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List of Abbreviations

BEIS	Department for Business, Energy & Industrial Strategy
CHP	Combined heat and power
CMA	Competition & Markets Authority
DECC	Department of Energy and Climate Change
DH	District heating
DSO	Distribution system operator
EPBD	Energy Performance of Buildings Directive
EU	European Union
NRA	National regulatory authority
PCM	Phase-change material
PSO	Public service obligations
TPA	Third-party access
TSO	Transmission system operator

1 Introduction

This report has been developed in the framework of the SMILE H2020 funded project. The overall scope of SMILE is to demonstrate different innovative technological and non-technological solutions in large-scale smart grid demonstration projects in the Orkney Islands, Samsø and Madeira, paving the way for their introduction in the market in the near future. The technological solutions vary from: integration of battery technology, power to heat, power to fuel, electric vehicles (cars, boats), aggregator approach to demand side management (DSM) and predictive algorithms. In this context, this report provides an overview of the legal framework at EU and national level with respect to heat generation and supply as well as regarding electricity and heat systems integrations.

According to the International Energy Agency, “heat is the largest energy end-use [worldwide]. Providing heating for homes, industrial purposes and other applications accounts for around 50% of total energy consumption”. In 2017, “only 10% of heat worldwide was produced from renewables” [1]. In the European Union (EU), the share of heat in the final energy consumption is similar as at the global level. However, there is a slight difference, as in the EU, it is heating and cooling which together represent 50% of the final energy consumption [2]. This might not seem so important as cooling is very limited in the final energy use in the EU [3], but the use of cooling is expected to strongly increase over the globe in the coming decades [4]. Due to the current small share of cooling in the EU energy consumption, and to the use of similar technologies for both heating and cooling (either using electricity for air conditioning, similarly to heat pumps, or for networks which can also pipe hot or chilled liquids), this deliverable will only use the term of “heating” even if cooling is also an option. Furthermore, this deliverable will only refer to some heating technologies, especially the ones used in the SMILE project: combined heat and power and the use of excess electricity from variable renewable energy sources, especially wind energy. However, there a number of other heating technologies, such as geothermal or solar thermal.

The main current problem for heat is its decarbonisation. In the EU, in particular, only a mere 13% of the heat consumed was produced using renewable energy sources in 2015 [5]. According to the European Commission “the heating and cooling sector must sharply reduce its energy consumption and cut its use of fossil fuels” [6]. To reinforce its use of renewable energy sources, the EU heating system can develop its integration with the electricity sector, where these sources are increasing. This way, the heat produced from electricity generated by renewable energy sources is indirectly, but still, low-carbon. In addition, this integration, part of the wider movement of sector coupling, can offer “important flexibility in [electricity] demand” [7], hence allowing the electricity system to manage larger inputs of variable electricity, therefore creating a virtuous energy transition circle.

More in details, this deliverable focuses on heat generation and supply in the EU, as well as on sector coupling between electricity and heat. After some background information on these topics, the corresponding policy and legal framework at EU and national level will be analysed before providing recommendations.

2 Background to heat generation and supply

This section will briefly illustrate the main aspects of the heating system as in principle most consumers (smaller and larger) will make use of some sort of heat supply. This is primarily the case in the Northern European countries which are faced with longer and colder winter periods. When discussing heat supply, we need to distinguish between two different approaches: small scale/domestic/individual heat supply and large scale/communal heat supply.

Small scale/domestic/individual heat supply entails that heat is generated at a small scale (a house or a flat). Use can be made of different energy sources and different technologies. Air or water is heated in a furnace or a boiler and circulated in the space to be heated by way of hot air, hot water or steam [8]. Heat pumps can also be used to convey (and not generate) the heat from outside to inside a closed space or vice versa [9]. The energy source used can be fossil (mostly oil or gas) or renewable (biomass burning, geothermal, solar thermal, etc.), but the heating system can also run on electricity. If the system is powered by electricity, then its sustainability will depend on the country's electricity generation mix. The main benefit from an individual system is that the user is able to control the system rather independently, except for the need to have access to the primary energy source (wood, electricity, gas, etc.). However, most boilers do not facilitate an easy change to another source as "individual heating solutions only allow one specific type of fuel", meaning that end user's "heating bill is fully financially exposed to price increases of a specific fuel" [10].

Large scale or communal heat supply is considered an alternative. It means that heat is generated on a large scale, for example, by making use of combined heat and power (CHP) systems, geothermal heat or of residual/waste heat from industry. CHP is a well-proven technology already widely used and which can make use of a variety of energy sources and different sizes of installation. The heat from these plants is often used to supply end consumers (mainly household consumers) *via* a system of district heating networks. These networks use the heat generated by medium to large-scale facilities and convey it to various end users through insulated pipes.

This deliverable will focus on further examining large scale heat supply by making use of CHP and district heating as this type of heat supply is considered as energy efficient and clean as it creates less CO2 emissions. Subsequently, we will also present some new technologies coupling the electricity and heat sector and as part of which the share of renewable energy in the system will increase. Finally, the last subsection will present how these techniques play a role on the islands of the SMILE project.

2.1 Combined heat and power

> Co-generation, also known as combined heat and power, is the production of electricity and heat at the same time. It can also be the production of electricity from the waste heat of a process [11].

This technic aims at combining the production of two forms of energy at the same time in order to reach significantly high energy efficiency levels. Indeed, while classic fossil-fuelled power plants have an average efficiency rate of 35%, a combined heat and power (CHP) plant achieves between 75 and 90% of efficiency, meaning that less primary energy is used to produce the same amount of electricity and heat [12]. The strength of CHP is that it is possible to use many different types of primary energy sources. It is possible to use fossil fuels (coal, oil or gas), different types of renewable energy sources, such as geothermal or biomass, but also to burn municipal or industrial wastes (either directly or after a transformation process, such as methanation) or simply to use the heat produced during the electricity generation process in a plant. Therefore, a CHP facility is very versatile and can make use of locally available energy sources.

Worldwide, "co-generation provides around 10% of total electricity generation" [13]. In the EU, this rate was stable at around 11% over the years 2005-2015 [14]. However, this figure is much higher in some Member States such as Denmark, where it represents between 40 and 50% of the total electricity generation over the same period [15]. Concerning the primary energy sources, a clear movement was observed in the EU during these 10 years: the collapse of peat and coal, a small increase in natural gas which remains the first source with over 40% of the fuel used for CHP, and a steady increase of renewables which double their share to reach 20% in 2015 [16]. The easiest way to use CHP for buildings is through a district network distributing this heat to entire neighbourhoods [17].

2.2 District heating

District heating (DH) consists in generating heat at a centralised facility and then to distribute this heat under the form of hot water or steam to numerous consumers through a network of pipes. This system is very flexible regarding the primary energy source it uses and can mix multiple sources at the same time or arbitrate to use the most adapted at a certain time (such as for price reasons or for environmental issues) [18]. It is also in theory much easier to replace a generating asset in order to switch the energy source used than for individual heating, as there is only one or a handful of centralised assets to replace instead of one or multiple in each building [19]. In addition, DH is particularly adapted to make the most of waste heat which would otherwise be lost, since it can connect industrial facilities to residential neighbourhoods, commercial areas or city centres. Finally, it is to be noted that

> a number of studies have shown that [DH] plants give better performance in energy efficiency and the abatement of air pollutant emissions, mitigate greenhouse gas emissions, and contribute greatly to the enhancement of public convenience and energy saving compared to [individual heating systems] [20].

However, the strength of DH – generating heat in a centralised location and distributing it to a high number of customers – is also its weakness. Indeed, it is not possible to efficiently transport heat on long-distances and this explains why DH networks are being developed primarily in densely populated areas [21]. For rural areas, the economic viability of a DH network has to be studied but might often end up insufficient. As a result, DH networks often form unconnected 'islands' located in populated parts of a country [22].

2.3 Sector coupling technologies

> Originally, sector coupling referred primarily to the electrification of end-use sectors like heating and transport, with the aim of increasing the share of renewable energy in these sectors (on the assumption that the electricity supply is, or can be, largely renewable) and providing balancing services to the power sector [23].

Nowadays, the concept has gained a broader meaning and the European Commission refers to "a strategy to provide greater flexibility to the energy system so that decarbonisation can be achieved in a more cost-effective way" [24]. Thus, it opens other ways than only electrifying the whole energy system. Sector coupling is about integrating the different available energy carriers (electricity, gas, hot water or air) to use the best energy source for satisfying final energy uses (heat, light, transportation, etc.).

Nevertheless, the electrification of various sectors such as transportation or heating allows to use the excess power sometimes produced by variable renewable energy sources (mostly wind and solar PV), which would otherwise be lost, following the same logic as for CHP. Different technologies can be used for this purpose such as Power-to-Gas, which entails that any excess electricity can be turned into hydrogen and then used in this form or another (transformed into methane by adding CO2 or returned back to electricity) [25]. But electricity can also provide heat to be used directly (heat pumps) or to be stored (for example in a hot water tank) and used later. In addition to avoid energy losses, sector coupling then also allows to “efficiently manage intermittency from wind and solar PV at an affordable cost” [26] by maintaining the electricity grid stable thanks to dispatchable demand.

2.4 Heat Supply on (SMILE) islands

The geographical focus of the SMILE project is placed on islands and especially on the Orkney Islands, Samsø and Madeira. One of the special features of an island is that they are separated from mainland. This aspect can have a strong impact on the heating technologies used on their territory. By contrast to electricity cables, it is usually not possible to connect a DH network to the mainland. Therefore, islanders have to use their local resources, if they can, or import primary energy sources, if they cannot. This may explain why most islands make use of small scale, individual fossil-fuels based heating systems. However, it is also possible to develop a local DH network as long as there is a concentrated group of people living at one or a few points of the island. This is the case in Samsø and especially of the municipality of Ballen where the SMILE project is being deployed. There, a CHP plant is established that is making use of local biomass as its primary fuel and that is feeding heat into a DH network, which distributes heat to two towns (Ballen and Brundby) [27].

Once that these practical aspects and notions have been mentioned and explained, it is possible to start analysing the policy and legal framework applying to heat and to its integration with electricity in the EU.

3 European Union policy and legal framework

Although heating and cooling represents half of the total EU energy consumption (and almost 80% for households alone) [28], this sector does not benefit from an integrated and/or harmonised EU regime. By contrast to the electricity and gas sector, there is no EU legislation in place governing heat supply (and/or cooling). As a consequence, the legal framework is scattered and incomplete. However, there are signs that this may change as the European Commission published a Heating and Cooling Strategy in 2016.

This section presents this EU strategy policy before discussing those part of EU law that currently govern heat supply in the EU.

3.1 EU policy

The most recent policy document from an EU institution governing heat supply is the 2016 communication from the Commission entitled: An EU Strategy on Heating and Cooling [29]. According to the Commission this strategy should

> help to reduce energy imports and dependency, to cut costs for households and businesses, and to deliver the EU's greenhouse gas emission reduction goal and meet its commitment under the climate agreement reached at the COP21 climate conference in Paris [30].

In other words, the Commission applies the well-known energy trilemma concept [31] to the EU heating policy as it endeavours to balance energy security, energy affordability and environmental impacts of energy production and supply.

The order in which the Commission presents its goals concerning heat supply is also interesting. In order to

> achieve our decarbonisation objectives, buildings must be decarbonized. This entails renovating the existing building stock, along with intensified efforts in energy efficiency and renewable energy, supported by decarbonized electricity and district heating. Buildings can use automation and controls to serve their occupants better, and to provide flexibility for the electricity system through reducing and shifting demand, and thermal storage [32].

In other words, the priorities for decarbonising the heating sector are 1) renovation of existing buildings, 2) increase energy efficiency, 3) promote renewable energy generation. Consequently, the first effort towards a decarbonised energy system aims at energy conservation, *via* behavioural change, insulation, and energy efficiency, before addressing the generation side. Indeed, if energy consumption increases, it only renders the switch towards renewable energy sources more difficult. In addition, these three topics are supported by decarbonised electricity and district heating.

In the final part of the document, the Commission announced a variety of measures it intends to implement with the Clean Energy Package (CEP – presented in the following subsection). These are organised in the same order as explained above and start by improving buildings, with a focus on renovation and energy efficiency (for both the building itself and for its heating system) and then on renewable energy generation [33]. In supporting these three improvement lines come the smart systems. Then, the Commission aims to "integrate thermal storage (in buildings and district heating) into flexibility and balancing mechanisms of the grid", to incentivise both "citizen participation in the energy market through decentralised production and consumption of electricity”, “the uptake of renewable energy in heat production, including CHP”, and “the take-up of fully interoperable smart buildings solutions, systems and appliances” [34]. All these elements announce a need for a transformation of the EU’s heating systems. Indeed, until now customers in some Member States were incentivised to heat their water tank during the night with different electricity prices over a full day, but the Commission foresees a much deeper integration of heat and electricity. Citizen participation is also envisioned through the electricity sector. Concerning renewable energy into heat production, there is much work to do, as in 2012, 75% of it was coming from fossil fuels, mainly natural gas [35]. It is capital to increase the share of renewable energy into the heat supply in the EU in order to reach the 32% of final energy consumption from renewable energy sources by 2030 goal [36], given the share of heat into the final energy consumption. Finally, the smartening of energy systems, firstly being deployed in the electricity system is being extended to heat, also in a view of system integration. This last aspect is probably the most important one from the EU policy on heating: system integration, also known as silos-breaking, in order to create an interdependent (and inter-supporting) energy system which can make use of the most efficient energy source at the best price according to characteristics such as its availability.

In the following paragraphs, how EU law currently governs heat supply is presented.

3.2 EU legal framework

The EU legal framework for heat is fragmented. Firstly, it is fragmented among different acts as there is no heating directive or regulation, and therefore heat supply is mainly governed on Member States’ levels. Indeed, while there are measures for governing the production of heat (especially CHP) and consumption (through energy efficiency and energy performance of buildings’ rules) at EU level, there is no legal framework governing heat supply, except for primary EU law (free movement and competition). Heat supply is therefore primarily a matter of national law. Below those parts of EU law that is relevant for the heat supply sector are presented.

3.2.1 EU legal framework for CHP

EU institutions have shown their interest for CHP for a long time already. According to recital 7 of the 2004 directive on cogeneration, its importance was already “recognised by the Council Resolution of 18 December 1997 and by the European Parliament Resolution of 15 May 1998 on a Community strategy to promote combined heat and power”. In addition, CHP had its own directive of 2004 [37], until it was repealed and absorbed by the 2012 Energy Efficiency Directive [38]. In the first article of the 2004 CHP Directive, the purpose of this text is made clear:

> The purpose of this Directive is to increase energy efficiency and improve security of supply by creating a framework for promotion and development of high efficiency cogeneration of heat and power based on useful heat demand and primary energy savings in the internal energy market.

The development of CHP is therefore motivated by energy efficiency and security of supply reasons and a coupling at the generation step of the electricity and heat sectors, as CHP can answer “useful heat demand” while saving energy primary resources in the electricity production cycle, due to its overall higher efficiency in comparison with a classic power plant.

Article 3 of the 2004 CHP Directive provides the definitions of the terms employed in the act, such as cogeneration or useful heat. But the most interesting one in the list is the notion of "economically justifiable demand for heat and cooling", which means

> the demand that does not exceed the needs for heat or cooling and which would otherwise be satisfied at market conditions by energy generation processes other than cogeneration.

In other words, CHP is justified when it produces heat for an existing demand which otherwise would have to be satisfied by the market. This notion is for example used in article 9 of the Directive regarding Member States' authorisation administrative procedures. This article requires Member States to evaluate their administrative procedures for the authorisation of CHP and this evaluation has to be made in the view of "encouraging the design of cogeneration units to match economically justifiable demands for useful heat output and avoiding production of more heat than useful heat". CHP is therefore clearly considered as a means to cope with existing heat demand and not to overproduce. It has to be noted that the same article also requests Member States to pursue their evaluation for "reducing the regulatory and non-regulatory barriers to an increase in cogeneration" and "streamlining and expediting procedures". CHP plants seemed then to deserve a simple regime for their authorisation.

As mentioned above, the 2004 CHP Directive was repealed and replaced by the 2012 Energy Efficiency Directive. Aside from integrating the definitions of cogeneration and other related notions in its article 2, this directive contains two relevant provisions for this development: articles 14 and 15. Firstly, article 14 requires that Member States "carry out […] a comprehensive assessment of the potential for the application of high-efficiency cogeneration" [39]. The Commission can request this assessment to be updated every five years [40]. Where this assessment identifies

> a potential for the application of high-efficiency cogeneration […], Member States shall take adequate measures for [accommodating] the development of high-efficiency cogeneration and the use of heating and cooling from waste heat and renewable energy sources [41].

In addition, there are obligations when thermal power plants of a certain capacity are built or refurbished to evaluate the costs and benefits of converting it to a CHP installation. The same applies for industrial sites which could be used for CHP based on waste heat [42]. Some exemptions still apply, such as for so-called peaker plants, which run a limited number of hours per year, mainly for coping with the peaks of electricity demand [43]. Finally, the Directive requests Member States to adopt authorisation procedures to "take into account" the outcome of both the "comprehensive assessment" and the cost-benefits analysis for thermal power plants and industrial sites [44]. However, there is no specific regime for CHP plants authorisations alone in article 7 of the 2009 Electricity Directive nor in article 8 of the 2019 Electricity Directive [45].

Secondly, article 15 of the 2012 Energy Efficiency Directive demands that Member States ensure that the electricity network operators (transmission system operators –TSOs- and distribution system operators –DSOs-) "guarantee the transmission and distribution of electricity from high-efficiency cogeneration" [46]. The idea behind this provision is to incentivise investments in CHP as these plants are guaranteed to run as much as possible through the year and therefore be more profitable, but also to guarantee that as much heat as possible will be generated, as if the power plant does not run because of a lack of electricity demand, it is also a lack of heat generation at the same time. This provision is confirmed by article 31 (4) of the 2019 Electricity Directive where Member States "may require the [DSO] when dispatching generating installations, to give priority to generating installations using […] high-efficiency cogeneration". Both directives go into the same direction on this point, save for the use of the verb "may" in the Electricity Directive, instead of "shall" in the Energy Efficiency Directive, thus with a lower degree of constraint.

It is to be noted that both articles 14 and 15 have not been amended by the new 2018 Energy Efficiency Directive [47].

In a nutshell, the EU legal framework for CHP is mainly to be found in the 2012 Energy Efficiency Directive with only a few mentions in other directives. However, the provisions dedicated to CHP remain procedural ones that only force Member States to assess the potential development of this generation technology and to take measures to facilitate its deployment when justified. Even the incentivising regime of priority access to the electricity grid for CHP plants is not compulsory.

3.2.2 EU legal framework for heat consumption

Measures regarding heat consumption can be found in two directives which both have been amended in 2018: the Energy Efficiency Directive and the Energy Performance of Buildings Directive (EPBD).

The 2012 Energy Efficiency Directive sets energy efficiency targets [48], requests Member States to "establish a long-term strategy for mobilising investment in the renovation of the national stock of residential and commercial buildings" [49], and demands Member States to provide meters to consumers if "technically possible, financially reasonable and proportionate in relation to the potential energy savings" [50]. Overall, the 2012 Energy Efficiency Directive provides a toolbox with targets and guarantees that consumers are informed of their consumption for them to take adequate measures. The 2018 amendments continued on this logic, with updated targets [51].

The 2010 EPBD requests Member States to set minimum energy performance requirements for buildings [52], provides some instruments that can be implemented by Member States, such as financial incentives and energy performance certificates [53], and orders Member States to establish a mandatory periodic inspection for heating systems of a certain size with recommendations on the system's adequate size for the heating demands of the building [54]. The 2018 amendments did not change the logic of the 2010 text either, mainly updating targets and thresholds. Just as for the Energy Efficiency Directive, the EPBD is mostly a toolbox for incentivising the erection or renovation of energy efficient buildings.

By contrast to the EU legal framework for electricity and for gas, mainly to be found in the 2019 Electricity Directive [55] and the 2019 Natural Gas Directive [56], (vulnerable) heat consumers do not benefit from specific rights and protection. There are two main reasons for that. The first one is that electricity and gas are already used for heating in many households, so consumers already benefit from the electricity and natural gas customer protection provisions, such as basic contractual rights [57], right to switch suppliers [58], right to out-of-court dispute settlement [59], or universal service guarantees [60]. The second reason is that due to the specificity of heat networks, their actors are not submitted to an EU legal framework with the guarantees enumerated above, as will appear in the next paragraphs. As a consequence, the legal regime for heat consumption in the EU is still limited to toolboxes, strategies and targets, but does not include the same level of protection as for the consumption of electricity or natural gas.

3.2.3 EU legal framework for heat supply

As mentioned in the introductory paragraph of this section 3.2, heat supply does not benefit from a harmonised legal framework at EU level. In other words, there is no Heat Supply Directive providing rules with regard to heat generation and supply. Consequently, there is no EU level obligation to implement unbundling, Third-Party Access (TPA) and freedom of choice of their supplier for heat consumers.

The reason for an absence of EU law could be the small scale of heat supply systems and any absence of cross-border trade. Firstly, the vast majority of the heat consumed in the EU is provided by individual systems, while only 8% is provided by DH networks (9% for the residential sector) [61]. And secondly, while DH networks follow the same logic as for electricity and natural gas, from generation to supply through transportation and distribution, these networks cannot be extended over long distances because of energy losses. Therefore, it is not possible with the current technology to interconnect distant large heating consumption centres. As a result, the heat is produced and consumed locally and it is not possible to create an integrated single market as for electricity and natural gas. This situation is actually indirectly recognised in European acts. Indeed, article 14 (2) of the 2012 Energy Efficiency Directive reads: "Account shall be taken of the potential for developing local and regional heat markets". This article refers to "local and regional heat markets" instead of a common market as for electricity and gas. In addition, recital 49 of the 2019 Electricity Directive states: "In view of the vertical links between the electricity and gas sectors, the unbundling provisions should apply across the two sectors". Here as well, heat is not organised the same way as electricity and gas and unbundling provisions do not apply [62].

However, it is possible to find some provisions applying to DH networks in different directives. First of all, DH is defined in article 2 (19) of the 2018 Renewables Directive as follows:

> 'district heating' or 'district cooling' means the distribution of thermal energy in the form of steam, hot water or chilled liquids, from central or decentralised sources of production through a network to multiple buildings or sites, for the use of space or process heating or cooling.

Additionally, article 2 (41) of the 2012 Energy Efficiency Directive presents a definition for efficient DH (not modified by the 2018 revision of the Directive):

> 'efficient district heating and cooling' means a district heating or cooling system using at least 50 % renewable energy, 50 % waste heat, 75 % cogenerated heat or 50 % of a combination of such energy and heat.

Aside from noting that "efficient" could actually be replaced by "sustainable" as it refers to the sources used to produce heat more than to the efficiency of the process itself or of the distribution and consumption, this definition is used in the Directive mainly for one provision. Indeed, article 14, the one requesting Member States to conduct a "comprehensive assessment" of the potential for CHP as seen in subsection 3.2.1, also applies to efficient DH networks. Here as well, Member States have to facilitate the development of such networks where there is a potential, including by studying the option of connecting industrial sites producing waste heat to the network.

Last but not least, the 2018 Renewables Directive provided a very interesting potential seed for the future application of some liberalised market rules to DH, for its transition to renewable energy sources. There are two parts of interest in this article. On the one hand, article 24 (2) requests Member States to set the frame to allow customers of district heating or cooling systems which are not efficient district heating and cooling systems, or which are not such a system by 31 December 2025 on the basis of a plan approved by the competent authority, to disconnect by terminating or modifying their contract in order to produce heating or cooling from renewable sources themselves.

With this provision, heat customers connected to a DH network gain the right to leave such a network if it does not use enough heat produced from renewable energy sources (or CHP). Depending on the countries this right might already exist or not, but usually it is difficult for customers in a building connected to a DH network to disconnect, either due to the national rules, or because they would have to buy a new equipment for their heating needs and maybe pay some money to the DH network operator, as it is not an easy task to find new customers without investing heavily to extend the network itself, which is why DH networks operators often see their investments protected by captive customers. Nevertheless, the second part of the same article allows Member States to implement a compensation to be paid in case of disconnection, for the reason mentioned just now. It results from this analysis that it might be unlikely that customers connected to a DH network will actually leave it if they have to install their own heating system based on renewable energy sources and to pay a compensation.

On the other hand, paragraphs 4 to 6 of the same article demand that Member States clearly incentivise a higher renewable energy share in DH networks. This can be achieved either by finding a way to reach a yearly 1% increase in renewables or CHP share in the total energy consumed through DH, or by establishing a TPA rule for suppliers of renewable or CHP sourced heat. TPA is a classic and essential rule of liberalised energy markets in order to allow competition between suppliers [63]. The logic of the 2018 Renewables Directive is that if a DH network operator is not able to transit fast enough to renewables or waste heat, then it has to authorise access to its network to competitors which are virtuous in this regard. That being said, there are limits to this principle, especially if "the system lacks the necessary capacity due to other supplies" of heat from waste heat, renewable energy sources or CHP, for technical parameters, or due to the proven risk of an "excessive" cost increase for final customers "compared to the cost of using the main local heat or cold supply with which the renewable source or waste heat and cold would compete" [64]. With this provision, the 2018 Renewables Directive clearly wishes Member States to be ready to use the stick to motivate DH networks operators to source more heat from renewable energy sources, but the real efficiency of this measure can only be assessed in the next few years, if it has been properly transposed and used by Member States. In the meantime, the essential facility doctrine might prove a case-by-case temporary solution to instil competition into some DH networks.

3.2.4 The essential facility doctrine

In the absence of secondary EU law governing heat supply, the rules of competition law apply. This means that any third parties who wish to access to the system (that is a natural monopoly) could require access to it. Any denial to provide access could possibly be an abuse of a monopoly position. However, in the EU use can also be made of the "essential facility doctrine", which progressively has been shaped by EU courts' decisions since 1974 [65]. In essence, "the essential facilities doctrine imposes on owners of essential facilities a duty to deal with competitors" [66]. The turning point in the jurisprudence, which has set the rules for the evaluation of the essential character of a facility and if its owner should provide access to it to its competitors, is the 1999 *Bronner* decision [67].

First of all, the coveted facility has to be indispensable. This translates as the Commission considering an essential facility as “a facility or infrastructure without which [the owner’s] competitors are unable to offer their services to customers” [68]. Second, the refusal of access to the facility by the owner “is likely to eliminate all competition” [69]. And third, this refusal has to be justified [70]. If the facility is indispensable, its impossible access for competitors will kill the competition and if the refusal is not justified, then it can be ordered to give access to the facility for a fair remuneration. This decision of forced access is taken on the basis of article 102 of the Treaty on the Functioning of the European Union (former article 82 TEU) regarding abuse of dominant position.

This case law has been later confirmed by a European Commission Guidance on the enforcement priorities in applying article 82 of the EC Treaty. The starting point for the Commission when it analyses a potential case of abuse of dominant position is that “any undertaking, whether dominant or not, should have the right to choose its trading partners and to dispose freely of its property” [71]. The risk to apply broadly the obligation of access to essential facilities is indeed to harm investments and innovation and to incentivise competitors to free-ride on investments made by others [72]. In the end, the consumer would be harmed by these missed investments and innovation opportunities. To better organise its analysis of suspected unjustified restriction of access to essential facilities and inform the potentially interested parties, the Commission has set three criteria:

— the refusal relates to a product or service that is objectively necessary to be able to compete effectively on a downstream market,
— the refusal is likely to lead to the elimination of effective competition on the downstream market, and
— the refusal is likely to lead to consumer harm [73].

In addition, the Commission will also consider “claims by the dominant undertaking that a refusal to supply is necessary to allow the dominant undertaking to realise an adequate return on the investments required to develop its input business” [74].

These criteria could potentially also be applied to DH networks. Indeed, DH networks are natural monopolies: it is not economically sound to build various competing networks on the same location. Instead of building a new network, a third party (supplier or consumer) would therefore apply for access to the system. The three conditions set forth by the Commission may easily be met. However, the reservation on the necessity to deny access by the local incumbent to allow an adequate return on its investment will also have to be taken into account. At the end of the day, if cases are brought to the Commission or to the EU Court of Justice requesting access to a DH network by a competitor, a balance will have to be found between competition and protection of investments, in the interest of consumers. The 2018 Renewables Directive somehow started to take steps in this direction with its article 24 seen in the previous subsection, opening the window for TPA to heat networks where not enough renewable energy is used.

In appearance, DH networks regulation is a different issue than sector coupling. However, the links between the two are stronger than first thought.

3.2.5 EU legal framework for sector coupling through energy storage

Electricity can be used to produce heat, such as *via* heat pumps or for instance by heating water in a tank. Hence, there is a potential for sector coupling between electricity and heat where the latter sector helps the former one especially as it integrates more variable renewable energy sources, or, as the European Parliament puts it, renewable energy technologies have a fundamental role to play, including through

> the use of sustainable biomass, of aerothermal, geothermal and solar energy, and of photovoltaic cells in combination with electric batteries, to heat water and provide heating and cooling in buildings, in conjunction with thermal storage facilities that can be used for daily or seasonal balancing [75].

Indeed, thermal storage facilities can be used to provide balancing services to the electricity system, by absorbing electricity when it is over-produced, especially by variable renewable energy sources, and mechanically reducing demand later on, when there will either be less production or potentially more consumption of electricity for heat needs (hot water for showers or laundry-making, space heating…). Article 24 (8) of the 2018 Renewables Directive heads into this direction when it provides that

> Member States shall require electricity [DSOs] to assess at least every four years […], the potential for district heating or cooling systems to provide balancing and other system services, including demand response and storing of excess electricity from renewable sources, and whether the use of the identified potential would be more resource- and cost-efficient than alternative solutions.

DH networks therefore have a strong role to play into the energy transition in allowing a higher share of renewable energy sources into the electricity system without imperilling the stability of the electricity grid and potentially at a lower cost than electricity storage. It is to be noted that the same kind of system of demand-response can be deployed with aggregated individual heaters. This is the case in the SMILE project, on the Orkney Islands, where different domestic heat set-ups are tested (with heat pumps, hot water tanks, electric batteries and phase-change material (PCM) batteries [76]) and "switched on […] when a signal is sent from the grid, via the turbine" [77], meaning that the individual heat system is switched on when wind turbines are (over) producing in order to avoid grid congestion and wind energy curtailment.

The integration of different energy sectors and their networks is also mentioned in the 2019 Electricity Directive, where article 58 (d) considers among the general objectives for electricity regulators (NRAs)

> helping to achieve, in the most cost-effective way, the development of secure, reliable and efficient non-discriminatory systems that are consumer oriented, and promoting system adequacy and, in line with general energy policy objectives, energy efficiency as well as the integration of large and small-scale production of electricity from renewable energy sources and distributed generation in both transmission and distribution networks and in facilitating their operation in relation to other energy networks of gas or heat.

This provision clearly highlights the potential of gas and heat networks to be coupled to the electricity network and to support it and tasks the NRAs to facilitate it.

Although reference was made to thermal storage in the paragraphs above, it must be stated that "thermal storage" *per se* is not mentioned in the 2018 Renewables Directive nor in the 2019 Electricity Directive. In fact, "energy storage" is mostly used in these two Directives and especially in the Electricity Directive which establishes its legal framework. According to its article 2 (59)

> 'energy storage' means, in the electricity system, deferring the final use of electricity to a moment later than when it was generated, or the conversion of electrical energy into a form of

energy which can be stored, the storing of such energy, and the subsequent reconversion of such energy into electrical energy or use as another energy carrier.

Therefore, the conversion of electricity into heat, its storing and its later use under the same form of heat falls under the legal definition of energy storage. This means that the frontier between the legal regime applying to the electricity and the heat sectors is particularly porous when it comes to thermal storage, as figure 1 shows.

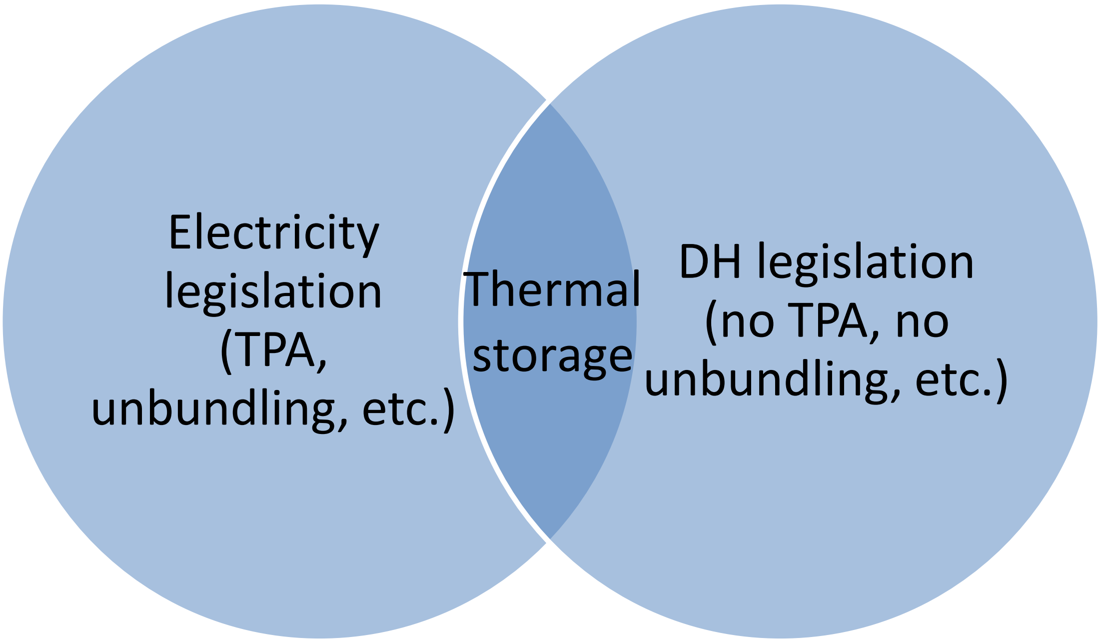

Figure 1 – Thermal storage between Electricity and DH legislation

As a consequence, if thermal storage is considered as energy storage in the electricity system, then the related provisions apply as well. As detailed in the SMILE deliverable D7.1, TSOs and DSOs are in this case prohibited from owning or operating thermal storage facilities fed with electricity which would be connected to a DH network, with the exemptions explained in the same deliverable [78]. In addition, if in the future liberalisation rules are applied to DH networks, then it is likely that the same logic applies and that DH networks operators are prohibited from owning or operating energy storage facilities, no matter the source of heat to be stored.

To finish assembling the pieces of the puzzle constituted by the fragmented legal regime applying to the heating sector, the reader will hereunder find a summary.

3.3 Summary

Although heating and cooling represent half the total EU energy consumption, there is no harmonised regime at this level. There is, however, a policy document, the 2016 EU Strategy on Heating and Cooling, which aims at reducing energy imports and dependency, cutting costs for households and businesses, and delivering on greenhouse gases emissions reduction goals. Sector coupling is also mentioned in this document, with thermal storage being presented as a means to support flexibility and balancing of electricity grids and for integrating higher shares of variable renewable energy sources.

In spite of a legal regime for heat supply concentrated in Member States, there are some provisions on this topic scattered among a number of EU directives. Firstly, CHP is considered and incentivised by the EU legislation since 2004. In essence, Member States have to carry out regular assessments of the potential for CHP and to facilitate its development if there are options. Also, DSOs can be forced to dispatch in priority the electricity from CHP plants, in order to increase the interest for and the running time of power plants using this technology.

Secondly, for the heat consumers connected to a DH network, there are no equivalent protection as for electricity or natural gas consumers. The few provisions on heat consumption in EU law are limited to toolboxes for incentivising energy efficient buildings and information of the consumer.

Thirdly, on heat supply itself, liberalised market rules such as unbundling, TPA and freedom of choice of the supplier do not apply, due to the small size of DH networks caused by the difficulty to transport heat on long distances. Nevertheless, DH is defined in the 2018 Renewables Directive which also requires Member States to periodically assess the potential for development of these networks and to facilitate their installation. Additionally, the same directive introduces a right for connected customers to disconnect from the network if it does not use enough heat from renewable energy sources or CHP, in order for this customer to produce its own renewable heat. Member States now also have to ensure an average progress of 1% per year of heat from renewable energy sources or CHP in DH or establish a TPA for suppliers producing heat from such sources. This could be called “virtuous TPA” and it starts to submit DH network operators to competition if they do not act for their decarbonisation. However, there are limits to the implementation of these measures, in order to respect the available capacity of the network and the final price for the customers.

Fourthly, EU case law created a duty for so-called ‘essential facilities’ operators to deal with competitors, when there cannot be competition without access to the facility. As DH networks are natural monopolies, this mechanism is likely to apply there and to lead to a negotiated, or if needed a forced access to a network for competitors. Here as well this possibility is limited as competition has to be balanced with the protection of the investments realised in the infrastructure.

Finally, some provisions in the new Electricity and Renewables Directives aim at fostering sector coupling. According to the 2018 Renewables Directive, Member States shall require electricity DSOs to regularly assess the potential for DH to provide balancing and other system services, including demand response and the storing of excess electricity from renewable energy sources, and to evaluate their resource- or cost-efficiency. The 2019 Electricity Directive also tasks the NRAs with facilitating the coupling of electricity, heat and gas networks, and most importantly defines energy storage very broadly. As a consequence, thermal storage can be legally considered as part of energy storage in the electricity system. Therefore, ownership restrictions for TSOs and DSOs active in the electricity sector already apply when an installation stores heat produced from electricity, and in the future, if liberalisation rules are applied to DH networks it is very likely that their operators will be prohibited as well from owning or operating thermal storage, no matter the heat source. If this takes place, measures will have to be taken to preserve small DH networks operators, just as it is currently done with electricity grids on islands or with a limited number of connected customers.

4 National policy and legal frameworks

4.1 Introduction

As already mentioned in the previous section, the main legal frameworks for heat supply are to be found at the national level.
In this chapter, the analyses will focus on the legislation applicable to the heat supply sector at national level, and in particular to the situation in the UK and Denmark. Portugal, although part of the SMILE project, is excluded as the country has very limited number of district heating systems [79], and no heat supply systems have been developed on Madeira within the SMILE project.

On the Orkney Islands (UK), in the framework of SMILE "a variety of different types of technologies [will] be implemented, including […] heat pumps, Sunamp PCM heat battery thermal store, hot water tanks, and batteries" [80]. All of these technologies are individual heating technologies or parts of such systems and the main reason for their deployment is to limit local wind turbines curtailment by switching on and off the decentralised heating systems as storage when excess electricity is available. There are no DH networks on Orkney, although these are used in mainland UK.

In Denmark, the use of DH is widespread. On Samsø alone, some "70% of the heat demand is covered by district heating based on biomass from local resources" [81]. DH is therefore widely used, with four plants on the islands [82]. The remaining heat consumption is provided by individual solutions. As a part of the SMILE project, it is considered to install a large electric heat pump connected to the straw boiler already present in one of the DH plants [83]. This should help to "combine the electricity sector with the heating sector" by using excess power delivered by the local wind turbines and reduce straw and oil consumption for the DH plant [84].

Therefore, on both islands, the SMILE project aims to make progresses into sector coupling between electricity and heat.

Finally, it is to be noted that the rules governing heat supply/DH in Orkney and Samsø are national in scope, and not local. The following paragraphs will thus only focus on the legal framework applicable in the UK and Denmark.

4.2 Heat generation and supply and sector coupling in the United Kingdom

As in the previous section, this paragraph will start with presenting the historical context and policy aspects of the heat supply sector in the UK. This is followed by an analysis of the legal regime governing (i) heat generation and especially CHP and (ii) heat supply, before turning to the elements promoting sector coupling between electricity and heat. Finally, some paragraphs will be devoted to some future developments.

4.2.1 Historical context and policy

In the UK, both CHP and DH have been underdeveloped. There are various reasons for that but Babus'Haq and Probert identified in the 1970s:

(i) the abundance of natural gas at low unit prices as well as the still low price per barrel of crude oil and (ii) the considerable freedom in the choice of fuels for the consumer compared with that prevailing in many other countries. Free-market forces have dictated the policies of successive Governments in this respect and so the responsibility for long-term energy planning has been abrogated [85].

This abundance of natural resources was certainly a major cause back then, however, it seems that at least since the 1990s and up until now, the economic doctrine as well as the lack of long-term thinking, planning and investment became the main cause for CHP and DH being still in their infancy in the UK [86].

As a result, around 14,000 heat networks "(of which around 2,000 are district heating and the rest communal)" were identified across the UK, supplying only "around 2% of all heat demanded from UK homes, businesses and industry" [87]. This figure is supposed to grow to 18% by 2050 "if the UK is to meet its carbon targets cost effectively" [88]. Currently, these DH networks rely massively on fossil fuels and especially on natural gas to produce heat, representing 91% of the heat these networks distribute [89]. These numbers reflect the characteristics of the UK heat supply system, representing "the single biggest reason we use energy in our society", and which is overwhelmingly produced from fossil fuels, with 80% for natural gas alone [90]. As a consequence, "heat is responsible for around a third of the UK's greenhouse gas emissions" [91].

However, this picture could change in the future. According to a 2012 policy document released by the Department of Energy and Climate Change, CHP should be more developed, at industry as much as at household levels, whether connected to a DH network or by the use of micro-CHP [92]. The UK already counts a number of policies supporting high efficiency CHP through its CHP Quality Assurance programme (CHPQA). With this certification, CHP plants can access exemptions from levies and taxes and if they run on renewable energy sources, they can also benefit from support schemes such as Contracts for Difference, "in addition to the commercial value of any heat and power generated" [93]. In 2017, CHP installations complying with the CHPQA programme, labelled "good quality CHP" represented 6.4% of all electricity generated in the UK [94].The same year, "the share of total fuel that was renewable was 16.5[%]", progressing year-on-year [95].

Regarding DH, the potential for expansion is also significant. The same 2012 policy document as mentioned above established that "up to half of the heat load in England is in areas that have sufficiently dense heat loads to make heat networks economically viable" [96]. In these areas, it will then "be less costly and more efficient to connect buildings, communities or industrial sites to a low carbon source through heat networks than to install individual building-level systems" [97]. DH are also "more convenient for consumers than gas boilers, due to a lower requirement for maintenance and repair" [98], and allow to easily replace the heat source or add new ones and therefore to transit heat production to renewable energy sources. Usually, DH networks "start small and expand over time", sometimes until spanning various neighbourhoods [99]. The reason for that is to start with a reduced number of reliable large consumers before to extend step by step the network to gain new clients [100]. However, the high capital cost of developing a DH network is the reason why customers connected to it do not benefit from the same protection as electricity or natural gas customers and cannot easily disconnect from the network nor switch suppliers "in order to provide certainty of returns on large capital investments" [101]. This particular situation in comparison to other energy carriers lead to heat not being submitted to market liberalisation rules in the UK [102], and that is why this section will have to gather the scattered pieces constituting the current framework for heat generation and supply and for sector coupling.

It follows from a 2018 study issued by the Competition & Markets Authority (CMA) on DH networks in the UK that "average prices on the large majority of heat networks […] are close to or lower than the price of the gas comparators" [103]. Additionally, it seems that "heat network customers [are] broadly as satisfied with their heating system as non-heat network customers" [104]. Nevertheless, the CMA highlights that there are some issues with regard to reliability, especially concerning unplanned interruptions [105]. The outcome of this study is thus rather positive on the deployment and operation of DH networks in the UK.

Since the Orkney Islands are situated in Scotland account also needs to be taken of the heat supply policy of the Scottish Government, which has competence over heat [106]. Its main policy document is the Heat Policy Statement Towards Decarbonising Heat, issued in 2015. Here, the Government states that heat "is the biggest element of our energy use (over 55%), and the largest source of our emissions (47%)" [107]. Therefore the policy document aims at increasing the volume of heat delivered through DH, to support the development of these networks through a District Heating Loan scheme and to consider applying a "potential regulatory frameworks for district heating in Scotland" [108]. These elements show, and will be confirmed in the paragraphs below, that the situation of the heating sector in Scotland is no different to the one in the rest of the UK.

4.2.2 Heat generation: CHP legal regime

CHP in the UK is not governed by a single act. Instead, a number of texts apply to planning, development, construction, operation and maintenance of CHP plants as well as their environmental impact. These rules are gathered by the UK Government and published on a regularly updated webpage [109].

The only act exclusively dealing with CHP is the Combined Heat and Power Quality Assurance Regulations 2016, nº 1108, that came into force on 1st January 2017. However, this regulation only amends other existing regulations dealing with support schemes so that they can apply to so-called "good quality" CHP. This concept was already presented above and is linked to the CHPQA and as such provides for access to various tax exemptions and support schemes. The only new element is that Ofgem, the British NRA,

> has put in place arrangements to enable smaller scale electricity generators [using CHP] to gain better access to the electricity supply market and obtain a higher price for their power. This new kind of licence relieves the electricity supplier from being party to various industry codes which are too costly and complex for small players [110].

It follows from the above that heat generation using CHP in the UK is subsidised *via* the concomitant production of electricity. This system amounts to an indirect financing of heat production on installation where it would otherwise be lost. Apart from this, the regime for CHP is no different from the classic regime for electricity production.

4.2.3 Heat supply

Heat supply is currently not regulated in the UK [111]. This means that by contrast to the electricity and gas sector, market liberalisation rules do not apply to heat supply. Although DH networks constitute a natural monopoly, there are no obligations with regard to unbundling and the establishment of independent network companies [112] or third-party access (TPA). And there is no freedom of choice of the supplier for the connected customers either [113].

Despite the absence of a Heat Supply Act, UK law does provide for some rules governing DH. Below we will examine these provisions. Then we will analyse the way in which the heat supply sector is organised and tariffs are being decided on and controlled.

4.2.3.1 The Heat Network Regulations

The main UK law governing heat supply is the Heat Network (Metering and Billing) Regulations 2014, n° 3120. This regulation provides interesting definitions concerning DH networks. First of all, there is a legal difference in the UK between “communal heating” and “district heat network”. According to article 2 of the Regulation,

> “communal heating” means the distribution of thermal energy in the form of steam, hot water, or chilled liquids from a central source in a building which is occupied by more than one final customer, for the use of space or process heating, cooling or hot water.

Therefore, the difference between an individual heating system and a communal heating is that the building heated is “occupied by more than one final customer”. But the heating network is small-scale and only inside a building.

By contrast,

> “district heat network” means the distribution of thermal energy in the form of steam, hot water or chilled liquids from a central source of production through a network to multiple buildings or sites for the use of space or process heating, cooling or hot water.

This definition corresponds to the one provided in subsection 2.2 of this deliverable. It is to be noted that both definitions integrate the cooling purpose, although they only contain the word “heat” in their name. This follows the logic presented in the introduction that cooling is not always mentioned for heating infrastructures but is often an option.

A third important definition is the one regarding heat supplier, which is “a person who supplies and charges for the supply of heating, cooling or hot water to a final customer, through— (a) communal heating; or (b) a district heat network”.

These three definitions together provide the basis for a legal regime for heat supply. Nevertheless, the provisions concerning heat system actors and especially the suppliers are very limited. According to article 3, heat suppliers have to notify to the competent Department (the Department for Business, Energy & Industrial Strategy (BEIS) in general but the Scottish minister in Scotland) which DH network or communal heating they operate. On the basis of this information, the Government can be informed of the total number of DH networks, their location, their installed capacity, the heat generated and supplied, etc. In parallel, article 4 requires heat suppliers to install meters at the premises of all their final customer, except if it is not cost effective and technically feasible.

Apart the above provisions, no other rules apply in the UK for DH networks. The Scottish Government states, “compared to gas and electricity, regulation of heat supply is in its infancy” [114]. In addition, it has to be noted that this 2014 regulation applies to Scotland as well although the responsible authorities are not the UK ones but national ones.

Finally, regarding DH networks planning, "the government has developed a heat map of England, which helps to identify areas of high heat consumption and potential sources of heat supply" [115]. This measure, although helpful for identifying the local potential, still remains an indication with no coercive power.

4.2.3.2 Organisation of district heating companies

In the electricity and the gas sector, the post second World War energy companies were vertically integrated: they had control from the production to the supply of energy, including on the transportation and distribution grids. With the liberalisation of the market since the 1990s in the EU, these companies had to be split in entities either completely separated or at least insulated the one from the other although in the same group. For the heat sector, such measures have not been taken in the UK. Therefore, vertically integrated companies are usually still charged with the task to generate, convey, distribute and supply heat to their connected customers.

4.2.3.3 Price systems and control

Since the heat supply sector is vertically integrated and heat consumers have no choice of supplier, it is relevant to examine how the price of heat is determined. It appears from the above mentioned 2018 study by the CMA that on average the heat supply tariffs set by DH companies "are close to or lower than the price of the gas comparators" [116]. This was already established in 2012 although not as precisely: "there is little evidence of consumers being disadvantaged by the monopoly status of their heat supplier in community heating arrangements" [117].

However, to avoid that customers of DH companies would be forced pay excessive heat supply tariffs, the CMA recommended that some price rules should be established. The two options presented by the CMA are the following:

> (a) cost-based approach – this would set tariffs based on cost (including a reasonable margin); and/or
> (b) benchmark price(s) – examples of benchmark prices include the price of alternative fuels such as gas (including the cost of an individual gas boiler) or electricity. We are recommending a gas benchmark […] [118].

If one of these tariff regimes enters into force and a supplier imposes prices on customers that "deviate significantly from the guidance and principles" [119], then a regulator should adjudicate on the case. The regulator question will be analysed further below in subsection 4.2.3.5.

Additionally, the CMA recommends that DH companies "give due consideration to whole life costs during the design and build phases, and how this is likely to impact prices for consumers" [120], in order to avoid customers having to pay for lack of thorough assessment by the former.

4.2.3.4 Third-party access

As mentioned above, there is no TPA nor freedom to choose a supplier for customers connected to a DH network, although there might be a case-by-case negotiation [121]. The CMA clearly explains the situation in the following lines:

> As such, for many heat network customers, the only practical substitute to being supplied by a heat network is the use of electric heating, which is an expensive alternative. In addition, some heat networks require that customers pay standing charges whether or not they use the heat (ie they are effectively unable to disconnect and terminate their contract). Together, these factors significantly restrict the ability of customers to switch away from their heat network, creating monopoly power for developers and freeholders [122].

As detailed in subsection 4.2.1, DH companies need to ensure a reasonable return on investment and to be incentivised to develop and expand their networks. However, in the future, it is possible that these networks expand continuously and might at some point be interconnected. At this point, regulatory changes will certainly take place in order “to enable connections to take place where the capacity is available” [123], in other words, to implement a TPA regime in these networks which would reach critical size allowing for a degree of competition.

4.2.3.5 Supervision

In the UK, the Office of Gas and Electricity Markets (Ofgem) supervises the application of the legal framework for electricity and gas, but not for heat, where there no is no supervision body [124]. Currently, heat customers are barely protected in cases of excessive pricing or poor service quality as there is no such supervisory authority. They can only address complaints to the CMA [125]. The most advanced system to provide protection to heat customers is the Heat Trust, a “collaboration between industry, consumer groups and government [which] resulted in a voluntary heat customer protection scheme” in 2015 [126]. This standard offers a threshold in “the quality and level of protection given by heat supply contracts and offers heat network customers an independent process for settling disputes” [127]. While this is a positive initiative to fill the absence of regulation, it only remains a voluntary document, to which all suppliers are not forced to abide to. It is therefore not a guarantee of protection for all customers.

For this reason, the CMA recommended to place the heat sector under the supervision of the Ofgem [128]. The regulator would ensure that “all customers of heat networks [are] given a comparable level of consumer protection to gas and electricity customers, irrespective of the size and age of the heat network”, including concerning prices, quality of service, dispute settlement and transparency [129]. An ombudsman should be accessible “with the ability to investigate suppliers and make binding recommendations” [130]. And information should be provided “to allow people to make appropriate decisions when considering whether to live in a property with a heat network and information for heat network customers to understand and act upon their bills” [131].

If this move towards an increased protection for heat customers connected to a DH network might weaken the very secure position of DH companies, it could also increase people’s willingness to be connected to it, as soon as they know they will be better protected. Adding more regulations for the benefit of customers seems a positive endeavor in this case.

4.2.4 Sector coupling

As mentioned above in subsection 3.2.5, on the Orkney Islands under the SMILE project, individual heating systems are pooled together and switched on when the island's wind turbines would be curtailed. This is an example of sector coupling between electricity and heat in the UK through aggregated demand-response.

Currently, there is no legal regime for electricity-to-heat sector coupling, but it is possible to analyse if the definition of energy storage in the electricity system covers thermal storage, as it does in the EU definition [132]. In deliverable D7.1 of the SMILE project, it appeared that a tentative definition was chosen by the Ofgem and should be published soon [133]. In this case, electricity storage would be defined as:

> The conversion of electrical energy into a form of energy which can be stored, the storing of that energy, and the subsequent reconversion of that energy back into electrical energy.

As one can note, at the difference of the EU definition for electricity storage, this formulation does not include the possibility to store and then use electricity under another form. As a result, Power to Heat is not an option under the potential electricity storage definition in the UK. This is not an issue for the SMILE project as no centralised large heat storage is being installed, but on the long run, for the UK, it might be necessary to have a clarification on this point, especially if DH networks will expand as intended and if sector coupling is increasingly used.

Indeed, the British Government already acknowledged that "heat networks themselves can provide seasonal as well as daily storage using large water tanks" [134]. But in 2018, it emphasised that a "wide scale electrification of heating" would create challenges for the electricity system, with possible major impacts on "demand patterns" and "peak loads", a concern for the electric grid management [135]. Consequently, it decided to further study for electric heating

> the potential for flexibility mechanisms to moderate the requirement for additional generation and network capacity, including the potential for inter-seasonal storage, smart systems, demand-side response (DSR) and interconnection to avoid the huge costs of meeting peak demand [136].

The Scottish Government seems slightly more positive on the potential of thermal storage and DH networks for the electricity system and especially the integration of variable renewable energy sources but comes to the same conclusion that more research is needed [137].

4.2.5 Future developments

The UK Government has a clear view on how heat networks should develop in the future:

> Usually, heat networks start small and expand over time, potentially connecting to each other as they grow, creating larger networks that span city centres and a variety of building types. When networks are sufficiently developed, additional heat sources can be connected. As networks become more sophisticated, it may be that customers could have the choice of more than one supplier, making competitive local markets possible [138].

The last sentence connects the technological progresses which might make possible to expand and interconnect DH networks to the viability of establishing freedom of choice of the supplier for customers. In a 2012 study, it is even mentioned that "as networks develop, the operation of the network, heat generation and supply will become more specialised and 'unbundled'" [139]. Eventually, a strong DH network's growth would create the need for a new legal framework for heat supply where the following aspects are dealt with:

- The costs of physical connection and any risks attached to it
- Use of system charges to be levied by the party through whose network the heat flows will pass
- The rights of heat consumers to switch suppliers where alternative sources of heat are available
- Common engineering standards to ensure connection is physically possible
- Cost transparency, whereby the network owner must separate the costs of operating the network from the costs of its own heat supply or generation business [140].

This regime would then be very close to the one applied to the electricity and gas sector.

In the meantime, the CMA recommends to the UK and Scottish Governments to already adopt a "statutory framework […] that underpins the regulation of all heat networks" [141], in order to go further than the mere voluntary standard today available: the Heat Trust. Without going as far as the liberalisation of the sector with separation of the network from generation and supply, the Authority recommends that heat customers benefit from "a comparable level of protection to customers of gas and electricity in the regulated energy sector", with a regulation encompassing "price, quality of service, transparency and minimum technical standards", and a regulator, Ofgem, with formal powers to enforce and monitor these regulations [142]. It seems that these rules would positively apply to both small-size and large DH networks (while a possible extension of liberalised market rules to DH networks would have to be limited to networks connected to a certain volume of customers, to spare small size networks). This new legislation would be welcome by DH connected customers, improving their situation and their rights and increasing trust in this heat supply solution, therefore facilitating a transition towards facilitated heat generation from CHP or renewables and possibly heat storage to support the electricity network in its own transition.

In the following paragraphs, the Danish case will be presented. The analysis is organised in the same way as for the UK in order to easily compare both Member States and the solutions they adopted.

4.3 Heat generation and supply and sector coupling in Denmark

The development of the Danish heat supply sector has been greatly influenced by policy goals of the Danish Government, the energy mix in the country, technical innovation, prevailing market conditions and fundamental changes in society. In order to understand the structure of the Danish heat supply market and the legislation governing heat supply it is, therefore, important to first look at the development of the DH market and the deployment of CHP. Next in this section, the Danish policy frameworks and legislation governing heat generation and supply is presented. Furthermore, because of the recognised benefits associated with integration of surplus electricity in the heat supply sector this section analyses the position that Denmark takes in this regard and the policy frameworks that refer to sector coupling. Lastly, a brief overview of future developments is given.

4.3.1 Historical context and policy

DH is a common method of heat supply in Denmark, especially in densely populated areas. DH systems developed from "small consumer areas with plants taking advantage of local resources: heat recovery from industrial plants, incinerators, heat pumps fed by sewage and cogeneration" [143]. The first DH systems were established in the largest cities in the 1920s where there were possibilities of exploiting surplus heat from electricity utilities [144]. Since the 1950s and 1960s many individual heating systems have been substituted by DH systems [145].

The development of DH did not proceed without adversity. One complicating factor for its development was the change of the Danish energy mix, which greatly influenced the heat supply market [146]. Before the 1970s Denmark was one of the few countries in the world that were almost totally dependent on imported fuels to cover its energy demand [147]. At the time, Denmark was nearly 100 % dependent on oil imports and the larger expansion of DH in the 1960s was based primarily on oil [148]. Due to the oil crisis in 1973-1974 most of the plants producing heat for DH networks converted to coal as primary fuel [149]. In order to avoid similar events in the future, the Government decided to develop its infrastructure and increase indigenous production of natural resources (such as biomass). The raised awareness on energy dependency from abroad led to further actions in order to ensure security of supply and changes to the energy mix by means of increasing the share of energy produced from local and sustainable sources [150].

The development of DH in Denmark is a product of thorough infrastructure planning and implementation of the systems attributed to collaboration between the local energy operators and the local authorities [151]. Through the promotion of the principle of 'green energy first', and the goal to phase out fossil fuels in the electricity and heat sectors [152], the Government prohibited in 2013 the installation of oil-fired boilers and natural gas heating in new buildings [153]. From 2016 it was no longer possible to install oil-fired boilers in existing buildings in areas with district heating. This plan of action demands that DH heat production plants are converted from coal to natural gas and waste incineration [154]. The goal is, furthermore, to rebuild existing power plants to CHP in order to produce both electricity and heat [155].

Denmark is one of the forerunning countries in the EU when it comes to the share of renewable energy in its energy consumption and especially in its electricity mix [156]. Wind power alone produced close to 44 % of the electricity consumed in the country in 2017 [157]. For the future, the Government has set a target of 100 % of its electricity coming from renewable energy sources by 2030 as well as a target of 100 % of its energy being consumed from these sources by 2050 [158]. At present, the Danish heat supply market has a relatively high share of renewable energy supply for space heating, a rather high level of domestic energy resources used for heating purposes and a high level of taxation for fossil fuels used in the heating sector [159]. The widespread use of DH and CHP is one of the most important reasons why it has been possible to increase energy efficiency and reduce carbon emissions over several decades in Denmark [160]. Not only does DH ensure that Denmark has a sound and reliable heat supply, it also greatly supports Denmark in maintaining a sustainable energy sector fulfilling the long-term energy policy targets [161].

4.3.2 Heat generation: CHP legal regime

CHP is recognised in Denmark as one of the most energy efficient and environmentally friendly ways to produce electricity and heat, as excess heat from the generation of electricity is used as DH for buildings in Denmark rather than merely wasting it [162]. The development of the Danish heat supply market resulted in a conversion of several power and heat plants, which provide heat from centralised CHP plants (originally constructed as power plants but converted to CHP plants) or from decentralised plants (originally constructed as heat plants but converted to CHP plants) [163]. Most plants today produce cogenerated heat and electricity and approximately one-third produces heat only [164]. Because of an increased conversion of power stations to CHP plants, more customers are being connected to the DH networks and over 60 % of the Danish DH is cogenerated with electricity saving around 30 % fuel compared to the traditional approach in which heat and power are produced separately [165].

The Danish Electricity Supply Act (*Elforsyningsloven* [166]) regulates the generation of electricity, including large CHP plants and article 1 of the Electricity Supply Act stipulates that the Act shall promote sustainable energy use, including energy conservation and the *use of cogeneration*, renewable and environmentally friendly energy sources. The Act is exclusively applicable to the production, transport, trade and supply of electricity and, thus, not to the supply of heat from these CHP plants. An analysis of the regulation of heat supply is provided in subsection 4.3.3.1.

4.3.3 Heat supply

In Denmark, DH supplies approximately 64 % of the total heat demand primarily in dense areas [167], but also in small towns and larger villages of around 500 households [168]. For example, the Ballen-Brundby district heating plant on Samsø supplies 300 consumers (households, shops, hotels). The role of heat planning is crucial in Denmark, as the following subsection will show.

4.3.3.1 The Heat Supply Act

The most important law in the Danish heat supply market is the Heat Supply Act of 1979 *(Varmeforsyningsloven*) [169]. The Act promotes in its article 1 the most economic and environmentally friendly use of energy for heating and hot water supplies to buildings. The Act regulates in its article 2 public heating supply installations with a heat output of more than 250 kW and CHP units with a heating output of up to 25 MW. For comparison, the size of the Ballen-Brundby district heating plant on Samsø is 1.6 MW. Projects under 25 MW, including electricity generation, approved in accordance with the Heat Supply Act do not require approval under the Electricity Supply Act [170]. Moreover, the Act provides in article 4 the legal basis for the approval by local authorities of project proposals for collective heat supply, including the supply of DH to new areas.

The overall objectives of heat planning in Denmark are: to promote the heating form that brings the most net-benefits to society; to promote the most environmentally friendly heating form (including promotion of CHP); and to reduce the energy supply's dependency of fossil fuels [171]. To reduce the dependency on fossil fuels and ensure the introduction of a higher share of sustainable fuels in the heat supply systems, Denmark implemented a systematic heat planning process separate from the general spatial planning regime [172]. The municipalities are the central players in the planning of collective heat supply. They carry out the heating planning and ensure that the extension of DH and changes in the DH systems are in line with the law on heat supply.

Local authorities are given the power to engage in local heat planning, decision-making on energy infrastructure and resource prioritisation [173]. "Local decision-makers have full authority over local heating system designs, but they do so relying on a centralised policy and a technical framework provided at the national level" [174]. This ensures that DH projects are in line with the overall national ambitions concerning the development of the heating sector [175]. The Danish Energy Agency "developed the legislation and accompanying guidelines, but simultaneously, the evaluation and the decision on the individual heating project are conducted by a local authority with detailed knowledge of local urban development, heat demand and any other relevant local considerations" [176]. Thus, when a DH unit or a DH network is established or a major change is made to an existing system (e.g. a change of fuel, the technical concept or expansion of production) a so-called project proposal must be prepared and sent to the municipality for approval. The project proposal must fulfil certain requirements with regard to the choice of fuels and include socio-economic and environmental analyses of different project alternatives [177]. The City Council then has to approve the project alternative with the largest socio-economic benefits [178].

On Samsø Island it is, therefore, the local authority that makes the final decision on heating planning and expansion of heat supply networks. The main focus of Samsø's energy system lies in the locally produced electricity and the aim to use local resources [179]. There are no centralised electric power plants on the island and the electricity production is solely from wind turbines and PV panels [180]. Consequently, there is no power plant on Samsø that can be converted into a CHP plant (see conversion of power plants to CHP plants in subsection 4.3.2) and at the time of writing, there are no CHP plants developed on the island. Instead, four DH plants have been developed on Samsø, which are connected to one third of the island's buildings and cover 40 % of the island's heating demand. Individual oil and biomass boilers as well as small shares of electric heating, heat pumps and solar thermal cover the remaining heating demand [181]. The DH plants on the island use biomass that is straw from the fields or wood chips from local forestry to heat the water in the system [182]. Being part of Denmark and its ambitious targets for sustainability, DH has become an important cornerstone to supply clusters of heat demands on Samsø [183].

The Heat Supply Act requires in article 28a that heat supply companies perform public service obligations (PSO), which encompasses certain activities such as inter alia increasing the number of households connected to the heat supply networks, rendering advice on rational use to consumers and ensuring secure supply of heat. It is the duty of the district council in cooperation with the heat supply companies and other involved parties to ensure reliable supplies (section 2). According to article 11 and 12, municipalities can require that new or existing buildings within designated DH supply areas have to be connected to the DH network. This effectively means that customers connected are obligated to pay a connection fee and/or a fixed annual fee to the heat supply company, whether or not they use the generated heat [184]. In some cases, there might also be an obligation to actually purchase heat, but if there is not such an obligation, it is possible for the consumer to establish an alternative individual heat supply source, providing that they also continue to pay the annual fixed fee to the public heat supply company [185]. Consumers are actively present in the heat supply market because of amendments to the Act, which impose requirements on consumer representation in heat supply companies that are owned by municipalities through the guarantee of pre-emptive purchase rights at market price (article 23f).

4.3.3.2 Organisation of district heating companies

In Denmark, it is common that municipalities or consumers work together as cooperatives that own the small-scale CHP plants and heating plants [186]. Consumer-owned companies normally hold the ownership in smaller areas whilst the municipalities hold the ownership in larger areas [187]. In 2016, 340 DH companies were organised as cooperative societies owned by the users, 50 were municipally owned and only few were private [188]. On Samsø, one company is owned by the consumers (Ballen-Brundby), one is privately owned, and two are owned by the utility company located on mainland

(NRGi).The construction and operation of heat supply networks is not separated from the production and sales of heat. In Denmark, heat supply is usually organised by a vertically integrated company [189]. By contrast, the owners of electricity and gas supply networks are unbundled from generation and supply, as stated by the Electricity Supply Act [190] and the Gas Supply Act [191], but such requirement is not adopted in the Danish Heat Supply Act.

4.3.3.3 Price systems and control

Heat supply in Denmark must be priced according to actual costs following the implementation of the 'non-profit principle' (article 4). Both DH companies and network operators (if separated, which does not often happen) are considered monopolies and, therefore, not permitted to make profit [192]. The Act stipulates in article 20 that prices may include all necessary fuel costs, wages and other operational costs, research activities, administrative and energy delivery costs as well as costs associated with performing a PSO and the necessary developments of the network [193].

Over the years the regime governing heat supply prices has developed to a more cost-effective regime and the Danish government has introduced voluntary benchmarking, where the maximum limit for the cost-based heat prices are based on an efficiently operating heating plant [194]. The Heat Supply Act requires in article 21 that the Danish Utility Regulator (*Forsyningstilsynet* [195]) validate costs and tariffs. Consequently, the regime does not require a pre-approval by the Utility Regulator but rather authorises it to make changes if tariffs or other conditions are unreasonable or not set according to the rules (article 21.4).

4.3.3.4 Third-party access

Regulated TPA to heat supply networks refers to unlimited access to DH networks and network owners are obliged to allow access to the company that so wishes. However, Denmark applies a negotiated TPA regime in which candidate heat producers (which are often suppliers at the same time) must submit a project plan to the municipality where the DH network is located [196].

Furthermore, the Heat Supply Act provides that access is preferentially granted to the third party who's supply is socio-economically better than the existing supply, as a kind of 'preferential TPA'. In order to ensure a socio-economic advantageous heat production, the Act contains a number of key provisions, including that the municipalities can oblige the owner of a collective heat supply system to prepare project proposals to utilise certain energy forms in the production of heat, i.e. ensure that third parties get access to the network where appropriate [197]. Article 2 of the Act provides that heat production within the potential supply area must be at the lowest possible cost. This means that competitive heat production must gain access to the customers and receive higher priority than the less efficient heat production.

4.3.3.5 Supervision

The name of the energy regulator in Denmark changed the 1st of July 2018 from the Danish Energy Regulatory Authority (DERA) to the Danish Utility Regulator (*Forsyningstilsynet*) [198]. "All tasks carried out by DERA has been transferred to the Danish Utility Regulator" [199]. Its area of competence is large and encompasses the DH sector where it handles complaints of general nature. All DH and CHP units have the obligation to submit information to the Danish Utility Regulator on prices and conditions, so that the authority can deal with complaints and objections. Prices of heat are subject to public supervision and the Heat Supply Act requires in its article 21 that the Utility Regulator validates costs and tariffs. The regime does not require a pre-approval by the Utility Regulator but authorises it to make changes if tariffs or other conditions are unreasonable or not set according to the rules (article 21.4).

The Energy Appeal Board (*Energiklagenævnet*) handles private consumers' complaints about DH companies concerning purchase and delivery of heat (article 26) [200]. The Board deals with complaints concerning the Authority's decisions in individual cases and any possible misinterpretations of the law [201]. Appeals can be made to the Danish Ministry of Energy, Utilities and Climate (*Energi-, Forsynings-, og Klimaministeriet*), the Danish Utility Regulator and the individual municipalities (article 26).

4.3.4 Sector coupling

Energy policy documents in Denmark show interest in different technologies for electricity and heating storage as a part of the flexibility mechanisms for the integration of a higher share of intermittent renewable energy sources into the energy mix [202]. The fulfilment of the policy goal to increase the use of sustainable energy sources in the energy mix increases the challenge of balancing wind and solar power. In Denmark, flexible DH systems help to balance these fluctuations in the power system and thereby support the integration of wind and solar power. According to the long-term 2050 ambitions, a very large share of the electricity and heating generation will have to come from renewable energy [203]. In that respect DH has a great advantage, as it is flexible with regard to both fuels and heating generation technology [204]. Some recognised technologies to improve the flexibility of the DH and CHP systems can help to further integrate intermittent power, such as for example heat storages, electric boilers and heat pumps [205].

If no adequate measures are taken, the integration of a high level of variable renewable energy into the electricity mix exposes the Danish grid to a high risk of malfunction. Therefore, most Danish CHP plants are connected to a heat storage facility to improve the flexibility of the energy system [206]. With heat storage facilities, CHP plants can produce excess heat and store it in the storage unit during the day when the need for electricity is normally high and, thus, production of electricity is high. In the evening, when electricity production is lower and the heat production is lower than the demand, it can simply use the heat energy from the storage [207]. This means that CHP plants optimise their cogeneration according to the electricity demand without compromising the supply of heat. This is a specific asset to the Danish energy system as CHP plants connect the electricity demand to the heating demand through the use of DH systems [208].

One development in Denmark of particular importance in the analysis of sector coupling is that electric heating was banned in 1988 in order to improve efficient utilisation of energy [209]. Subsequently, the ban was specified in the Executive Order on connection for collective heat supply systems (*Bekendtgørelse om tilslutning m.v. til kollektive varmeforsyningsanlæg* [210]) to prevent the installation of electric heating in existing buildings with water based central heating systems that were located in areas of public DH or gas supply. The prohibition applies only if the electric heating is installed as the primary heat source and not as a supplementary heat source (e.g. comfort heating in bathroom floors) [211]. Furthermore, there are a number of exemptions to the regime set out in article 2 and 15 such as for example buildings where it was installed before the ban was adopted (article 2), buildings where it is deemed technologically too expensive to install a central heating system (article 15.1), buildings that are already equipped with renewable energy applications that can cover more than half of the building's energy demand (article 15.2) and low-energy buildings (article 15.6) [212]. Moreover, the City Council may grant exemptions in special cases (article 17) [213]. The ban on electric heating has been loosened up in the last couple of years following the intention of the Government to reduce the taxes on electricity and electric heating, and to make electricity more competitive with other fuels [214].

In the energy policy document of Samsø, called 'Samsø Energy Vision 2030', the aim is to reach 100 % renewable energy use by 2030. In this document, thermal storage is mentioned as an important storage technology. One of the most relevant references is :

> Electricity storage is ~100 times more expensive than thermal storage, while thermal storage is ~100 times more expensive than gas and liquid storage. Therefore, where possible, it is important to connect wind and solar to these cheaper forms of storage energy (i.e. thermal, gas, and liquid) rather than the much more expensive electricity storage [215].

Accordingly, there are no prospects for development of electricity storage [216]. On the contrary, thermal storage is recognised as an important and economically viable form of energy storage. The electricity that Samsø currently exports could be integrated into the local system and replace other fuels and, thus, a connection of the electricity and heating sectors could provide relatively cheap storage possibilities [217].

The history shows that heat and electricity supply systems have become more and more integrated over the last decades. This is especially true when looking at the increased production of CHP and the construction of thermal energy storage capacity to balance the daily and weekly imbalances between heat and electricity demands. Regardless of this development, no regulating mechanisms governing the use of electricity and heat storage have been adopted in the Danish electricity and heat supply laws.

4.3.5 Future developments

The structure of the Danish heat supply system has changed considerably, with a shift away from individual oil boilers towards collective systems such as DH. Heat is still produced using fossil fuels but is increasingly being produced by using renewables. The transformation towards a fossil free energy sector also creates challenges to the heat sector and not the least to the DH and CHP sectors, since increased utilisation of renewable energy sources for heating purposes – especially using CHP plants – makes the heating sector dependent on the production of electricity. CHP plants are expected to take on a new role in the overall energy system, acting rather as medium-load facilities and back up capacity than as base-load facilities [218]. This development is expected to increase the costs associated with heat losses and maintenance of heat supply networks. Consequently, some areas might benefit economically from using individual heating solutions and an analysis of DH in future energy systems examines whether DH should be expanded or possibly restricted in the period up until 2035 [219].

Moreover, electricity is increasingly used for heating purposes using heat pumps while CHP plants and wind energy fluctuations are expected to determine when heat should be produced. Therefore, heat storage is included in future scenarios. Heat storage plays an important role in the intelligent electricity system in order to include wind power. Electricity storage in Denmark is, however, not foreseen for the future as "the use of the electricity market (hydroelectric power stations abroad) is cheaper" [220]. As a consequence of these considerations, a transition of the Danish heat supply sector is again taking place to reach the policy goal to be independent from fossil fuels and the developments analysed will challenge not only the technology but also the economics and regulation of heat supply networks.

Whereas competition has been introduced in the Danish gas and electricity sectors, competition has not been implemented in the Danish heat supply sector. The studies carried out by the Energy Agency, starting in 2014, analysed appropriate legislative measures to increase competition also in the heat supply sector [221]. Taskforces were assigned to examine whether or not to amend the ownership structure in the heat supply market and the price regulation. Some amendments to the price regulation regime have already been introduced, e.g. the benchmarking system to increase efficiency in the heat supply market [222]. The introduction of a regulated TPA regime in the heat supply market is also examined following recent investigations to introduce a regulated TPA regime in the Swedish heat supply market [223]. In Denmark, it is possible that the strengthened strategic energy planning, outlined in the Energy Agreement of 2012 [224], creates a better basis for ensuring that all heat sources – access for third parties - are utilised in DH networks, which *per se* entails enhanced TPA to the heat supply networks [225]. Currently, heat supply networks are not connected but rather operate as local separated 'islands' and do not create the possibility of free trade. However, with technological developments, energy efficiency improvements, more variable energy sources and climate change considerations, considerable changes can be expected in the Danish heat supply policy in the future.

One development of particular interest on Samsø is the investigation to interconnect three of the existing individual DH networks on the southern part of the island in order to harvest operational benefits from a larger network [226]. Benefits associated with the interconnection of these DH networks are the sharing of production capacity across the existing networks and a larger thermal storage. For developments of this kind it is important to emphasise that the introduction of a regulated TPA regime to heat supply networks could benefit the utilisation of more local energy sources, but could also threaten the investments realised to develop the current networks in the first place. As of now, there is no law in Denmark regulating the ownership of thermal storages but with recent developments at the EU level (see section 3.2.5) there is a probability that owners of DH networks of a certain size will at some point be prohibited to operate heat storage facilities. This will have, just as for the UK case, to be assessed and if implemented, exemption measures will probably have to be adopted for DH networks under a certain size (and especially the ones on islands, where population is usually reduced and the possibility for extension and interconnection very limited).

4.4 Summary

The level of development of DH networks varies strongly between the UK and Denmark. While in the former it represents supplies only 2% of all the heat demand, in the latter it accounts for over 60% of the total heat demand. This situation has historical origins with a long-time commitment of Denmark for CHP and DH. This gap between the two countries also explain the difference in the depth of the regulation on both shores of the North Sea.

In the UK, the heat supply is not regulated nor submitted to liberalisation market rules (which apply to electricity and natural gas). As a result, there is no unbundling, TPA nor freedom of the choice of the supplier, but there are also no price regulation nor supervision of the market. A single regulation, from 2014, applies exclusively to DH networks, but only to provide some interesting definitions and to push forward the deployment of heat meters. However, the competition authority recommended in 2018 to implement soon a set of measures to offer to heat customers the same protection as for electricity and gas customers. This should translate by Ofgem, the existing NRA for electricity and gas, to supervise the heating supply sector, by the definition of cost-based or benchmark prices for heat, by quality of service requirements and controls, dispute settlement options and transparency rules. On sector coupling, the tentative definition adopted by Ofgem for energy storage in the electricity system does not including electricity conversion and use as another energy carrier. Therefore, it might be important at some point to clarify the legislation applying to large-scale facilities storing heat produced out of electricity. For a wide scale electrification of the heating system, the UK Government proposes, with reason, to conduct more studies in order to better assess the potential impact on electricity grids (as it can help balancing the network but also increase peak load).

In Denmark, liberalised market rules do not apply to DH either. However, the regulation of the sector is much more develop than in the UK. A price control mechanism exist, mixing a cost-based model built on the 'non-profit principle' with a benchmarking referring to an efficiently operating heating supply. A kind of 'preferential' TPA is implemented, where candidate producers/suppliers have to negotiate their access to the network with the municipality but will be preferred if they provide socio-economically better supply than the existing one. Furthermore, the NRA dealing with electricity and natural gas is also responsible for heat, controlling prices and conditions and offering dispute settlement. On sector coupling, a policy change is currently taking place as electric heating which was banned from building during the past 30 years is being reintegrated in order to facilitate the integration of excess renewable energy sources into the electricity system. In Denmark, electricity storage is not defined and not perceived as a solution for the future, at the difference of thermal storage. In this sense, a legal framework is missing for thermal storage based on electricity conversion.

For the longer term, liberalised market rules could be considered for DH networks in both the UK and Denmark, if technological progresses allow to transport heat on longer distances and interconnect various densely populated areas. In this case, exemption rules should be adopted as well for small size networks supplying a limited number of customers, just as for electricity networks. Islands, usually with small populations and very limited possibilities for interconnection, should in this case definitively benefit from such a facilitated regime.

5 Conclusions and recommendations

This deliverable presented rules regarding the production and supply of heat in the EU, in the UK and in Denmark as well as the options for integrating electricity and heat supply for facilitating the transition to renewable energy sources in the energy system. As it is, although heating and cooling represent half the total EU energy consumption, there is no harmonised regime at this level. Each Member State therefore developed its own regime, with different rules and a strongly fluctuating penetration rate for district heating (DH) and/or combined heat and power (CHP).

In the following paragraphs, the conclusions and recommendations arising from the SMILE project are presented organised by theme: specific consumer protection rules, liberalisation of the heat supply sector, sector coupling, and the role of municipalities in DH networks development.

5.1 Consumer protection rules for heat customers

At the EU level similarly as in the UK, heat customers do not benefit from the same protection as their electricity and gas counterparts do. They only benefit from general consumer protection law but not from a specific regime. Actually, these customers are often captive, cannot freely disconnect from a DH network and may be subject to excessive prices without proper solutions to avoid them. However, proposals have been made in the UK to implement regulations and control (by the existing NRA for electricity and gas, Ofgem) on prices, quality of service and transparency, and to provide dispute settlement mechanisms specifically for heat. In Denmark, these provisions already exist and participated to the widespread success of DH networks.

- **Recommendation 1**: The EU should provide some legal guidance, for example through a Heat Supply Directive to guarantee that heat customers connected to a DH network benefit from the same protection as electricity and natural gas customers. This document should include the obligation for Member States to appoint an NRA for the heat supply sector which would control the prices, can revise them if excessive, supervise quality of service, ensure transparency and provide a dispute settlement mechanism for customers and electricity producers/suppliers alike.

5.2 Future extension of liberalised market rules to the heat supply sector

At some point in the future, it may be possible to transport heat over longer distance, hence connecting densely populated areas and creating nation-wide or even cross-border markets. In this case, liberalised market rules could be applied to the heat supply sector, as it would have reached critical size and could accommodate a variety of suppliers. Then, it would be possible to unbundle DH companies, separating production and supply from transportation and distribution networks operation, to implement third-party access (TPA) and freedom of choice of the supplier in order to introduce competition into heat production and supply. Nevertheless, this development should include adapted exemptions.

- **Recommendation 2**: If in the future it is deemed possible to impose the liberalisation of the heat supply sector, then exemptions will have to apply as they do today for the electricity sector. The exemptions for the electricity are listed and explained in deliverable D7.1 of the SMILE project but two cases already seem to justify a specific treatment for heat supply. If a

DH network supplies less than a certain number of connected customers (100,000 for electricity), then some liberalisation rules could be derogated to. If the network is located on an isolated territory, such as an island, then this could apply too, as these areas are usually sparsely populated and very difficult to interconnect to other DH networks.

- **Recommendation 3**: The EU has introduced the principle of a 'virtuous TPA' with the 2018 Renewables Directive where suppliers producing heat from renewable energy sources or CHP can automatically gain access to DH networks where the operator is not active enough in its transition to the use of renewable energy sources (with some limits, such as network capacity and final price). Denmark has implemented a mechanism comparable to some extent in order to incentivise 'socio-economically better supply' than the existing one. Member States are incentivised to make full use of the 'virtuous TPA' mechanism implemented by the 2018 Renewables Directive in order to provide experience on the introduction of a limited TPA into heat networks.

5.3 Rules for sector coupling through thermal storage

Sector coupling through integration of heat and electricity systems is seen as a necessary evolution of the energy system in the EU, in the UK and in Denmark. Thermal storage (from large-scale to small-scale aggregated) can help a lot to provide flexibility and balancing services to the electricity network, especially when excess power from renewable energy sources might otherwise be curtailed. Currently, energy storage in the electricity system is defined by the 2019 Electricity Directive and includes conversion of electricity to another energy carrier (including heat), which is a positive outcome. However, this broad conception also creates an unclear legal situation when a thermal storage facility connected to a DH network stores heat produced from electricity as it ends up at the connection point between a liberalised and a non-liberalised regime. In the UK and in Denmark the situation is even worse, as the UK's tentative definition for energy storage in the electricity system does not include conversion and as Denmark as no definition whatsoever.

- **Recommendation 4**: The definition for energy storage in the electricity system should be harmonised in the EU when the 2019 Electricity Directive will be transposed in the Member States (for the UK, it depends from the realisation or not of the Brexit). Once this happens, it will be necessary to have a reflection on the long term on the role and regulation of thermal storage in supporting the electricity network and more specifically on which entity can own and operate it. Indeed, electricity TSOs and DSOs are already prohibited to own or operate energy storage and this applies to thermal storage too. However, if liberalisation applies at some point to DH, then the same question will apply for DH network operators which would be willing to own or operate thermal storage.

5.4 District heating network development competence to municipalities

In Denmark, the development and the operation of DH networks relies on municipalities, as they benefit from extended competences in this field, such as authorising or rejecting access to the network for a candidate third-party supplier. This model of proximity has proved efficient in view of the deployment of DH in Denmark (though this is not the single factor). The transposition of the Citizen and Renewable energy communities provisions from the 2019 Electricity and 2018 Renewables Directives also have the capacity to reinforce the proximity aspect of heat generation, supply and storage.

- **Recommendation 5**: If it is not already the case, Member States are recommended to let the bulk of the competences needed for planning, developing and managing DH networks to municipalities or provinces as they know better their local territory, and to support them in this endeavour (such as financially or with expertise).

- **Recommendation 6**: The new Citizen energy communities could play a role in supporting the electricity grid via the heat supply system, for example through aggregated heat load or thermal storage, both powered by electricity (art. 11 (c), 2019 Electricity Directive). The new Renewable energy communities could also enhance heat production from renewable energy sources, through production, consumption, storage and sale of this energy, or by sharing it within the community (art. 22 (2), 2018 Renewables Directive). In the latter, Renewable energy communities could become heat suppliers and access an existing DH network or build their own. It is recommended to Member States to implement a voluntary legal framework for these energy communities when transposing the Directives, in order to support their development in the heat supply system and incentivise locally driven sector coupling.

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