. Newly introduced in Belgium, The Netherlands, Sweden and also in Eastern Europe.

Framework conditions: In early December 2014, the initative “Energy Efficiency Networks” was instigated as an immediate measure from the National Energy Efficiency Action Plan (NAPE). The German federal government, and 22 industry and trade associations, signed an agreement on the introduction of energy efficiency networks with the objective of creating a total of 500 such networks by 2020. The stated purpose of these networks is based on the results of the project "30 Pilot Networks", in which the concept of learning Energy Efficiency Networks (LEEN networks) was developed through experience with nearly 400 participating industrial companies and buildings.

The energy efficiency progress has more than doubled, by company, compared to the natural growth in German industry, reaching an average of 2.1% per year per participating company. This is equal to an average energy cost reduction per company of about 180,000 euros per year within four years. Based on these results the government expects that the initiation and implementation of 500 additional networks will achieve savings of up to 75 PJ primary energy or 5 million tons GHG emissions by 2020.

Project data: An energy efficiency network communicates the participation of local businesses, companies and building owners in a region or industry with a view to identifying and investing in cost-efficient energy efficiency measures. The objective of these investments is to reduce energy costs and CO_2 emissions on a voluntary basis. The advantage of the network approach is to produce this information in a time and cost efficient manner for the network participants. The information gathered is also moderated and scientifically proven and provides a structured way to manage relevant confidential datasets of companies. The learning environment of the networks has the effect of providing impulses to the different actors when evaluating and analysing potential energy efficiency measures.

Participants exchange experiences, learn from each other and set a common network goal for saving energy and reducing CO_2 emissions. The network methodology inspires the implementation of organisational and investment measures from existing energy audits and energy management practices. Energy efficiency networks are designed to run for at least three to four years. During this time there are continuous experience exchanges among the participants and the annual monitoring is an essential guarantee of success.

The focus of the network activities is on efficiency improvements in the cross-cutting technologies (e.g. electric drives, ventilation, pumps, lighting, heat recovery and provision of compressed air/heat/steam/cold) as well as organisational measures, and promotional and possible funding opportunities. Trained and certified moderators and energy technical consultants accompany companies and work with proven and adequate work tools that deliver directly usable results. This guarantees the quality of the process during the operation.

Lessons learnt: There are many lessons learned from the LEEN approach in Germany and other European countries and several barriers are addressed with this very innovative network approach. A number of actors profit from the networks in which pertinent information related to RES H/C technologies, financing models, profitability and economic calculations relevant for decision makers can be exchanged. Such actors include industrial companies with substantial energy consumption facing investment decisions for RES H/C and energy efficiency. The interaction in a learning environment allows participant companies to reduce transaction costs for gathering the information, and produce reports on the potential investments. They also learn from other participants how such cases have been sold to their boards of directors. The social dynamic of the exchange demonstrates that companies invest more in RES H/C and energy efficiency measures when they are included in networks. This is indicated by the results of the demonstration project in Germany with more than 400 companies; the increase in energy efficiency and RES H/C investments in these companies is twice as fast as the average in German industry. The networks approach also encourages the training and certification of moderators and energy technical consultants on the aspects of LEEN. Having the energy consultant involved in the investment calculations and technical potentials increases the trust and reliability of the LEEN approach while allowing participating companies to materialise their savings. Specialist speakers report on the current state of technology, giving further impulse to energy managers. Working with the network carrier (chambers of commerce or industrial association) a multiplication effect is experienced, compared to other industries in the region. The lessons learned in this respect are that there is a need to train different actors across Europe to implement the LEEN method across different industrial producers and building owners. The tools for the economic assessment and monitoring tools helped to prioritise actions and to verify, in a scientifically correct manner, the savings achieved.

Further lessons from the LEEN approach indicate that the acquisition of companies remains a challenge for initiators in the local regions. The standards of the networks have been modified, adjusting the contracts to run the networks for two years and reducing the participating companies to 5 instead of 10. This flexibility reduces the barrier for rejecting the participation in them. Political and local level support is needed, particularly in the form of funding for participating.

Sources: https://www.energie-effizienz-netzwerke.de/een-de/index.php

3.3 District heating and cooling

3.3.1 Successful integration of renewables in district heating

Location: Marstal is a town in southern Denmark

Framework conditions: District heating in Denmark began without “appropriate framework conditions” or national political objectives and developed mainly through local and private initiatives. This changed during the 1970s when the oil crises prompted the introduction of an energy policy in Denmark. As a result the first Heat Supply Act was introduced in 1979 setting up rules and a framework for heat planning. From then on municipalities had to map the existing heat demand, the heating methods applied and energy usage. Furthermore, municipalities were required to estimate future heat demand and heating options. The aggregated data was collected and processed by the counties. Planning in the 1980s generated a more environmental friendly supply while investments in the domestic natural gas infrastructure and combined heat and power (CHP) plants became key priorities. Based on an agreement between the State and the public utility companies in 1986, small CHP-plants were installed to decentralise production capacity and district heating was introduced in smaller cities. A ban against electrical heating was applied to new buildings in 1988 and extended for existing buildings with water based heating systems in 1994. To simplify and decentralise the decision-making process for the installation of new district heating plants, the planning hierarchy from the 1980s, consisting of three levels - State, county and municipality, was reworked in 1990. The municipalities became solely responsible for heat planning except for some of the overall regulations laid by the Minister. Key points for the development of district heating are a guarantee of loans from the municipality to reduce capital costs, and strategic energy planning where heat planning is coordinated as part of other municipal planning. The goal of the national climate policy is to reach 100% fossil fuel free electricity and heat production by 2035.

Project data: Around 1,500 members of the Marstal district heating system receive 55% of their energy from solar production (15,000 m² and 18,300 m² solar collectors) and 45% of their energy from locally produced biomass (4 MW biomass boiler). Furthermore, the district heating system in Marstal includes a heat pump supplying the energy storage (10,000 m³ and 75,000 m³ pit heat store) and a turbine (Organic Rankine Cycle) using the energy from the flue gas produced in the biomass boiler to generate electricity. The goal of the project is to demonstrate a large-scale innovative, cost-effective and technically 100% sustainable renewable energy system. The long-term goal is to establish 20 similar facilities in 10 countries within Europe. These countries are Austria, Czech Republic, Denmark, France, Germany, Italy, Poland, Spain, Sweden and England. The project is co-funded by the European Union through the 7th Framework Programme.

Lessons learnt: Planning of district heating should be undertaken in coordination with other energy planning, in particular electricity. The large share of wind power in the Danish energy system can only be utilised effectively if electricity is used in heat pumps which also use waste heat. District heating enables the use of fluctuating renewable energy sources. Local acceptance and knowledge of local resources and conditions are crucial to the development of district heating. Framework conditions such as legal issues, taxes etc. are also important. Non-profit structures can protect consumers from exploitation of monopolies and for this reason it is appropriate to involve companies owned and run by local consumers or communities as well as by the local authority.

Source: Miedaner et al. (2015)

3.3.2 LowEx district heating

Location: Different LowEx district heating concepts in Finland, Denmark and Germany

Framework conditions: In terms of future energy supply in the building sector, district heating provides significant possibilities regarding a more efficient utilisation of energy resources and a better integration of RES and surplus heat into the heating sector. In this context, low temperature district heating plays a key role, especially in connection with nearly zero energy buildings. As these buildings demand low supply temperatures for space heating and hot water preparation they enable transportation losses in the distribution networks to be reduced and the overall efficiency in district heating to increase. The LowEx approach follows this concept by matching the quality of energy supply and demand to decrease energy losses and irreversible dissipation while optimising the usage of high-value energy sources.

Project data: The IEA DHC Annex TS1 provides a framework promoting the discussion of future heating networks with international experts. It aims to work out a development direction for the diffusion of low temperature district heating systems in the future. The Annex TS1 follows the approach of a task-shared Annex. Thus, no individual research projects will be started within the Annex. Nevertheless, the Annex TS1 facilitates the exchange of research results derived from international initiatives and national research projects. Furthermore, it allows information concerning low temperature district heating to be gathered, compiled and presented while providing solutions for expanding and rebuilding existing district heating networks. The whole project is based on several selected case studies. Some of these case studies are briefly described below:

- **Hyvinkää (FI):** The project in Hyvinkää aims to estimate the long-term performance of low temperature district heating for nearly zero energy houses. During the project, a life-cycle analysis is carried out at the community level. Furthermore, boundary conditions and opportunities for district heating are to be explored by the project while taking into account the Finnish climate. As a result new business and service models for district heating in single family houses should be derived.
- **Lystrup (DK):** The main goal of the project is the implementation of a low temperature district heating network that supplies consumers at a temperature level of 50 °C. Furthermore, the buildings in the network need to be connected in a way that makes reheating redundant on the consumer site as well as on the district heating site. The district heating supply water is supplied directly into the heating systems of the buildings to keep the supply temperature low. Thus, no heat exchangers are needed.
- **Ludwigsburg (GER):** The project in the city quarter of Ludwigsburg aims to create a low temperature district heating sub-grid as an extension of the main district heating network located in the neighbouring quarter. Additionally, thermal solar energy needs to be integrated into the new grid. The low temperature network utilises a temperature level of 40 °C which is supplied by the return temperature of the existing network. The focus of the project is on the demand side management, network structure, chosen supply concepts and storage management.

Lessons learnt: The reduction of the temperature level in district heating networks offers a suitable and feasible approach to include RES (e.g. solar thermal, geothermal or waste heat) in district heating. Furthermore, heat losses from the network can be reduced (e.g. overall heat loss in Lystrup was reduced to a quarter) and plastic pipes can be used for the distribution network instead of metal pipes. The combination of LowEx district heating and nearly zero energy buildings provides beneficial synergy effects in terms of renewable energy diffusion and environmental protection. LowEx district heating offers the possibility of overcoming existing barriers that are usually connected to district heating: it (i) defines new standards in terms of network connection for new and existing buildings, (ii) realises essential savings by substituting expensive infrastructure materials, and (iii) enables access to multiple low temperature energy sources.

Source: Schmidt et al. (2014)

4 Policy recommendations to overcome barriers

The analysis laid down in chapter 2 of this work package revealed several relevant barriers that hinder a strong diffusion of efficient and RES based H/C technologies. Implementing policies to overcome these barriers can accelerate the take-up of RES-H/C.

Some generic principles can be recommended when designing policies for different cases, fields and stakeholder groups:

- **Systemic approach:** A systemic approach should be adopted to consider the entire innovation system.
- **Tailor to national context:** Policy instruments have to be tailored to the national context to increase their efficiency and acceptance. These include legal framework conditions, current policy implementation, climate, technical aspects (structure and state of the building stock and its H/C provision), socio-economic demand-side structure (e.g. ownership of buildings, SMEs and large companies), and supply-side structure (technology producers, energy utilities,) etc.
- **Tailor to target groups and specific barriers:** Policy bundles need to be properly designed to address the often heterogeneous target groups as well as existing technology specific barriers.
- **Stakeholder involvement:** When it comes to the implementation of designed policies the commitment of all relevant stakeholders is essential; the involvement of all market actors significantly affects the effectiveness of policies and regulations.
- **Monitor, evaluate and adjust:** The proper monitoring and evaluation of policy instruments is crucial for the success of proposed bundles. Detailed monitoring and evaluation offer the possibility of improving implemented policy instruments and react to unexpected effects which might occur through these instruments.

Based on the barriers analysis for different user groups, an initial set of recommendations is outlined below, differentiated between space H/C in buildings (section 4.1), process H/C in industry and tertiary sectors (section 4.2) and district heating and cooling (section 4.3). The outreach of certain recommendations is EU wide but some of them also go beyond EU competences towards national, local and regional authorities.

4.1 Space heating and cooling

An effective target-oriented policy environment needs to be proposed for the buildings sector, including a proper implementation and monitoring of recommended policy packages (Kranzl et al., 2014).

- The role of long-term objectives for the building sector is very important in order to achieve a higher penetration of both RES-H/C and energy efficiency renovations and technologies. Measures dealing with the improvement of the thermal performance of buildings diffuse slowly due to the inertia of the building stock. Short-term measures play an important role in the long-term compliance with objectives. For this purpose, quantitative savings targets for CO_2 emissions or primary and final energy demand are necessary to specify the level of targeted policies.
- More ambitious renovation standards for existing buildings, including provisions for substitution of older equipment with RES-H/C technologies, has to

be addressed in future policy changes. The introduction of "Nearly Zero Energy buildings" by the Energy Performance of Buildings Directive (EPBD), as a uniform term for the energy efficiency standard of new buildings, was an important step. However, new buildings will still account for a minor fraction of the H/C demand of the building sector in 2050. Future European efficiency regulations should therefore target existing buildings, establishing similar uniform standards for renovations.

- With regard to finance, existing instruments such as structural and energy efficiency funds should focus on ambitious efficiency measures and RES-H/C in buildings. Existing subsidy schemes of fossil fuel based heating systems, leading to a distortion of competitiveness for RES-H/C systems, need to be abolished.
- Stop-and-go financing of RES-H/C support schemes, which are mainly based on the availability of the public budget, can be prevented by the introduction of state-budget independent financing schemes similar to energy saving obligation mechanisms
- It is increasingly important to control the possible increased demand for cooling and air-conditioning through renovations as well as through new construction. This aspect is more important and has a greater weighting than the improvement of regulations objectives and support conditions for these technologies.

The structure of barriers for residential and non-residential buildings is very specific for different target groups. The relevant target groups at the decision-making level include owner-occupiers of residential buildings, landlords and building owner associations and societies as well as the public sector. Other actors associated with the construction industry, such as architects, engineers, planners, craftsmen and construction companies, also play an important role. The following target oriented policies are recommended, grouped by type of barrier:

Access to capital:

- An introduction of state-budget independent financing mechanisms would establish long-term investment planning security, not only for building owners, but also for craftsmen who can use such a mechanism as a marketing tool.
- Income tax incentives at member state level for landlords and owner-occupiers are a useful complementary support instrument in order to reach additional stakeholder groups who are reluctant to raise credits and prefer to invest by realising tax savings. In order to guarantee an effective allocation of public funds, such an instrument should focus on deep renovation measures and RES-H/C technologies.
- A certain share of the energy and environmental taxes could be used for support schemes (e.g. Energy Efficiency Fund, buildings renovation fund) for the technologies concerned in buildings. Before introducing such taxes, an additional focus should be given to necessary measures avoiding lock-in effects. These might concern specific non-preferred technologies or social imbalances, especially for low-income households.
- Debt guarantees for renovation, and RES H/C investments and credits, supported by the European Energy Efficiency Funds, structural funds or other funds can be channelled through national banks as well as public administrations.

Imperfect information:

- Building certificates are an important information instrument for owner-occupiers, landlords and tenants. However, the comparability of the energy performance of buildings is only partially due to different methods of calculations between and within member states. A harmonisation of building certificates based on energy needs calculations, considering building physics parameters, would significantly improve the effect of this instrument.
- So far, the display of building certificates is only required for large and public buildings resulting in a limited reach. A mandatory display of building certificates for any real estate advertisement, including those at web-based property engines, would enable building certificates to be established as part of property assessment.
- Establishing local professional education centres for energy efficient renovations and RES-H/C technologies, as well as adequate up-to-date training are crucial requirements since craftsmen act not only as the installer but also as the retailer of technologies and information providers for building owners.
- Quality surveys regarding local experts (e.g. installers, planners, architects, etc.) and tailored customer relation activities (e.g. periodic mailing, local events) could be important information tools for different target groups in this sector.
- Establishing and supporting consultancy tools (e.g. programmes and online platforms promoting best practice examples and benefits) and models for the development of renovation roadmaps for individual buildings would provide a cost-optimal step-by-step implementation plan for major renovations independent of the individual financial situation of building owners. This would prevent the lock-in effects of single measures.
- An introduction of mandatory energy labels for existing heating systems which might be issued by chimney sweeps.
- Ownership communities can be addressed through the promotion and diffusion of sustainable housing administration, including a professional and standardised approach, in order to appropriately evaluate RES-H/C and efficiency investments.
- Public authorities within the EU member states should adopt their own obligatory commitments, in accordance with the objectives of the Energy Efficiency Directive (EED), but also including and highlighting commitments for RES-H/C investments within their building renovation activities. These activities can also be coupled to EU guidelines for sustainable public procurement.
- The commitment should identify a year, such as 2018, as a starting point for implementing the lowest energy building standards for modernisation rates and increasing the quality and ambition of energy renovations. This would aim to enhance RES-H/C penetration (this has to be accompanied by sufficient budgetary allocations for the purpose).

Bounded rationality:

- Improvement of the risk insurance for selected RES-H/C technologies and efficiency renovations in combination with proposed changes in taxes in member states. Changes in taxes might be a motivation to move beyond bounded rationality.
- The promotion of alternative cost-effectiveness measures (e.g. present value, internal rate of return), rather than basing investment decision-making on payback times and establishing green image awards, might be impulses for a higher penetration of RES H/C.

Split incentives:

- Revision and improvements in tenancy laws and housing policy at member state levels in general, but particularly with respect to privileged energetic modernisation and the tolerance of these obligations by building owners or users. Furthermore, improved cost sharing models (e.g. allowing throughput of only 50% of energy costs or add-on costs for RES H/C systems to the tenant) for modernisations with the users and owners are needed. The inclusion of the energy efficiency and RES-H/C aspects should be analysed in the form of detailed and conceptual studies (e.g. promote energy service/performance contract schemes).

Perceived and measured risks:

- Biased prices and market distortions could be removed by fading out subsidies and other incentives for fossil based H/C systems. In this context, the justification for new subsidies for fossil fuel technologies, in the case of the interpretation of energy efficiency legislation (e.g. Art. 7 EED), has to be avoided.
- To overcome legal restrictions and administrative burdens concerning RES H/C and to foster its diffusion, local authorities could incorporate incentives into zoning laws (e.g. allowing higher utilisation of space if advanced saving targets are met). Alternatively they could revise and improve approval procedures.

4.2 Process heating and cooling

The structure of barriers along the production cycle and the perception of the different actors of an innovation system (at national and EU levels) must be recognised as a whole. With this in mind, efficient policy measures can be formulated to increase the successful implementation of RES-H/C and energy efficiency in industrial systems.

Policies should not only take into account existing barriers and market deficits for RES H/C and efficiency, but more attention should be paid to unused support factors for both RES H/C and energy efficiency deployment. It is primarily socio-psychological and technical factors which influence investment decisions and can produce significant transformation.

Market deficits are mostly addressed and corrected by national governments and the EU, but this can also take place at local level (federal states/provinces and cities/municipalities levels). A large number of barriers can also be reduced or tackled by measures implemented by the economy and individual companies (including technology producers, banks, insurance companies, advanced education institutions, industrial associations and chambers of commerce). Furthermore, corporate innovations (such as contracting models, consultancy, energy efficiency networks, working committees and spin-offs) contribute to reduce barriers within the innovation system.

The use of RES for H/C in high temperature processes (>500°C), in specific furnaces, still requires substantial R&D activities. While it is theoretically possible to use biomass in steel and glass production – at least to a certain extent– this is not yet technically proven by demonstration projects. Such projects could substantially improve the confidence in new investments and reduce perceived risks.

For companies included in the EU emissions trading scheme, the certificate price (or its opportunity costs) directly improve the cost-effectiveness of RES solutions compared to fossil fuel heat supply. Such an incentive to switch to RES is still lacking for processes and sub-sectors outside the EU ETS. Energy taxes based on CO_2 intensity of energy carriers could be a possible mechanism to fill this gap.

Additionally, the following strategies could be useful to overcome existing barriers:

Access to capital:

- The financial options for SMEs depend on their credit-worthiness as assessed by their local banks. Banks often lack the ability to properly assess H/C investments due to their lack of technical know-how. Furthermore, banks lack innovative RES and efficient H/C credit programs due to low investment sums which are, to a lesser extent, less interesting for SMEs. The recommendation is to evaluate the creation of new RES H/C and energy efficiency credit lines.
- The EU has several financial mechanisms for Energy Efficiency (e.g. EEEF, EEFIG, Structural funds, PF4EE, project development assistance and horizon 2020) with means to channel financial resources through different institutions down to the investors in each country. Considering RES-H/C as an energy efficient investment can contribute to the expansion of this area. The combination of the EEEF with other innovative financial approaches, such as crowd-funding, could enhance a wider acceptance of less attractive credit-worthiness.

Imperfect information:

- SMEs have limited personal capacity and often limited internal know-how. They are dependent on advice from consultant engineers, producers and installation companies. Energy audits should also provide recommendations with regard to the use of RES.
- It would be advisable to survey the quality of engineering consultants in different EU member states providing the advice, design and installation of RES–H/C technologies in industry. There is an apparent need for action with respect to improving building capacity from professional organisations and continuing education institutions for industrial consultants. This is also true for other sectors.
- A similar situation is experienced by planners, architects, engineers and companies responsible for installation and maintenance in industry. The technological advancement of RES-H/C technologies has improved considerably and quickly during the last two decades (e.g. heat pumps, small CHP, waste heat re-use, measuring and ICT equipments). These fast developments are not sufficiently addressed by the relevant education institutions. Implementing information campaigns, highlighting the feasibility and reliability of RES H/C as well as initialising information platforms (e.g. local energy efficiency networks), could be helpful measures in this context.
- The current curricula and professional training programs should be complemented by investment calculations for RES-H/C technologies as well as by efficiency measures. In particular, programs and online platforms addressing SMEs should be further improved and supported in order to improve the time invested by very busy collaborators in SMEs. Further demonstration projects (e.g. best practice examples) by the EU, involving several member states, can enhance the development and put in practice the targeted tools for RES-H/C.
- Co-benefits of RES-H/C and energy efficiency technologies should be highlighted in public communication, including for example health and safety benefits as well as economic profitability. More independent advisory associations and consultancies should also be implemented.

Bounded rationality:

- Investment decisions related to energy efficiency are often evaluated solely on their payback time and short payback times are required (often below 2 or 3 years). Payback time is not an adequate measure of cost-effectiveness and rules out many cost-effective measures. Net present value or IRR are more suitable. The promotion of these alternative rating measures could be a beneficial impulse to the diffusion of RES H/C in this sector.

Perceived and measured risks:

- Proper market conditions should be created by removing subsidies and additional incentives for fossil based H/C technologies even if providing a specific level of efficiency.
- The specific technical barriers have to be addressed and reduced. For instance, for absorption cooling plants or organic ranking cycle plants, heat pumps or waste heat use within two production sites, as well as the use of renewable energy for H/C, have to be considered. All these technologies display high potential for application in the medium sized industries in Europe, and with cost-digression patterns this potential can increase further.

4.3 District heating and cooling

District heating could play a major role in a sustainable H/C energy supply with high shares of RES in Europe, especially in urban areas. Therefore, district heating networks need to consider the integration of RES. Generally, district heating and cooling projects face significant risks and barriers during their development, implementation and operation phase. These risks need either to be borne by local or regional authorities alone or also allocated to private investors.

Access to capital:

- Proper support and incentive schemes should be developed and evaluated while administrative efforts on approval and reporting processes should be reduced simultaneously in order to simplify the realisation of such projects. Support schemes might also promote pioneer projects to overcome technological challenges and obstacles of innovative, highly integrated, highly efficient and renewable based district heating and cooling applications. Support schemes could include financial incentives such as subsidies at national level, innovative funding or debt guarantee mechanisms.

Imperfect information:

- Information and social media campaigns concerning RES supply for district heating need to be developed, along with intensifying qualification and training for technology experts (e.g. craftsmen, engineers, planners, installers, architects). Knowledge surrounding the possibilities of RES technologies is often lacking among decision-makers, because in many countries RES (beyond biomass boilers and CHP) is still a niche in district heating. These campaigns should also provide platforms promoting the exchange of experiences (e.g. best practice examples and connected benefits). The EU Horizon 2020 program could be a suitable platform as shown by successful existing projects such as, for example, SDH[3].

- Knowledge transfer across member states is especially crucial for district heating as it is very unevenly distributed across the countries with some countries hardly using any district heating. These include Spain, Greece and Portugal. Knowledge transfer needs to take place in various fields such as policy regulation, feasibility studies, and planning of DH systems (Connolly et al., 2015).
- Developing management guidelines on planning and business models for cities might be a beneficial supporting instrument to raise the awareness of existing possibilities. It is particularly planners in cities who are often not aware of the various RES options and have less expertise/knowledge than local supply companies.

Bounded rationality:

- The acceptance by local citizens needs to be raised by improving awareness, and highlighting the advantages of district heating and cooling. Adequate customer relations activities, such as local information events, might be suitable tools to overcome this barrier.

Perceived and measured risks:

- The wider diffusion of RES in district heating and cooling networks is strongly influenced by the competing fossil fuel prices (e.g. natural gas, oil) which are currently low. Increasing the relative cost-effectiveness of RES projects can be done via a quota system as analysed in WP3, but also through taxes on fossil fuels. Denmark is an example of how taxes on fossil fuels can support RES in district heating.
- Due to the long-lasting capital stock, improved long-term investment security via, for example, energy and emission targets could support RES investments.
- Local authorities are identified as crucial actors, particularly in the H/C sector, as they are responsible for regulations, spatial planning and planning applications. Their influence on other actors’ choices in terms of designing, building and renovating is accordingly strong. Therefore, a better coordination with and closer involvement of local and regional authorities should be a major element of EU policies.
- Industrial excess heat is still often not used in district heating networks in Europe. Mitigating risk, clarifying legal issues and disseminating best practice examples could be a useful support to improve this.

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[3] http://solar-district-heating.eu/

5 Conclusion

The analysis conducted in this report revealed a broad variety of barriers and obstacles inhibiting the diffusion of energy efficient and RES H/C technologies in the different sectors observed. These included the residential and non-residential building sector, the industrial processes and tertiary sectors as well as the district heating and cooling sector.

Some barriers have been identified to be unique and only relevant for a specific sector or target group while other obstacles are observed across all sectors. Best practice examples followed the analysis with the aim of extracting lessons learned and successful policies, business models and projects to address and overcome different barriers and obstacles. The objective was to show exemplary best practices across different EU member states. The following section highlights the main findings of WP5.

In the building sector (see Table 5 below) two major barriers have been identified as hindering the deployment of energy efficient and RES H/C in European residential and non-residential buildings. Firstly, the high initial costs of these technologies are identified as an important barrier; compared to conventional fossil fuel solutions RES H/C systems are considerably more expensive. Larger investments negatively affect the attractiveness of RES H/C for potential investors in the building sector. The removal of all subsidies and other incentives for fossil based H/C systems is therefore recommended, thus correcting market distortions and price signals from fossil fuel technologies.

Secondly, building owners, tenants and, to a certain degree, energy consultants show a lack of awareness of energy efficient and RES H/C technologies. A dearth of information and detailed know-how on the possibilities and benefits (e.g. 3.1, 3.1.2) of RES H/C systems makes such technologies appear less favourable when investment decisions are taken. Energy policies should therefore highlight the importance of information campaigns addressing both the demand as well as the supply of these systems (e.g. 3.1.4). On the demand side, building certificates, energy labels or customer relation activities initialised by local experts are suitable tools to achieve a greater awareness of RES H/C technologies while the promotion of professional education centres and up-to-date training should be addressed on the supply side (e.g. 3.1.5). The recommendation is to improve the systems in place at EU level.

Regarding the complex structure of building ownership in the residential and non-residential building sectors, different barriers are important for various stakeholder groups. It is recommended that budget constraints for single-family home owners should be handled by new financial instruments (see 3.1.3) while the collective decision-making based on shared property in multi-family homes needs other incentives and additional information to encourage investment in RES H/C. Housing companies are mainly affected by the landlord-tenant dilemma characterised by the split incentives of RES H/C systems in these buildings (e.g. 3.1.6). To solve this problem new cost-sharing concepts between landlords and tenants are recommended to be included in the current tenancy laws in EU member states. The harmonisation process of tenants' law might be an opportunity to bring in sharing concepts at EU level. Process heating and cooling see Table 6 below) is also dominated by two major barriers inhibiting the wider diffusion of energy efficient and RES H/C technologies. First of all, actors in this sector are strongly influenced by concerns and changes affecting the core business of their enterprises. Decision-makers are often locked in a state of inertia when investments in RES H/C systems are evaluated. This situation is caused by a lack of information on best practice examples and well-operating pilot and demonstration projects (e.g. 3.2.6). Best practices such as learning energy efficiency networks (e.g. 3.2.7) address a wide range of barriers and demonstrate that investments can take place within social processes. Furthermore, concerns about production interruptions or negative product properties due to the implementation of RES H/C technologies frequently hamper the realisation of such investments. Thus, information campaigns highlighting the feasibility and reliability of RES H/C applications as well as programs promoting best practice projects and benefits of these technologies are recommended (e.g. 3.2.3, 3.2.5). This particularly concerns waste heat use within industrial production in combination with district heating networks for neighbouring companies. Secondly, a lack of strategic priorities and governances based on fossil fuel pricing and market conditions hinders the deployment of RES H/C technologies in the industrial process and service sector. An approach to overcome this obstacle is to remove subsidies and incentives for fossil fuel H/C systems creating impulses towards a more sustainable supply structure in the EU.

Besides these general barriers, specific obstacles occur depending on the size of the company. While RES H/C technology investments for small and medium enterprises are mainly influenced by budget constraints that could be overcome by new financial incentive schemes and instruments, larger enterprises often have to face barriers related to their organisational structure; it is usually a challenge to address these through policy recommendations.

Finally, companies outside the scope of the EU Emissions Trading Scheme (ETS) currently lack incentives to switch from fossil fuels to RES. Revising the energy tax regime to be based on CO_2 intensity of energy carriers could be an approach to generate incentives for a fuel switch, also outside the EU ETS.

The district heating and cooling sector (see Table 7 below) has to deal with high initial costs for the development and implementation of networks. This barrier could be addressed through the implementation of innovative financial instruments and new business models promoted by suitable policies. In addition, an existing barrier in this sector is the poor awareness of potential customers regarding the benefits and possibilities connected to this technology. To tackle this obstacle, policies should foster the realisation of information and social media campaigns providing information for a wide range of addressees. Adequate local customer relations activities and programs or online platforms for the promotion of best practice examples (e.g. 3.3.1, 3.3.2) might increase the public awareness and perception of district heating and cooling networks.

Table 5: Selected barriers and policy recommendations for target groups in the building sector

Use case	Target group	Barriers	Policy recommendations
Residential and non-residential building sector	All investors and building owners	Biased prices and market distortion through subsidies and incentives	Remove subsidies and other incentives for fossil based heating systems (even for efficient ones) Avoid interpretation of energy efficiency legislation to justify subsidies for fossil fuel technologies (e.g. in case of Art. 7 EED)
		Low awareness regarding the benefits and costs of efficient RES H/C technologies	Implement, harmonise and display building certificates including GHG and primary energy per m² Introduce mandatory energy labels for H/C technologies (e.g. DACH/ EHPA quality label for heat pumps) Adjust building codes to limit GHG and primary energy per m² (alternatively: request minimal share of renewable energy for each building)
		Lack of information regarding RES H/C technologies and systemic approaches	Introduce adequate customer relations activities (such as periodic mailing after certain years of last installation, participating/organizing local events, social media etc.)
	Others intermediaries	Installer, planner, architects: Lack of proper qualified and trained experts Preferences for conventional (fossil fuel based) H/C technologies	Promote local professional education centres and survey the quality of consultancy in member states Initialise programs and online platforms promoting best practice examples and benefits Provide up-to-date training on different technologies including RES H/C and systemic approaches
		Financial institutes: Lack of finance schemes and credit lines (e.g. local banks)	Implement and improve state budget independent financing mechanisms, tax incentives (e.g. income taxes, energy and environmental taxes), debt guarantees and credits (e.g. EEF, structural fund) for RES H/C investments
		Local authorities: Legal restrictions and administrative burdens (e.g. approvals)	Include incentives into zoning laws (e.g. allow higher utilisation of space if advanced GHG goals are met) Revise approval procedures at local levels and improve them accordingly
Choice of initial heating/cooling system at time of construction of new residential/ non-residential buildings	Private persons (i.e. future owners)	Single-family homes/multi-family homes: Budget constraint and financing (e.g. minimise up-front construction costs)	Implement new financial incentive schemes and finance instruments (e.g. green loans, crowd-funding) for RES H/C investments
		Multi-family homes: Collective decision making (e.g. shared property/co-property)	Implement financial incentive schemes and finance instruments for low-income families in MFHs Produce information and social media campaigns Improve condominium ownership regulations
	Housing companies	Investment decisions are often driven by up-front cost or payback time	Promote alternative cost-effectiveness measures besides payback time (e.g. net present value, internal rate of return) Establish green image awards for housing companies

Use case	Target group	Barriers	Policy recommendations
Choice of heating/cooling system at the time of necessary (or before) renewal (residential/non-residential buildings)	Private persons (i.e. owners)	Single-family homes: Bounded rationality: replace with the same system, no planning / evaluation of alternatives (lock-in effects)	Instigate nandatory building energy certificates that show-case options at the latest 15 years after the latest retrofit of heating system Introduce mandatory energy labels for H/C technologies
		Competition with other modernisation measures (e.g. new bathroom)	Implement tax incentives for green savings
	Housing companies	Split incentives (landlord-tenant dilemma)	Allow only 50% of energy costs to be passed to tenants (e.g. tenancy law) Allow add-on costs for RES heating systems to be passed on (e.g. tenancy law) Promote energy service/performance contract schemes
	Public bodies	The procurement routines are still not up to date regarding RES H/C	Promote energy service/performance contract schemes and adjust public tendering rules accordingly

Table 6: Selected barriers and policy recommendations for target groups in the industrial process and service sector

Use case	Target group	Barriers	Policy recommendations
Industrial process and service sector	All investors	Lack of strategic priorities and governance (e.g. market conditions, biased fuel pricing, ETS)	Remove subsidies and other incentives for fossil-based heating systems (even for efficient ones)
		Concerns about core business (e.g. production interruption, negative influences on process and product properties)	Provide information campaigns and demonstration projects highlighting feasibility and reliability of RES H/C technologies Initialise programs (e.g. energy efficiency networks) and online platforms promoting best practice examples and benefits
	Installer, planner, architects	Lack of proper qualified and trained experts Preferences for conventional (fossil fuel based) H/C technologies	Promote local professional education centres and survey the quality of consultancy in member states Initialise programs and online platforms promoting best practice examples and benefits (e.g. with a focus on systemic aspects)
	Financial institutes	Lack of finance schemes and credit lines (e.g. local banks)	Improve communication of the profitability of energy efficiency and RES H/C investments. Banks should evaluate the creation of RES H/C and energy efficiency credit lines. Expand existing financial instruments for RES H/C
	Local authorities	Legal restrictions and administrative burdens (e.g. approvals)	Include incentives into zoning laws (e.g. allow higher utilisation of space if advanced greenhouse gas reduction goals are met)
Choice of initial heating/cooling system for processes **or** **Choice of replacing existing heating/cooling system for processes**	Small and medium enterprises	Budget constraints and finance (e.g. minimise up-front construction costs) Transaction costs	Implement new financial incentive schemes and finance instruments (e.g. taxation, tradable certificates, debt guarantees, green investment funds, crowd-funding) Foster simplified energy performance contracts
		Lack of knowledge and information concerning energy consumption (e.g. absence of internal energy experts) Absence of impulse results in replacing old system with similar new system	Provide information campaigns for RES H/C and energy efficiency Encourage independent advising associations and consultancies Promote energy efficiency networks and energy monitoring
	Large enterprises	Preferences for high investment yields and low payback times (neglecting profitability) Short-term decision perspective	Promote alternative cost-effectiveness criteria besides payback time (e.g. net present value, internal rate of return) Foster energy performance contracts
		Internal information flow and allocation of responsibilities	This barrier is not easily addressed through policy recommendations as it relates to the internal operation of companies

Table 7: Selected barriers and policy recommendations for target groups in the district heating and cooling sector

Use case	Target group	Barriers	Policy recommendations
District heating and cooling	All investors	High initial cost for network infrastructure	Implement new financial incentive schemes and finance instruments (e.g. green investment funds, crowd-funding, citizen participation)
	Installer, planner, architects	Lack of proper qualified and trained experts Preferences for conventional (fossil fuel based) technologies	Promote local professional education centres and survey the quality of consultancy in member states Initialise programs and online platforms promoting best practice examples and benefits
	Financial institutes	Funding mechanisms, debt guarantees and improving investors' confidence	Provide demonstration projects, innovative funding and debt guarantee mechanisms for the further development of large infrastructure projects such as low temperature district heating (e.g. LowEx) and CHP in cities Aggregate projects to make them available for green funds
	Customers	Low awareness regarding the benefits and costs of DH/C technologies Lack of information regarding DH/C technologies	Provide information and develop social media campaigns Generate adequate custumer relations activities (such as periodic mailing after a certain number of years, participating/organising local events etc.) Initialise programs and online platforms promoting best practice examples and benefits
	Heat supplier	Specifications of heat supply temperature level with respect to the design of existing networks	This barrier is not easily addressed by policy recommendations as it is dependent on each individual case
		Middle-/long-term strategic framework conditions (e.g. demand and supply guarantees)	Implement innovative and suitable contracting models and approaches to increase risk insurance for external heat suppliers
	Operators	Access to DH grid denied by grid operator to protect own generation	Regulate DH grid access
		Natural monopoly might result in higher prices (also cross-financing of other municipal activities from selling heat).	Improve competition / regulate prices
District heating and cooling in new city districts/quarters	Investors and other intermediaries (e.g. customers, heat supplier)	Competition (e.g. initial costs, energy prices, piping) with individual (fossil fuel-based) heating systems	Remove subsidies and other incentives for fossil based heating systems Implement framework conditions and concepts with respect to compulsory connection for new buildings

Use case	Target group	Barriers	Policy recommendations
		Low heat demand due to energy efficiency standards for new buildings (e.g. low energy buildings, NZEBs)	Promote and support information campaigns and business models for low temperature district heating (e.g. LowEx)
Extension of district heating and cooling networks by connecting existing buildings	Investors and other intermediaries (e.g. customers, heat supplier)	Obstacles with respect to construction restrictions (e.g. existing natural gas/waste water pipes/ communication infrastructure) Inconveniences during the grid connection of existing buildings Competition with alternative energy supply (e.g. gas networks), often even owned by same utility. Remaining lifetime of existing heating systems in buildings	This barrier is not easily addressed by policy recommendations as it is dependent on each individual case

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7 Annex

Table 8: Specific barriers for different subsectors in industry

Subsectors	Barriers
Basic chemicals industry	- Uncertainties concerning sales markets - risks for optimised production processes - low number of plant manufacturers
Metal production	- regulatory aspects (e.g. heat recovery for sinter plants) - technology development towards CCS and uncertain future technologies
Non-ferrous metal production	- internal allocation of energy costs - realisation of measures through employees
Paper industry	- high development effort for innovative solutions - acceptance of secondary fuels
Earth and stone industry	- high development effort - acceptance of alternative fuels - complexity of efficiency measures
Glass and ceramic industry	- insufficient evaluation of measurement data from industrial furnaces - complexity of efficiency measures for existing plants (e.g. heat recovery)
Food industry	- lack of technical standards for investments/components (especially in SME)

Source: Fette et al (2012)

Figure 5: Summary of results for the assessment of barriers and best practices in the EU

Space heating and cooling		**Process heating and cooling**		**District heating and cooling**
Technologies: CHP, heat pumps, solar thermal systems, biomass boilers (furnace), solar thermal cooling		Technologies: CHP, heat pumps, solar thermal systems, biomass boilers (furnace), solar thermal cooling		Technologies: DH
Residential	Non-residential	SME	large enterprise	
see Figure 1: Categories of barriers				
Actors and user perspective: Investors/decision-makers: owners, owner-occupiers, owner communities, housing companies Providers: energy suppliers, craftsmen, construction companies, contractors, manufacturers Intermediaries/other actors: tenants, finance corporations, insurance companies, planners, energy advisors, installers, energy-agencies, engineering services providers, associations, supervisory authorities, research and development institutes, user groups, social environments, media, policy-makers, energy regulators		Actors and user perspective: Investors/decision-makers: owners, management Providers: energy suppliers, craftsmen, construction companies, contractors, manufacturers Intermediaries/other actors: employees, shareholder, business partners, suppliers, customers, finance corporations, insurance companies, planners, energy advisors, installers, energy-agencies, engineering services providers, associations, supervisory authorities, research and development institutes, user groups, social environments, media, policy-makers		Actors and user perspective: Investors/decision-makers: producers Intermediaries/other actors: users, finance corporations, insurance companies, planners, installers, associations, supervisory authorities, research and development institutes, social environments, media, policy-makers
Selected best practice examples: - Heat Pump City (heat pumps in Etten-Leur, Netherlands) - Biomass boiler (biomass boiler in Chepelare, Bulgaria) - Innovative business models (Solar thermal system installers Novasol and Sumersol in Andalusia, Spain) - A web tool for energy efficient renovations (Slovakia) - Long-term support for heat pumps (heat pumps in Sweden and Switzerland)		Selected best practice examples: - Integration and utilisation of waste heat in industry (Germany, Austria, Sweden) - Biomass boiler (process heat for Peka Kroef, Netherlands) - Brewery as a pioneer in terms of sustainability (Austria) - Promotion of market penetration of trigeneration (EU) - Learning Energy Efficiency Networks (Germany, Switzerland, Austria)		Selected best practice examples: - SmartReFlex (district heating in Marstal, Denmark) - LowEx district heating (Finland, Denmark, Germany)

Source: own illustration