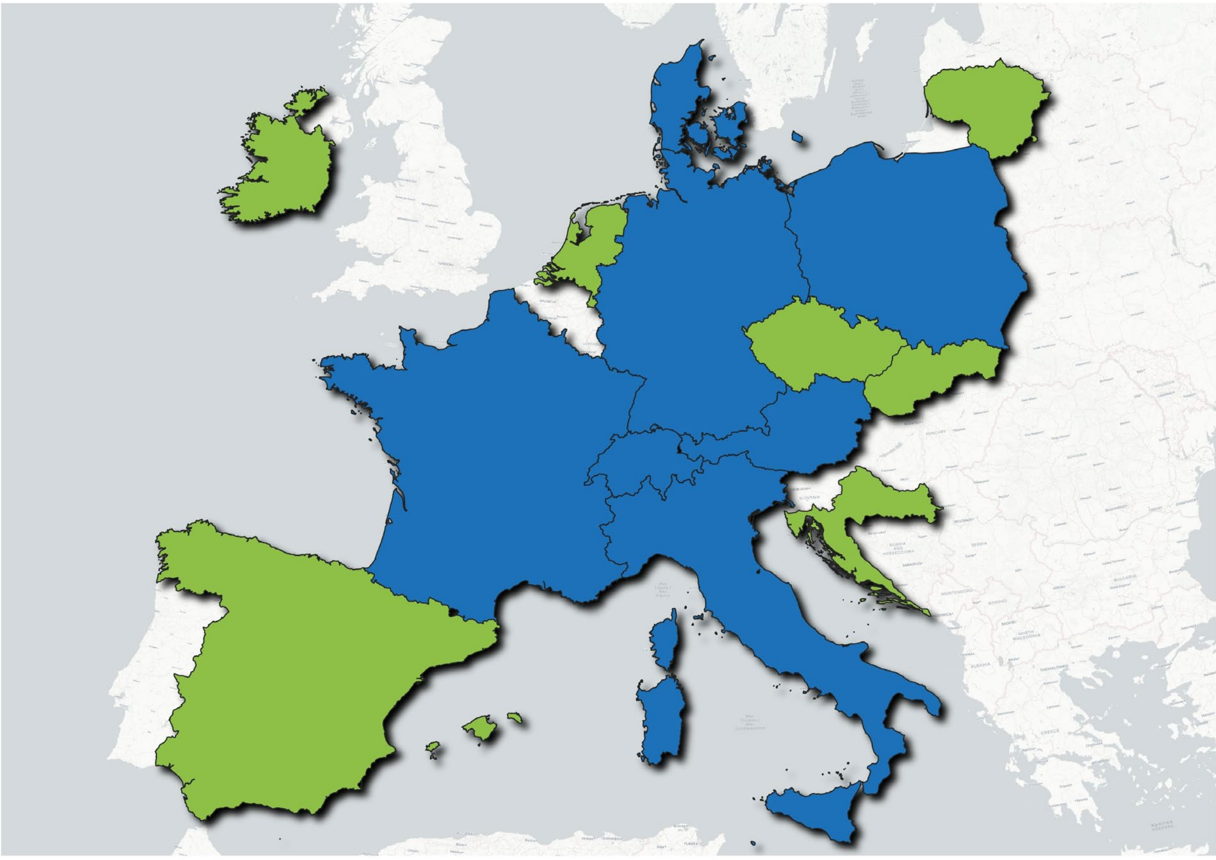
RES DHC

Renewable Energy Sources for District Heating and Cooling

Transformation of existing urban district heating and cooling systems from fossil to renewable energy sources

Renewable Energy Sources in District heating and Cooling

EU Level Survey



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1. SCOPE

This survey covers district heating and cooling (DHC) networks in the European Union and addresses relevant aspects impacting renewable energy sources in district heating and cooling systems (RES-DHC) at EU level. More detailed analysis focusing on the national and regional level of selected EU regions will be described in the regional surveys also being carried out under Task 2.1 of the RES-DHC project.

The EU survey identifies 7 countries outside the consortium and regional survey countries with high potential for RES DHC. This potential is characterised in two different ways:

(1) countries which currently have a small number of DHC networks, with the potential to quickly and successfully increase the share of renewables in their DHC mix by deploying modern DHC networks; and

(2) countries where DHC networks are already established and the renewable share of DHC is low have the potential to achieve very high shares of renewables in their DHC mix, by transforming and decarbonising existing networks towards more efficient systems with renewable heat sources.

2. SOURCES OF INFORMATION

This survey has taken information from reports, previous surveys and database entries from previous projects and relevant organisations active in the heating and cooling sector. All information sources are referenced in Table 1.

Source type	Author	Title	Link
Report	Aalborg University	Business Cases and Business Strategies to Encourage Market Uptake (2018)	https://vbn.aau.dk/ws/portalfiles/portal/290997081/HRE4_D7.16_vbn.pdf
Resource database	Celsius	Celsius toolbox	https://celsiuscity.eu/toolbox/
Database	Cloudscene	Data centre markets	https://cloudscene.com/browse/markets
Article	Danish Energy Agency	Danish Experiences on District Heating	https://ens.dk/en/our-responsibilities/global-cooperation/experiences-district-heating
Report	ENTRAIN Project	Guidelines for the Simplified Evaluation of the Potential for Renewable Heat	https://www.interreg-central.eu/Content.Node/ENTRAIN/Guidelines-for-evaluation-of-renewable-heat-potential-[ENG].pdf
Report	Euroheat & Power (EHP)	Country by country (2019)	https://www.euroheat.org/cbc/2019/
Database	Euroheat & Power	Country Profiles	https://www.euroheat.org/knowledge-hub/country-profiles/
Database	European Commission	Eurostat Energy statistics	https://ec.europa.eu/eurostat/web/energy/data/database
Report	European Commission Joint Research Centre (JRC)	Decarbonising the EU heating sector (2019)	https://ec.europa.eu/jrc/en/publication/decarbonising-eu-heating-sector-integration-power-and-heating-sector
Database	Eurostat	Renewable energy for heating and cooling (2020)	https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20200211-1#:~:text=In%202018%2C%20renewable%20energy%20accounted,when%20the%20share%20was%2012%25
Report	Heat Roadmap Europe	Main Report and Heat Roadmaps by Country	https://heatroadmap.eu/roadmaps/
Report	Heat Roadmap Europe	Towards a decarbonised heating and cooling sector in Europe (2019)	https://vbn.aau.dk/ws/portalfiles/portal/316535596/Towards_a_decarbonised_H_C_sector_in_EU_Final_Report.pdf
Policy Paper	International Energy Agency	District Heating and Cooling: Environmental Technology for the 21st Century (2019)	https://www.iea-dhc.org/the-technology

Report	International Energy Agency	Share of renewable energy in district heating networks 2018 (2020)	https://www.iea.org/data-and-statistics/charts/share-of-renewable-energy-in-district-heating-networks-2018
Database	International Energy Agency	Share of renewable energy in district heating networks (2018)	https://www.iea.org/data-and-statistics/charts/share-of-renewable-energy-in-district-heating-networks-2018
Report	REWARDHeat	PESTLE analysis	No yet published: https://www.rewardheat.eu
Report	RHC-ETIP	Inventory of funding instruments (2020)	https://www.rhc-platform.org/content/uploads/2020/10/Deliverable4.2.pdf
Report	RHC-ETIP	Strategic Research and Innovation Agenda (2020)	https://www.rhc-platform.org/content/uploads/2020/10/RHC-ETIP-SRIA-2020-WEB.pdf
Report	RHC-ETIP	Vision for 100 % renewable heating and cooling in Europe (2019)	https://www.rhc-platform.org/content/uploads/2019/10/RHC-VISION-2050-WEB.pdf
Report	ReUseHeat	Market and stakeholder analysis (2019)	https://www.reuseheat.eu/wp-content/uploads/2019/03/D2.1-Market-and-stakeholder-analysis.pdf

Table 1: Sources of Information

3. STATE OF THE ART & MARKET

The heating and cooling sector represents half of the energy consumption of the EU, 75% of which is supplied by fossil fuels. Buildings (including residential and services sector) make up the largest share of total final energy consumption – accounting for 40%.[1] The breakdown of the energy consumed in buildings for heating and cooling is shown in Figure 1. District heating plays a minor role, supplying around 11% of the final energy for heating and cooling of buildings.

Currently, approximately 60 million EU citizens are served by district heating (DH), with an additional 140 million people living in cities with at least one DH system. 11% of the EU space heating demand is supplied by district heating networks, but there are large differences at country level. Figure 2 maps the district heating share in the fuel consumption for space heating in 2015 in the 27 member states (MS). In Annex 1 the countries and corresponding district heating shares are listed.

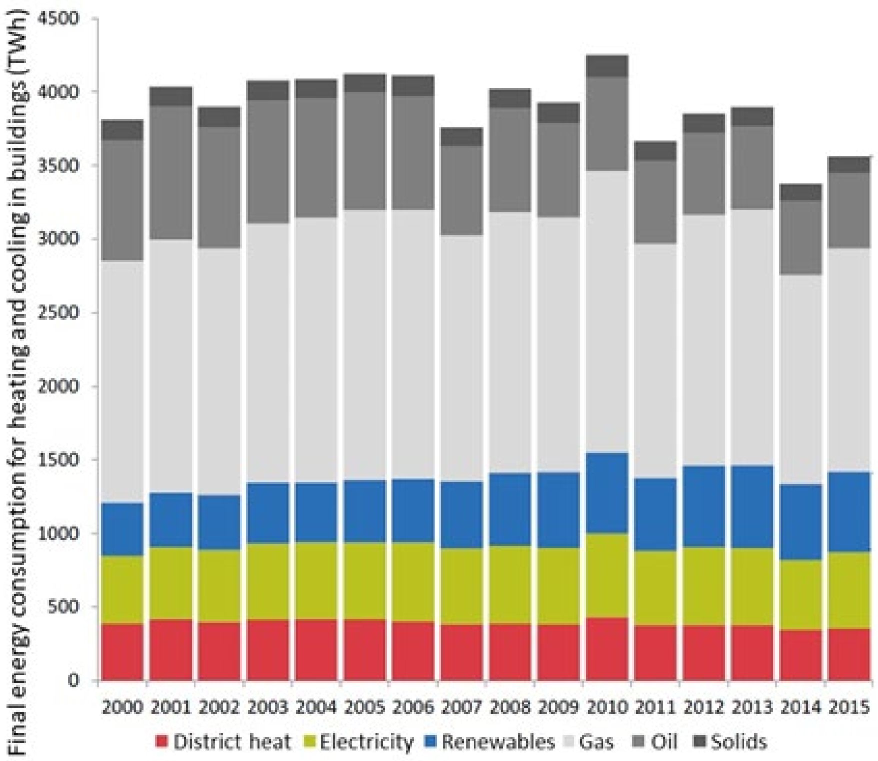

Figure 1: Historical development of fuel consumption for heating in the EU. (Image from: JRC (2019): Decarbonising the EU heating sector.)

[1] JRC (2019): Decarbonising the EU heating sector.

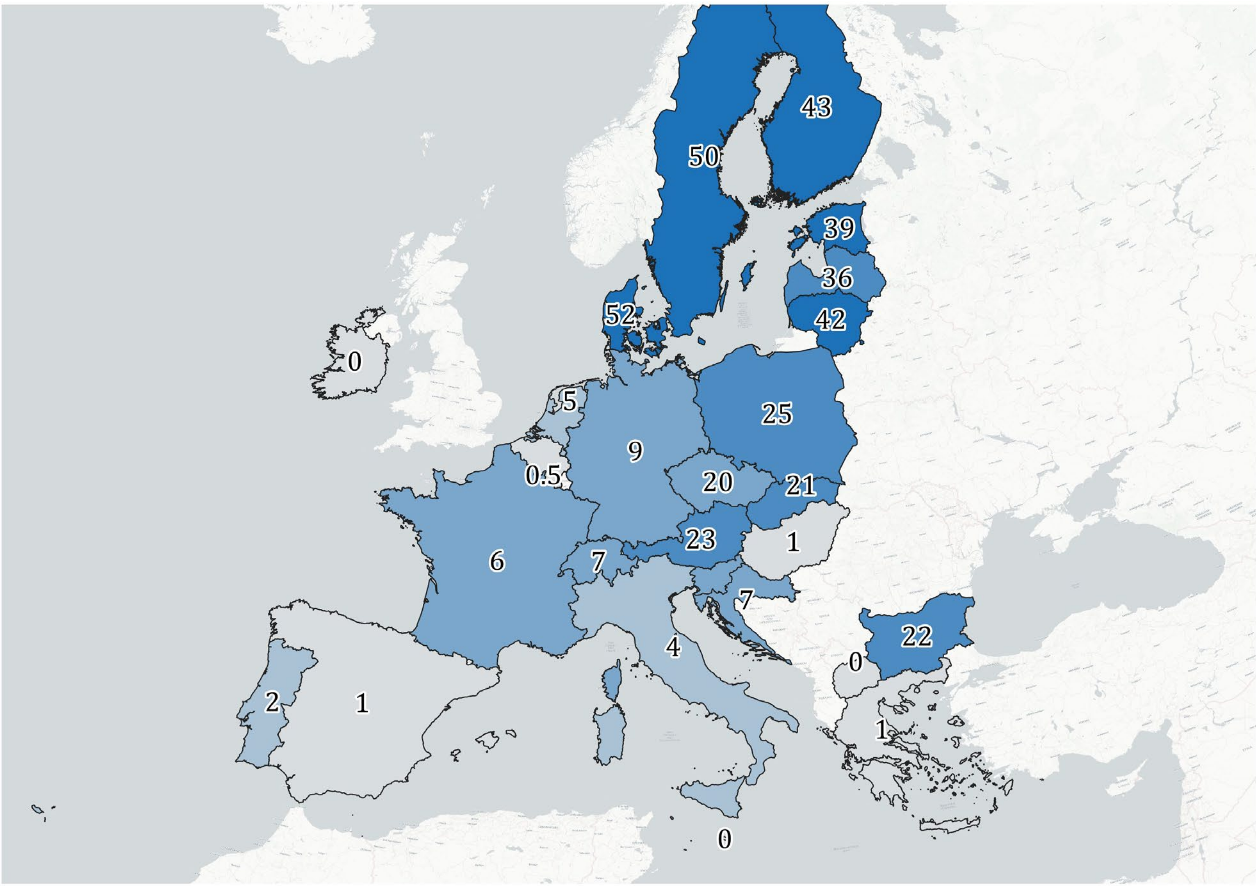

Figure 2: Percentage share of district heating in energy consumption for heating (2015).
Image: Hamburg Institut. Source of data used: JRC (2019): Decarbonising the EU heating sector.

Denmark, Sweden, Finland, Lithuania, Estonia, and Latvia have the highest **market shares of district heating**. On the lower end of the scale: Malta, Ireland, Cyprus, Belgium, Hungary, Spain, and Greece have district heating market shares of 1% or less.

Renewable shares in the heating sector also vary between the countries from around 6% (Ireland and Netherlands) to 65% in Sweden. On average, renewable energy accounted for 21% of the total energy used for heating and cooling in the EU. The countries are mapped in Figure 3 and the individual country shares are listed in Annex 1. The predominant renewable energy source for heating is biomass, accounting for 12% of heat consumption – largely used in inefficient stoves and boilers.

The **share of renewable energy sources in the generation of district heat** (subsequently referred to as **RES DHC**) is presented in Figure 4. The Netherlands has the highest share of RES DHC (80%), but DH holds a minor overall market share of just 6%. Sweden, Lithuania, Denmark, and France also show high renewable shares in their district heat. For several countries, no data could be obtained.

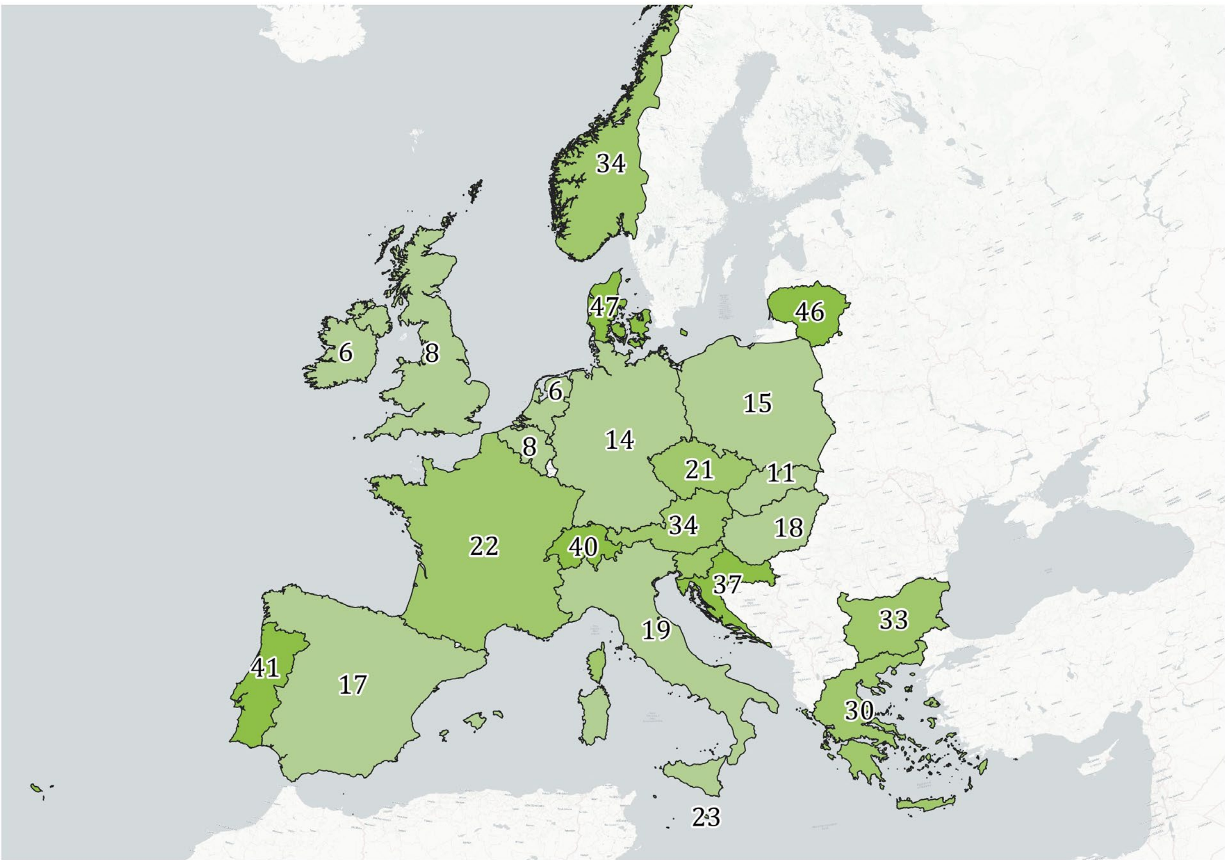

Figure 3: Share of renewable energy in gross final energy consumption for heating and cooling 2018. Image: Hamburg Institut. Source of data used: Eurostat (2020): Renewable energy for heating and cooling.

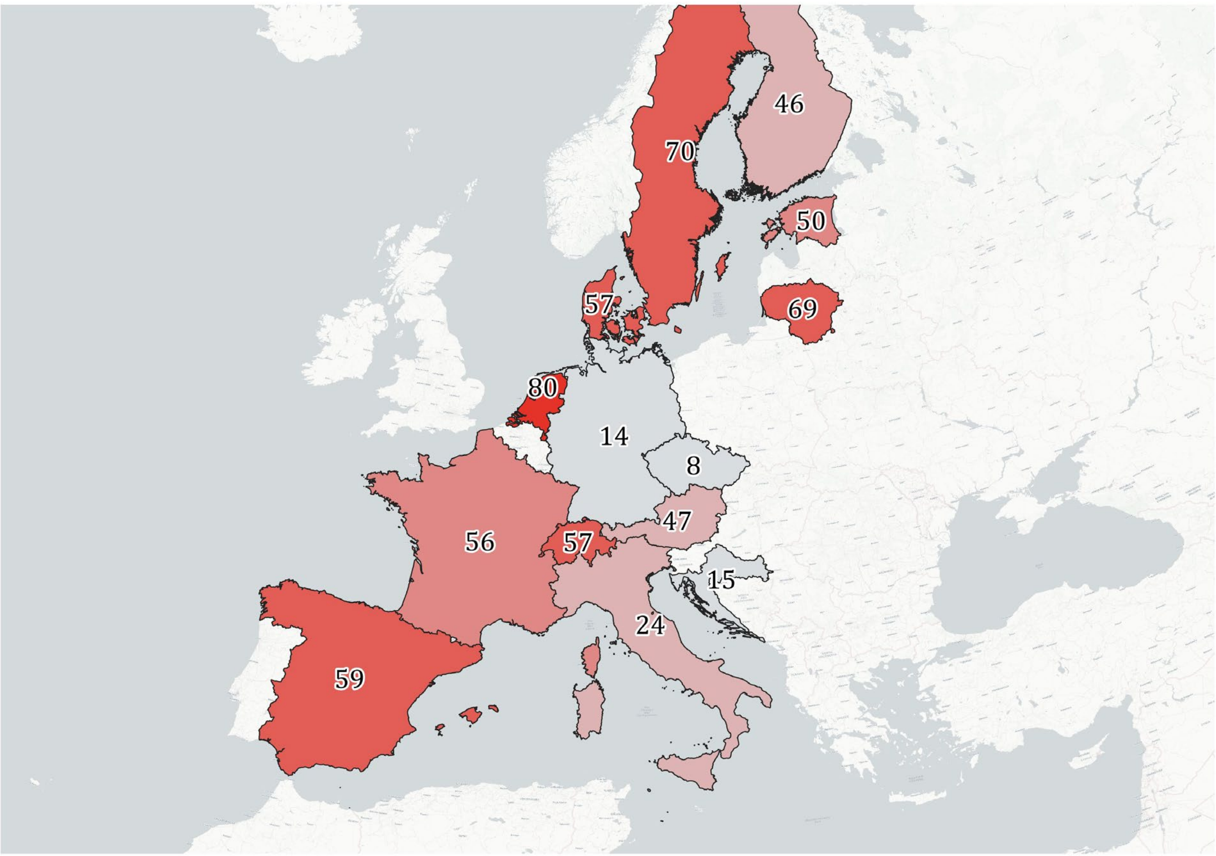

Figure 4: Share of renewable energy in generation of district heat. Image: Hamburg Institut. Data: EHP Country by country; IEA (2020).

Today, 4th generation DH (4GDH) is emerging as a new system to replace the existing 3rd generation DH. 4GDH is also known as low-temperature DH (LTDH). Benefits are delivered both in heat distribution and heat generation. On the distribution side, network heat losses, the risk of scalding and thermal stress are all reduced, while the quality match between heat supply and heat demand is improved. On the heat generation side, lower network supply and return temperature helps improve combined heat and power plant power to heat ratio and recover waste heat through flue gas condensation, achieves higher coefficient of performance values (efficiencies) for heat pumps, and enlarges the utilisation of low-temperature waste heat and renewable energy. For the integration of renewable energy sources and waste heat in district heating systems, existing DH systems must be transformed into more modern systems.

Good examples of 4GDH are found in the Scandinavian and Baltic countries with high shares of renewables integrated into efficient low-temperature DH systems. Eastern, South-Eastern as well as some Central European countries have more inefficient DH systems designed for higher temperatures supplying an inefficient building stock. In these countries, the challenges are greater: They have to establish new 4GDH systems, expand, and transform existing DH systems (1st or 2nd generation) towards higher efficiency and more renewable sources, as well as improve the energy performance of the building stock.[1]

RES-DHC constitutes an enabler and driver of the deployment of renewable heating and cooling technologies (RHC). More intensive deployment of RHC is possible. Potential development pathways for decarbonising the heating and cooling sector are shown in Figure 5. Two scenarios for decarbonising the heating and cooling sectors by 2040 are shown (50% and 100% decarbonisation). The full RHC scenario is ambitious, but feasible with proper support measures at member state- and EU-level, particularly if electricity taxation and fossil fuels subsidies are tackled alongside the provision of support for R&D.

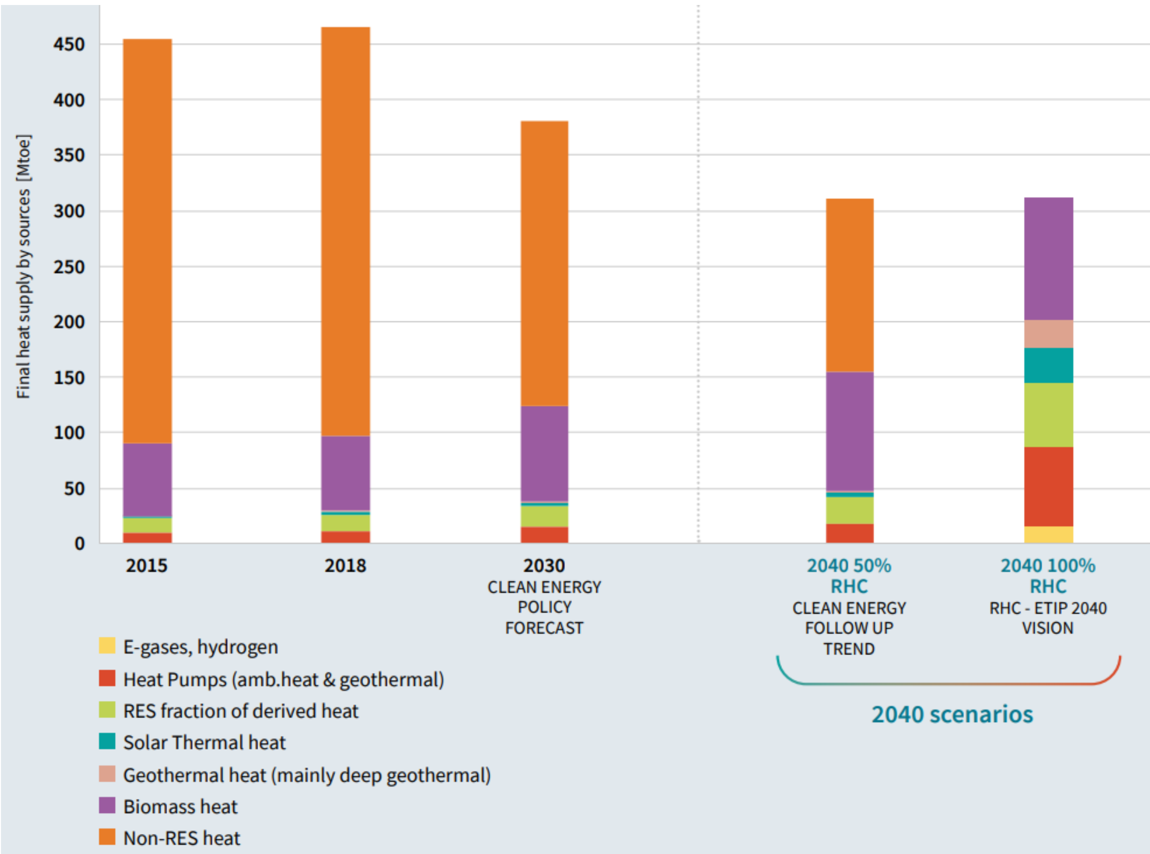

Figure 5: Heat production by sources and use. Image: Renewable Heating and Cooling – European Technology and Innovation Platform (2020): Strategic research and innovation agenda for climate-neutral heating and cooling in Europe.

[1] Towards_a_decarbonised_H_C_sector_in_EU_Final_Report.pdf (euroheat.org)

The DHC state of the art revolves around applying new technology e.g. AI, optimising existing technology, optimising the transport of energy, efficiently planning and deploying the networks using the latest modelling/data, integrating energy storage and reversible heat pumps, and adapting to local renewable resources like biomass, solar thermal and geothermal energy. Renewed investment is needed to ensure the transformation of existing DHC networks and a higher penetration of new and smart networks in heating and cooling markets, contributing to the decarbonisation of the European heating and cooling sector.

4. STAKEHOLDER ANALYSIS

When considered at EU level, there are a wide variety of stakeholders involved in the development of the RES-DHC market. Europe is a world leader in renewable heating and cooling technologies, and while economic and political developments at European level have an impact on the RES-DHC market, heat generation, supply and consumption are characterised by their local nature. Unlike the electricity and gas sectors, the heating and cooling sector is deregulated; significantly impacted by local conditions and involves a variety of local actors, with often diverging interests. The regional surveys produced by the RES-DHC project (Tasks 2.1) will provide an in-depth analysis of the local stakeholders involved in each of the selected regions. This survey will characterise the relevant stakeholders at EU level and will provide a general summary of the more localised actors, in an effort to describe the norm in EU countries.

The **institutions of the European Union** (Commission, Council, Parliament, BEI, FEI) set the research agenda through the definition and strategic planning of the Horizon Europe programme and other funding instruments for research and innovation. These funding programmes, aided by stakeholder consultations, outline what research actions and technologies will be funded, and get innovative renewable energy projects off the ground. As part of its work programme, the European Commission develops strategic documents that communicate the research priorities of the current programme, to all relevant stakeholders including the Heating and Cooling Strategy (2016) and the Energy System Integration Strategy (2020). The European Parliament influences both the research agenda and the RES-DHC market through policy directives and packages such as the Renewable Energy Directive, Energy Efficiency Directive and Clean Energy for All Europeans Package, that outline specific energy targets.

Member States and national governments influence the development of the RES-DHC market within their borders primarily through their National Energy and Climate Plans (NECP) and public expenditure. NECPs outline how each country plans to address energy efficiency, renewables and greenhouse gas emissions, in line with EU climate targets. Countries can promote RES-DHC by setting high targets for thermally-driven renewable heating and cooling. National governments can also develop their own action plans and funding programmes to develop DHC, as seen in Denmark in the 1970s in response to the oil crisis and more recently in the Netherlands, as part of efforts to phase out natural gas.

The **renewable heating and cooling industry** influences the market through internal R&D strategies, joint initiatives and collaborative projects. At European level, the industry is represented by the **European Technology and Innovation Platform on Renewable Heating and Cooling**, which brings together stakeholders from the biomass, geothermal, solar thermal and heat pump sectors – including the related industries such as district heating and cooling, thermal energy storage, and hybrid systems – to define a common strategy for increasing the use of renewable energy technologies for heating and cooling.

International and national energy companies are involved through heat supply and/or grid operation. These companies own and operate large scale thermal plants that are traditionally used to supply heat to networks across Europe and they may also own the DHC network. Due to the local nature of heat, **municipalities and city stakeholders** can play a major role in the RES-DHC market. Strong involvement of local authorities supports the implementation of such projects; and cities are well placed to design low-carbon pathways including a district energy strategy that considers societal, environmental and economic benefits.

Consumers across Europe can impact the RES-DHC market by supporting the continued decarbonisation of the heating and cooling sector and by taking on a more active role in the system e.g. by becoming prosumers or forming energy communities. It is important to maintain consumer confidence and comfort as the DHC sector moves away from fossil fuels towards a decarbonised, low-carbon heat supply. A crucial aspect is the heat price, when compared with individual and traditional solutions.

5. FINANCING & INCENTIVES

DHC and renewable energy projects can be funded in many different ways, using both R&D funding and private financing. In this section, the core financing instruments at EU level, that provide funding for RES DHC, are presented.

Each project is different, so there is no ready-set solution, but there are European programmes and investment funds, as well as national funding instruments, specialized in getting RES-DHC projects off the ground. A comprehensive analysis of the national funding instruments available to support RES-DHC is outside the scope of this survey. The regional surveys produced by the project will provide information on the national schemes available in the selected regions.

Public funding on EU level

Further information can be found in the Inventory of funding instruments[1]. According to this inventory, there are an estimated 26 funding instruments at EU level, outlined in **Annex 2**. At European level, DHC project and RES-DHC projects are financed using grants (18) from public and private organisations, equity funds (3) from public authorities and financial institutions, financial schemes such as loans (5) and guarantees (6). Subsidy (1) and support schemes in the form of tax deductions and fiscal incentives are also used to support the use of RES in DHC.

In December 2020, the **multiannual financial framework for 2021-2027 (MFF)** was adopted, a regulation providing for the long-term budget for EU funding programmes.[2] Here, the most important EU funding mechanisms are described.

The **European Structural and Investment Funds (ESIF)** channels over half of EU funding through 5 funds, of which 2 are potentially relevant to funding RES DHC projects. The **European regional development fund (ERDF)** promotes balanced development in the different regions of the EU and has low-carbon economy projects as a priority. It is a co-financed programme, meaning that EU funding must be matched by a set percentage of national funding (co-financing rate varies by region). The adopted MFF for 2021-2027 states that the ERDF allocates around 200.36 billion EUR. The **Cohesion fund (CF)** is aimed at MS with a Gross National Income per inhabitant less than 90% of the EU average, namely for the for 15 MS: Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia and Slovenia. It aims to reduce economic and social disparities and to promote sustainable development and is now subject to the same rules of programming, management, and monitoring as the ERDF. The CF allocates 42.556 billion EUR in the MFF 2021-2027.

The **European Funds for Strategic Investments** contain the **InvestEU Fund** which allocates 2.8 billion EUR as well as the new funds for the **Connecting Europe Facility – Energy** with 5.180 billion EUR. The **InvestEU Fund** aims to mobilise investments which otherwise would be difficult to finance.

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[1] https://www.rhc-platform.org/content/uploads/2020/10/Deliverable4.2.pdf (Grant Agreement: 825998)

[2] Press release by the Council of the EU: MFF for 2021-2027 adopted. Online: Multiannual financial framework for 2021-2027 adopted - Consilium (europa.eu); mff-2021-2027_rev.pdf (europa.eu)

One policy objective among others is supporting infrastructure investments in the areas of sustainable transport, renewable energy, energy efficiency renovation projects, digital connectivity as well as environmental and climate resilience research. The second investment fund, the **Connecting Europe Facility – Energy (CEF Energy)** is funding cross border renewable energy projects (generation and infrastructure). The CEF offers financial support to projects through guarantees and project bonds. These instruments create significant leverage since they act as catalysts to attract further funding from the private sector and other public sector actors.

EU Horizon 2020 was the biggest EU Research and Innovation programme ever made. The subsequent programme, **Horizon Europe**, allocates 76.400 billion EUR in the seven-year period from 2021 to 2027. The projects funded by this programme typically focus on research and innovation as they aim to increase the EU's global scientific competitiveness. Regarding the topic of RES DHC this means that the Horizon Europe programme can enable the market uptake of new energy efficient renewable heating and cooling technologies.

The LIFE Programme for Environment and Climate Action allocates 4.812 billion EUR in the MFF from 2021 to 2027. Around 1 billion EUR are reserved for small scale energy efficiency and renewable energy projects. Several projects already funded by LIFE concerned renewable district heating, as for example LIFE4HeatRecovery (low temperatures and urban waster heat for DHC)[1].

The **EU Innovation Fund** is targeting market uptake of innovative renewable energy technologies, CCS, and solutions especially for energy intensive industries. The budget comes from EU ETS allowances and is between 2 and 12 billion EUR.[2]

The **European Investment Bank** is also an important actor in financing RES DHC projects. From 2021, the EIB Group will align all financing activities with the goals of the Paris Agreement and will unlock 1 trillion of climate action and environmentally sustainable investment in the decade to 2030 following the new energy lending policy.

In recent years, the European Central Bank announced a shift towards a greener monetary policy[3]. While the ECB is still financing coal, oil, and gas, and has price stability as its prime mandate, the president Christine Lagarde has made climate a priority in the bank's policy going forward. The ECB will invest in Bank for International Settlements' green bond fund, which invests in renewable energy production and energy efficiency, and will consider future investments in green bonds.

[1] https://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=6815

[2] EU Bank launches ambitious new climate strategy and Energy Lending Policy (eib.org)

[3] European Central Bank sets up climate team, considers green bonds – EURACTIV.com

Private funding

Several private funds such as pension funds are expected to invest increasingly in renewable energy projects and potentially also RES DHC projects across Europe. The use of private finance will be increasingly required to deliver necessary investments for reaching the climate targets in the heating and cooling sector. Examples for private funds are the Canada Pension Plan which launched a European renewables platform in December 2020 and the Green Investment Group Renewable Energy Fund by Macquarie Group Ltd.

Since current levels of investment in sustainable energy are not enough to meet the EU's climate targets for 2030, the Sustainable Energy Investment Forums (SEI Forums) is working with national stakeholders in order to boost large-scale investment and financing for sustainable energy projects.

6. POLICIES & REGULATIONS

Various policies at European level have influence on renewable energy in the heating and cooling sector and on RES DHC in the MS. The table below provides an overview of the **most important EU level regulations, directives, and strategies affecting RES DHC directly and indirectly**.

EU regulation, directive or strategy	**Most important aspects related to RES in the heating and cooling sector with indirect effect on RES DHC or directly affecting RES in DHC systems**
European Climate Law (draft under negation)	Legal framework and binding EU climate targets. Until September 2020, the goal was 40% reduction in GHG emissions in 2030 as compared to 1990 levels. In December 2020, the European Council agreed on a reduction of 55% in 2030 and climate-neutrality by 2050. The European parliament has pushed for a more ambitious 60% objective for 2030. Negotiations will continue in spring 2021. The EU Climate Law does not include specifications regarding the heating and cooling sector.
EU Emission Trading System (EU ETS)	(current scope of the EU ETS is proposed to be revised under the intermediate target of at least 55% net reduction in greenhouse gas emissions by 2030, see European Climate Law) Cap and trade system for emissions. DH generation units utilizing fossil fuels and emitting CO_2 are covered by the EU ETS as part of the power and heat generation sector, if their capacity is 20 MW and above.
European Green Deal (2019)	Strategic project and action plan for a climate-neutral and resource-efficient economy. Involves the renovation strategy and revision of several directives, such as the RED II, EPBD etc.
Renewable Energy Directive (RED II) (2018)	Targets for the decarbonisation of the heating and cooling sector (current RED II goals might have to be revised and updated with new increased 2030 climate targets, see European Climate Law): – MS shall endeavour to increase the share of renewable energy in the heating and cooling sector by an indicative annual 1,3% until 2030. (Article 23) – District heating and cooling (Article 24): MS should increase the share of energy from renewable sources and from waste heat and cold in DHC by at least 1% until 2030

	(except MS with shares of RES DHC of 60% and above). Third Party Access for suppliers of renewables and waste heat/cold. Right to disconnect from inefficient networks for consumers. Right of consumers to be informed on renewable share and energy performance of the DHC system. – Guarantees of origin for energy from renewable sources should be implemented also for RES DHC. (Article 19)
Energy Performance of Buildings Directive (EPBD) (from 2010, revised 2018)	– The EPBD sets minimum standards for energy efficiency in buildings. – Cost-optimal methodology for calculating energy performance of buildings. – MS must provide long-term building renovation strategies to the EC with updates every three years (last update was due by March 2020). – The renovation strategies must include indicative milestones for 2030, 2040, 2050 and policy action plans in order to achieve the national targets.
Energy Efficiency Directive (EED) (2012)	– Reduction of primary energy consumption: initially 20% by 2020; now 32.5% by 2030 (relative to 2007). – MS are required to carry out a comprehensive assessment of the national heating and cooling (last one due 31st December 2020). – Definition of “efficient district heating and cooling” (Article 2.41 of 2012/27/EU).
Heating and Cooling Strategy (2016)	Strategy to increase the building efficiency as well as the share of renewable energy in heating and cooling. Focusing on following aspects: – renovation of buildings; – increasing the share of RES in heating and cooling (reference to RED and EPBD, as well as European Structural and Investment Funds, the EU Horizon 2020 Programme and the Integrated Strategic Energy Technology Plan); – reuse of energy waste from industry (e.g. by feeding waste heat into district heating systems, cooling via cogeneration and absorption chillers feeding into DC systems, establishing the necessary grid infrastructures); – involving consumers and industries.

Renovation Wave (2020)	The target of this strategy is to double the renovation rate in order to cut emissions and reduce energy poverty. Renovation should be one priority in national economic stimulus plans. Revisions of EED/EPBD planned: – stepwise introduction of binding targets for building stock efficiency – supporting heating and cooling supply schemes in combination with renovation/efficiency measures Revision of RED II planned: – increasing targets for RES shares in heating and cooling – establishing a binding minimum standard for using RES in buildings – facilitating the access to ambient energy sources and waste heat potentials
EU Strategy on Energy System Integration (2020)	Strategy paper highlighting electrification aspects of renewable heating and cooling: – the major role of heat pumps as a direct renewable heating technology, the heat pump roll-out promoting electrification of the heating sector (decentralised heating in the service and residential sector as well as large-scale heat pumps in DHC). Acknowledgement of the higher level of taxes and levies applied to the electricity and lower levels of taxation for fossil fuels as the main barrier for the heat pump roll-our (lack of level playing field). – complemented by renewable/low-carbon fuels (e.g. hydrogen, biogas) where direct heating or electrification are not feasible or not efficient – extensive reference to smart district heating systems with energy customers exchanging heat – largely unused potential of waste heat from industrial sites, data centres or other sources should be utilized, e.g. in DHC systems – key action is to facilitate using these potentials, e.g. through strengthened requirements for connection to DH networks
Ecodesign Directive and Energy Labelling Regulation	Consumer information: The directive/regulation set standards for labelling of the energy performance of boilers (oil, gas) as well as heat pumps and heat storage units.

Table 2: Overview of EU policies and their most important contents related to RES in the heating and cooling sector and (if mentioned directly) to RES in DHC systems.

7. OBSTACLES AND BARRIERS FOR RES DHC

There are a variety of barriers and obstacles obstructing the further development of RES-DHC. These barriers are often country or region-specific, due to institutional inertia, over-reliance on fossil fuels or lack of awareness, but there are cross-cutting barriers that are evident across Europe.

Technical barriers can be found and differ depending on national circumstances. In Eastern Europe, the challenge is retrofitting existing networks so that they can operate at lower temperatures, integrating locally available energy sources in the process. In countries with few DH networks, the challenge lies in the development of new networks. It can be difficult to replicate solutions if the technology is not established in the country. In an ideal scenario, you need high heat demand density, with a mix of heating and cooling demands throughout the year, either cheap RES or waste heat available in place. The absence of any of these elements places economic constraints on the system. The compatibility of the building stock with the low operating temperatures required for 4th generation DHC also plays a role. While new builds are suitable for low temperature district heating, owners of existing buildings are typically not willing to invest in their buildings. Improving insulation and ventilation systems to the required standard is a barrier.

Political and regulatory barriers to the large-scale role out of RES-DHC are evident across Europe. Political action and decarbonization targets tend to focus mainly on the electricity sector. A strong desire to address the heating sector, and set ambitious targets, is needed. District heating and cooling is affected by numerous laws and policies, at EU, national and local levels. The legislative framework covers a wide range of areas, such as market regulation and customer protection, energy and environment, emissions and building standards. A lack of state-based financial support is a major barrier in most countries. Stable support from government actors and clear regulations are needed to attract investors to the sector. Negative framework conditions such as fuel price subsidies, mis-regulated heat prices, or promotion of individual solutions (such as fossil fuel boilers) distort the market and represent a barrier to the expansion of RES-DHC.

RES-DHC projects face **financial and economic barriers** due to high CAPEX costs and long payback periods. Combined with regulatory uncertainty, this makes it difficult to attract private investment such as pension funds. Additionally, upfront investment costs are sometimes given disproportionate priority in decision making processes. Having the right funding scheme is crucial to maintain a reasonable overall cost; it requires finding investors who are willing to make long-term investments and establish transparent working relationships. Having a clear and reliable business model is key for securing political and financial interest and attaining a return on investment as profitability can be low in some countries.

RES-DHC can also be impacted by **social barriers**. DHC is not a well-known solution in many countries, as are the benefits it provides. Disruption to everyday life during the construction of projects can quickly turn local people against projects. It is important to involve citizens early in the development of projects, through energy communities, and focus on the environmental and social benefits delivered by RES-DHC. There can also be issues related to cost expectancy. End-users often assume that transitioning to a greener solution such as RES-DHC will result in higher energy prices, and in some cases, buildings owners have unrealistic expectations about the cost savings delivered by DHC. **Knowledge and perception barriers** prevent the uptake of RES-DHC in favour of individual heating solutions. Politicians, city planners, building owners and installers are simply not aware of the benefits delivered by RES-DHC, within the context of urban environments. DHC systems also have a poor reputation in certain eastern European countries.

8. OPPORTUNITIES AND DRIVERS FOR RES DHC

The EU aims to have a net-zero greenhouse gas emissions economy by 2050. With its strategy on heating and cooling (H&C), the European Commission strongly emphasised the role of H&C in the decarbonisation process. The Renewable Energy Directive set a target of 32% renewables in final energy consumption by 2030; about 40% of this share is projected to come from the H&C sector. To effectively decarbonise H&C, the EU, national governments, and the overall community of stakeholders need to act quickly. Due to the long lifespan of H&C technologies (15 – 30 years), the window of opportunity is quite narrow. Actions taken today can have a significant impact on future efforts due to technological lock-in. Coordinated strategies are required across all levels to achieve net zero emissions by 2050. RES-DHC fueled by solar thermal, geothermal, bioenergy, and ambient and waste heat recovery can be the backbone of the future decentralized energy system, and represents the most effective and economically viable option to **reduce the H&C sector's dependence on fossil fuels and cut down CO_2 emissions.** If the observed trend of urbanisation continues, and if the right investments are made, almost half of Europe's heat demand could be met by district energy by 2050.

The EU produces more waste heat than the demand of its entire building stock, with the majority of this heat being produced as a by-product of industrial processes. Industrial emissions account for 21% of EU GHG emissions. The recovery and re-use of industrial waste heat can help reduce primary energy demand, reduce energy costs and CO_2 emissions, increasing the overall efficiency of the sector. Studies have shown that an estimated 20-50% of industrial energy consumption is ultimately discharged as waste heat and 18-30% of this waste heat can be recovered and utilized. Low-temperature waste heat that is not consumed within industrial processes (unavoidable waste heat) can then be fed into nearby DHC networks. Simultaneously, there is a large amount of low-grade heat readily available in urban areas. Waste heat is emitted within cities every day, from data centres, metro systems, supermarket refrigeration and sewage systems. Modern cities with intelligent, low-temperature DHC networks can capture and utilise these unconventional sources of waste heat, e.g. by boosting their temperature with heat pumps to the required system temperature. Approximately 72% of European citizens live in urban environments, where heat demand is at its greatest. **The integration of waste heat in DHC networks offers a viable source of low-carbon heat as well as significant savings in primary energy consumption.** When RES and heat pumps are also integrated, these DHC networks can provide support to the electricity network by providing grid balancing services and integration of variable renewable electricity. A transition to DHC, combined with energy saving measures, could contribute as much as 58% of the carbon dioxide emission reductions required in the energy sector by 2050.

The evolution of the DHC sector mirrors that of the wider energy sector, towards increasing renewables integration. **To enable and drive the integration of sustainable heat sources, DHC network operating temperatures must be lowered.** In traditional DHC systems, networks operate at temperatures between 60-90°C and heat is generated in centralised production plants and distributed to end-consumers. The emergence of 4th generation (30-60°C) DHC is facilitating, and in many cases necessitating, the efficient integration of RES. Heat pumps, solar thermal plants, heat storage systems and many other RES H&C technologies operate more efficiently when the DHC network operating temperature is reduced. **Decentralised production plants and waste heat recovery** will replace the large central fossil power and heat units and DH infrastructure will be used to supply locally-produced heat to buildings. Decentralisation of the heat production and supply, with individual RES-DHC solutions, will lead to reductions in distribution-related heat losses in many cases, since heat will be produced closer to where it is consumed and transported at lower temperatures. In addition, reduced dependency on fossil fuel imports will lead to a more secure heat supply. With the integration of individual, building-level heat pumps, low-temperature networks can also provide bi-directional heating and cooling through the same pipes.

Cities can act as multipliers of RES-DHC. The decentralised nature of renewable heating and cooling (RHC) technologies has brought energy production closer to cities, where it is consumed, allowing other actors, to take on a more active role in the energy system and to drive the transition towards RES-DHC. Through the integration of RES in DHC networks, cities have the opportunity to deliver a wide range of sustainability objectives, including addressing local air pollution, mitigating climate change, supporting the local economy through job creation, promoting energy security, and building future-proof energy infrastructure, creating more liveable urban areas in the process. This is well underway in cities such as Copenhagen and Vienna, where large-scale DHC networks supply increasingly low-carbon heat to the city inhabitants. The responsibility lies within the cities to incorporate heat supply aspects in urban spatial planning and to deploy DHC solutions as part of their heat transition.

There are a **variety of actors involved in promoting the development of RES-DHC** (as outlined in Section 4) but policymakers and local authorities are ideally placed to drive the uptake of these clean technologies. Policymakers are powerful, top-down actors in the system. They set the regulatory framework, the decarbonization targets, and the fuel taxes that will enable RES-DHC to reach its full potential. Local authorities and city stakeholders are especially important due to the local nature of heat. Local authorities can pursue the development of low-carbon DHC networks in their locality. With creative financing, involving a variety of players, this can be used to deliver sustainable heat within the locality. Local authorities and city governments have emerged as leaders of the energy transition in recent years, taking proactive action on climate change and setting more ambitious energy targets than their national counterparts. However, successful implementation of projects cannot be guaranteed without proper involvement of, and support from, the local community. **It is crucial to engage relevant local stakeholders in the early stages of project development,** as local opposition is extremely difficult to overcome.

The role of private actors as enablers and potential drivers of RES DHC is important, too. Increasingly, private actors such as local businesses, multi-national corporations and industry as well as civil society actors (energy cooperatives, local associations) are initiating the development of efficient and renewable DHC systems in their communities. As outlined in the recent strategy on Energy System Integration from the European Commission, energy integration is the pathway towards an effective, affordable, and deep decarbonisation of the European economy. **DHC can play a major role in energy system integration** by linking different parts of, and providing flexibility to, the energy system. Modern low-temperature DHC systems connect local energy demand with renewable and waste energy sources, as well as the wider electricity and gas grid – contributing to the optimisation of supply and demand across energy carriers. By increasing the synergies between electricity and heat networks, multi-energy carrier integration can support the integration of surplus renewable electricity, reducing curtailment and the need for direct electricity storage, while lowering electricity demand peaks. During times of high supply, when the price is low, surplus electricity can be integrated into heat networks through heat pumps and thermal energy storage. Innovative business models and new control strategies are required to enable RES-DHC stakeholders to contribute to sector integration and benefit from the flexibility provided by DHC systems.

Thermal energy storage (TES) is a key enabler of widespread RES integration. The occurrence of RES supply does not always coincide with demand for heating and cooling. By decoupling supply and demand, TES facilitates increased use of renewable and waste heat sources and increases the overall flexibility of the energy system, across all scales. Additionally, DHC networks can shift electricity loads to off-peak time periods using TES systems. TES technologies can store heat and cold across various different spatial and time scales, including daily and inter-seasonal energy storage. Large scale applications are particularly important for RES-DHC, as they enable high shares of RES-uptake.

Both the European policy framework and prevailing business models relating to the DHC sector were developed for conventional 3rd generation DHC networks. **New legislation is needed to promote the deployment of RES-DHC solutions**. As a first, and essential first step, binding legislation to phase out fossil fuel-based heating systems must be developed. Heating solutions have long lifetimes and the policy decisions taken today will have significant implications for meeting future climate and energy targets. A carbon tax would level the playing field by disincentivising the consumption of fossil fuels, internalising externalities and promoting RES heat sources in the process. At the national level, member states should also ban the installation of fossil-fuel boilers, starting with new-builds and expanding to existing buildings. RES-DHC offers a viable alternative in urban environments and individual heat pumps can be installed in rural areas. **Novel and innovative business models are needed to promote RES-DHC**, where heat is sold as a service or through a Pay-as-you-go model. Shifting business models from high- to low-temperature will leverage public and private investment into the sector. Innovative business models are required to attract both new and institutional investors, where in addition to the monetary value, the green dimension of the investment is also valued.

9. MAPPING OF DATA CENTRES

As outlined by Heat Roadmap Europe, as well as in the 2016 EU Heating and Cooling Strategy, enough waste heat is produced to cover the entire heat demand of EU buildings. In line with the principle of energy efficiency first, it is essential that this energy loop is closed by either avoiding, reducing or reusing this wasted energy. Recovering industrial waste heat into DHC networks offers a way to recycle this heat. Additionally, increased attention is now being paid to unconventional sources of waste heat, especially data centres. These centres are the backbone of the digital world and require huge amounts of energy in the form of electricity and space cooling. As the data centre industry continues to grow, so too does its energy demand. Data centres can become flexible multi-energy hubs by connecting to DHC networks. This would allow the waste heat to be recovered and fed to nearby buildings and the demand for cold can be met using district cooling, avoiding increased pressure on electricity grids.

This section maps out the data centres in the selected case study countries. There are 3 types of data centres (Enterprise, Colocation and Edge). Enterprise data centres are built, owned, and operated by individual companies and are optimized for their end users. They are most often housed on corporate campuses. In colocation data centres, multiple companies rent space within a data centre facility[1]. Waste heat recovery is not part of the core business model adopted by data centres. A significant amount of flexibility and willingness to engage with DHC network operators is required. In principle, enterprise data centres are better suited for integration because their single entity owners are able to make unilateral decisions, avoiding the strict service level agreements that govern colocation data centres, where multiple companies are involved. However, these data centres are often reluctant to get involved for a number of reasons. They are critical to the operation of these companies and connection to a DHC network will result in a certain level of disruption (construction works, changes to existing cooling systems). There can also be issues related to data privacy and corporate protectionism. Colocation data centres function similar to most businesses, striving to increase sales and lower costs, and so connection to DHC networks can be achieved if the business case is compelling. All data centres will increasingly need to connect to DHC networks in the future, if national energy efficiency targets are to be met. Failure to do so will make these companies vulnerable to increases in electricity costs, as well as taxes on either CO_2 or waste heat.

Austria

There are 66 colocation data centres in Austria, with the majority being located close to either Vienna (39) or Graz (7).

France

France was primarily serviced by France Telecom up until 1998 when the French government aimed to make competition mandatory in response to a European Directive. The past two decades have

[1] https://www.cisco.com/c/en_in/solutions/data-center-virtualization/what-is-a-data-center.html#~types-of-data-centers

seen significant improvement with the emergence of other major telecommunications providers. The digital economy accounts for 4.2% of France's GDP (2,426 billion euro) and there are 250 colocation data centres in the country. Clusters can be found in Paris (104), Marseille (12), Lyon (16), Lille (16) and Strasbourg (7). French colocation facilities provide over 444.2 MW of power and has a range of rack power options from 1.5 kW to 10.8 kW.

Germany

Germany has a total of 451 colocation data centres, most of which can be found close to Frankfurt. The digital economy contributes 8% to Germany's total GDP of 3,449 billion euro. There are several data centre clusters throughout the country, with the main colocation data centre markets in Frankfurt (120), Dusseldorf (28), Munich (50), Hamburg (44) and Berlin (34). German colocation facilities provide over 628.59 MW of power and has a range of rack power options from 0.9 kW to 25 kW.

Italy

Italy has a thriving data centre industry, with a total of 124 colocation data centres. The digital economy contributes 3.5% to Italy's total GDP of 1,788 billion euro. There are several data centre clusters throughout the country with the primary colocation data centre markets in Milan (44), Rome (22), Turin (10), Arezzo (3) and Padova (4). Italy also provides an important connection between Africa and Europe through submarine cables.

Poland

There are 115 colocation data centres in Poland, with clusters in Warsaw (36), Katowice (11), Poznan (10) and Krakow (10).

Switzerland

There are 103 colocation data centres in Switzerland and the digital economy contributes 4.5% to the Swiss GDP of 628 billion euro. There are clusters in Zurich (45), Geneva (14), Lausanne (10), Bern (5) and Basel (4). Switzerland's colocation facilities provide over 160.72 MW of power and has a range of rack power options from 0.90 kW to 2.70 kW.

GDP values taken from Statista[1].

[1] https://www.statista.com/statistics/685925/gdp-of-european-countries/#:~:text=With%20a%20Gross%20Domestic%20Product,largest%20in%20Europe%20n%202019

10. HIGH-POTENTIAL REPLICATORS

The following EU countries, outside of the project consortium, have been identified as having high potential for RES-DHC: Croatia, Czech Republic, Ireland, Lithuania, Netherlands, Slovakia, Spain.

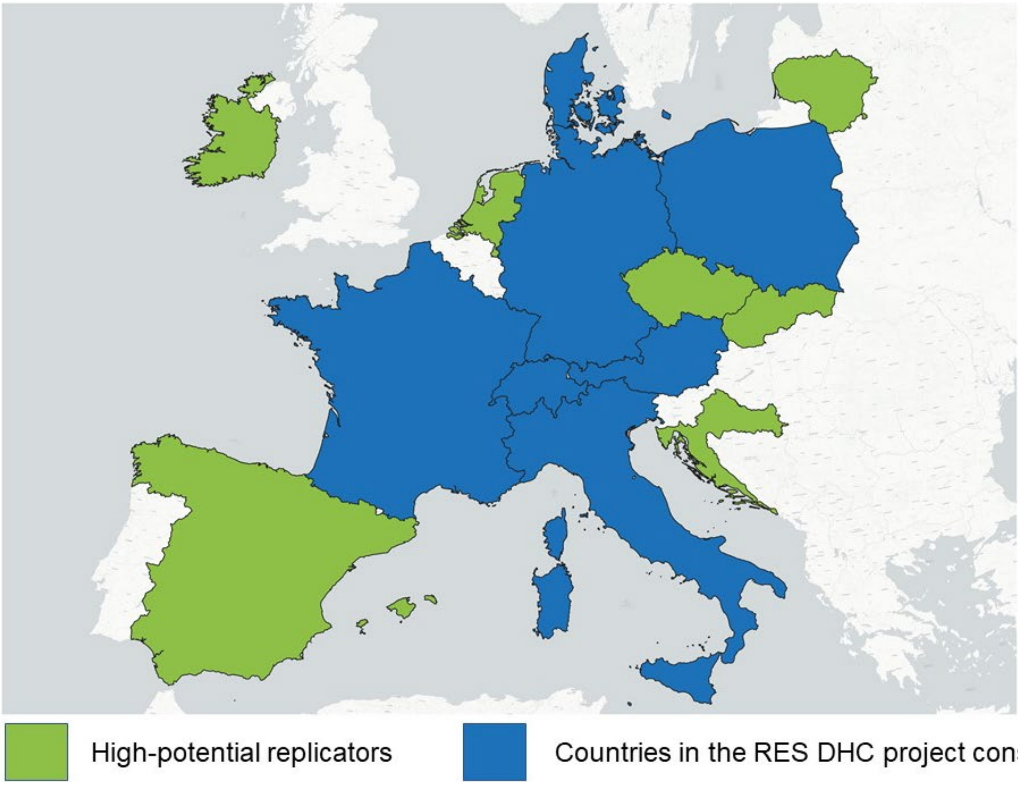

Figure 6: Map of (i) countries of selected RES-DHC regions and (ii) high potential replicator countries. Image: Hamburg Institut.

Generally speaking, high potential for RES-DHC can be defined in two ways: 1) Countries with traditionally low amounts of DHC, that have potential to deploy modern, renewables-based networks with low operating temperatures; and 2) Countries with high amounts of fossil fuel-based DHC, that have potential to decarbonise and retrofit these networks, towards a low-temperature, renewable heat supply.

When selecting high-potential replicators, several selection parameters were defined in order to reach a heterogenous and representative country selection:

- To provide an analysis that is representative of the entire European Union, countries were selected to ensure a **wide geographical distribution**.
- The selected countries differ in many ways including their **size, population, and climate**.

- They also differ significantly in their **progress towards the complete decarbonisation of their heating and cooling supply**, with some countries achieving a high share of renewables (Lithuania), while others are lagging well behind the EU average of 22.1% (Ireland, Netherlands).[1]

Croatia: The country has a low share of DH (around 7%). The share of renewable energy in heating is quite high with around 37%, whereas the share of renewables in DH is lower (around 15%). A large share of DH is currently generated by natural gas, therefore it has a huge potential to switch to renewable DH as well as establish DH in general. The Croatian cooling demand is expected to rise in the coming years, so district cooling generated from renewable sources is also a relevant aspect.

The Balkan country is situated between Central and South-Eastern Europe And has a population of 4.07 million. Its continental Mediterranean climate is moderately warm with mild winters and warm summers. Tourism dominates the Croatian service sector, accounting for one fifth of the Croatian GDP. Currently, around 7% of the heating demand in the residential sector is covered by DH.

Around 13 companies in 18 cities supply district heat for covering the space heating and sanitary hot water demand. In total, around 436 km of DH networks exist in Croatia with an installed thermal capacity of 2221 MW and 435,870 citizens served by DH in 2017. There has been no expansion of District Heating in the last fifteen years in Croatia and there is a considerable need for refurbishment of existing networks to increase customer confidence, energy efficiency and profitability.

DH in Croatia is generated by natural gas (around 79%), oil and petroleum products (6%), and renewables and heat pumps which are used both in cogeneration plants and local boiler plants (around 15%). A study conducted by Heat Roadmap Europe showed that very large amounts of unused excess heat are already available in Croatia from existing thermal power plants, and industrial plants, while there is also a huge potential to utilise renewable resources for heating.[2]

The precondition for the further development of the district heating systems in the Republic of Croatia is the intensive renewal and technological improvement of the existing systems, especially in terms of switching to low-temperature district heating systems. One major challenge is to raise more awareness about District Heating and to create conditions for it to become profitable by allowing price levels to facilitate development.

[1] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20201229-1?redirect=/eurostat/news/whats-new

[2] https://heatroadmap.eu/wp-content/uploads/2018/11/STRATEGO-WP2-Country-Report-Croatia.pdf

Czech Republic: The existing high share of district heating as well as the increasing demand for cooling and the low share of renewable energy sources in the DH systems mean that there is extremely high potential to deploy RES-DHC in the Czech Republic by transforming existing DH grids as well as establishing new RES DHC systems.

Czechia is a land-locked country in Central Europe with a population of 10.65 million. The climate is temperate oceanic with warm summers and cold and snowy winters. There is a strong tradition of district heating in the Czech Republic, with networks supplying heat to 1.7 million households, which corresponds to 4.1 million citizens. 20% of the fuels supplying the residential heat demand is district heating with an impressive number of 40% of the households connected to a district heating grid.[1] Renewable energy sources (mainly biogas and wood) have a share of 8% in the district heat generation.[2] In terms of the country's overall heat demand 40% is consumed by the residential sector, with the remainder by the industry (35%) and services (25%) sectors.

The long-term decline in heat consumption in the country represents a major challenge for the DHC sector. Improvements in the insulation of residential buildings and the roll out of measuring and control devices have reduced the residential heat demand in recent years. The number of households disconnecting from district heating systems has increased, due in part to rising prices. While the decline of Czech heavy industry, combined with improvements in energy efficiency, has reduced the industrial heat demand.

Czech Republic has significant potential to develop RES-DHC, by decarbonising its district heating supply. Significant investment is needed to modernise its existing networks and lower network operating temperatures. The county's main target is to reduce total greenhouse-gas emissions by 30% by 2030 (compared with 2005 levels), equivalent to an emissions reduction of 44 million tonnes CO_2, along with a 20.8% contribution to the European 2030 renewable energy target (32%). Looking more closely at the heating and cooling sector, the country has set a target of 22% RES H&C by 2030, building on its 2020 target of 13%. Summer temperatures are increasing, driven by climate change and exacerbated by the country being land-locked. The demand for cooling is set to grow exponentially and there is high potential to supply this demand with district cooling. The low operating costs of district cooling (especially when combined with district heating) will make it increasingly economical when compared with electrical air conditioning. Heating plants which can produce cold from waste heat in the form of cold water can also exploit this development.

[1] https://www.euroheat.org/knowledge-hub/district-energy-czech-republic/

[2] https://dbdh.dk/the-czech-republic-district-energy-potential-for-a-low-carbon-economy/

Ireland: Still in its DHC infancy, Ireland is a replicator with the huge potential to leapfrog the fossil DH era that many other European countries are still in. Instead of transforming old DH systems, modern RES DHC system can be installed in Ireland and facilitate a low carbon heating and cooling supply – accompanied by renovations for increased energy performance, if the building stock is to be supplied.

Ireland is a country and island in western Europe with a population of 4.9 million. Ireland has a temperate, oceanic climate characterised by frequent but light rainfall. Summers are warm and winter temperatures are mild. Together with the Netherlands, Ireland has the lowest share (6%) of renewable heating and cooling in Europe. Biomass accounts for 79% of renewable heat production. The Irish total heat demand is 56.86 TWh, 94% of which is supplied by fossil fuels. Heat accounts for 35% of energy-related emissions and 38% of final energy consumption; and is supplied mainly by oil, gas, and solid fuels[1]. The majority of heat to buildings is supplied through individual gas and oil boilers.

The district heating sector in Ireland is still in its infancy and supplies less than 1% of the overall heat demand. However, district heating is expected to play an increasingly important role in decarbonising the heating and cooling sector. Two planned district heating system in Dublin have received €25 million in government funding through the Climate Action Fund and initial results from the 'Heat Atlas for Ireland' study suggest that up to 57% of the country's total heat demand could be covered by district heating networks, with the necessary investments and a supportive regulatory framework.

Although Ireland does not yet have a heat strategy, Project Ireland 2040 National Planning framework states that "District heating networks will be developed, where technically feasible and cost-effective, to assist in meeting renewable heat targets and reduce Ireland's GHG emissions". The Support Scheme for Renewable Heat (SSRH) will support renewable heat production for DH schemes in the future, with subsidies for heat pumps and a support tariff for biomass and biogas heat production.

The Irish data centre market is expanding rapidly. There are currently 46 colocation centres in the country, with 43 of these clustered around Dublin. Ireland's TSO (EirGrid) estimates that data centres will consume as much as 29% of the country's electricity by 2028. Several projects are currently being developed to recover the waste heat produced in these centres, such as the Tallaght district heating scheme. Codema, the Dublin energy agency, has also developed a Region Energy Master Plan, which sets out a pathway to achieve its carbon emission reduction targets for 2030 and 2050. The above support measures and recent project developments paint a bright future for the uptake of RES-DHC in the country.

[1] https://www.seai.ie/data-and-insights/national-heat-study/

Lithuania is a high potential replicator in the RES-DHC project because of its quite ambitious renewable targets for district heating, which most probably cannot be reached simply by scaling up biomass DH generation – other renewable sources such as solar thermal energy and heat pumps will be established in the coming years.

Lithuania is a country located on the Baltic Sea in the North-East of Europe, with a population of 2.79 million. Lithuania has a humid continental climate. Summers are mild and winters are very cold, with average temperatures below 0°C. Lithuania has a total heating and cooling demand of 27.17 TWh, with 46% of this demand being supplied by renewable energy[1].

The district heating and cooling sector is well developed. District heating accounts for 57% of the country's heat demand, rising to 76% in cities. Distribution losses are approximately 10%. There are 357 district heating systems in the country, with the vast majority operated by municipality-owned companies. 68.7% of DH supply is renewable (mainly biomass). Most of this biomass is sourced within the country, while some of the biomass is important from neighbouring countries. This, combined with the transition away from gas in recent years has lowered heat prices and delivered various other benefits to society including increased energy security and local job creation. Lithuania has committed to developing highly efficient CHP plants, that will be fuelled by biomass and municipal waste. Two new plants are expected to satisfy around 40% of Vilnius and Kaunas district heat needs.

Lithuania has made significant progress in decarbonising both its energy and heating and cooling sectors to date. The country's National Energy Independence Strategy commits to a 45% of final energy from renewable sources in 2030, well above the EU target of 32%. The plan also sets out a target of 90% renewable district heating, highlighting the ambition to decarbonise the sector and become a European leader in RES-DHC.[2]

The Netherlands has a very low district heating share in their overall heat supply. As the DHC share is expected to grow in the coming years and gas will be phased out of the heating sector, RES DHC will become extremely important in decarbonising the Dutch heating and cooling sector, making the Netherlands a high-potential replicator in our project.

The Netherlands is a highly urbanised and densely populated country in western Europe with a population of 17.28 million. The country has a temperate climate with moderately warm summers and cool winters. Along with Ireland, the Netherlands has the lowest share of renewable heating and cooling in the EU (6%)[3]. At present, heat is suppled mainly using gas boilers, fuelled by indigenous

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[1] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20200211-1

[2] https://ec.europa.eu/energy/sites/ener/files/documents/necp_factsheet_lt_final.pdf

[3] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20200211-1#:~:text=In%202018%2C%20renewable%20energy%20accounted,when%20the%20share%20was%2012%25

gas fields. There are very few DHC networks which show a quite high share of renewable sources and waste heat with approximately 80%[1].

The total primary energy supply in Netherlands in 2018 consisted of 36.1% oil, 6% biofuels and waste, 1.9% wind, solar etc, 1.3% nuclear, 43.4% natural gas and 11.5% coal. Heating and cooling make up 50% of final energy consumption, with half of this going to the space heating of buildings. According to Heat Roadmap Europe, by 2050, district heating could be expanded to cover around 56% of the heating market in the Netherlands, compared to just 6.6% in 2015. The majority of heat is expected to be supplied by large heat pumps, cogeneration (50% biomass, 50% gas) and waste heat recovery. Geothermal energy is expected to make up 6% of the district heating supply.

The Netherlands overall target for 2030 is a 49% reduction of GHG emissions compared to 1990 levels. The long-term objective to 2050 is to reduce GHG-emissions by 95%. The Dutch Climate Act highlights the use of district heating in densely populated areas with older houses and the Gas Act stipulates that new buildings will not be connected to the natural gas grid. Political decisions taken in recent years emphasise the high potential for the rapid development of RES-DHC in the country. The Dutch National Climate Agreement states that the integration of waste heat and renewable heat in DHC networks is an alternative to natural gas and can potentially cover up to 50% of the heat demand in buildings. The production of renewable heat will be subsidized, and the use of waste heat will be promoted. RES-DHC has the potential to grow significantly in the coming years, as gas is phased out of the heating sector.

Slovakia has a high potential for RES DHC projects. On the one hand, existing DH systems will be transformed towards integrating RES – and on the other, new RES DHC systems will be installed directly. With a precited increase in cooling demand, RES for district cooling will also be needed.

Slovakia is located in central Europe and has a population of 5.45 million people. The country has relatively warm summers and cold, humid winters. Nuclear energy is used to supply over half of the country's electricity demand. Overall, 11% of the Slovakian heat and cold demand is met by renewable energy[2]. In 2015, the total demand for heating and cooling was 79.77 TWh. Heat in Slovakia is supplied mainly by natural gas (55%) and biomass (27%), while coal boilers still play a significant role in supplying heat. District heating was supplied to 1.8 million citizens (35% of total population). 21% of the primary energy used for heating in the built environment is supplied by district heat. Cogeneration accounts for a 54% share of the district heating supply. District cooling is not well developed, however there is significant potential to do so in the future.

[1] https://www.euroheat.org/knowledge-hub/district-energy-netherlands/

[2] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20200211-1#:~:text=In%202018%2C%20renewable%20energy%20accounted,when%20the%20share%20was%2012%25

Heat consumption in the country has decreased in recent years due to warmer temperatures and insulation of residential buildings. Heat consumption in residential properties supplied by district heating systems decreased by 26% between 2004 and 2014 and has fallen further in recent years. However, DHC will continue to play a major role in Slovakia's energy system in the future. In accordance with the Energy Efficiency Directive (2012/27/EU), Slovakia has developed a heat map that shows the heat demand per municipality as well as the available heat production sites and district heating systems. The National Energy and Climate Plan proposes a 2030 overall renewable energy target of 18% and outlines support for efficient district heating systems with heat supplied from RES (especially locally available biomass/biomethane), heat pumps and waste heat from industrial processes. DHC networks will be optimised by installing cogeneration units. Measures to increase the share of RES in district heating systems anticipate an annual growth rate of 1%. This target is set to become a binding one for the overall sector, covering the 2021 – 2030 period and driving the uptake of RES-DHC.[1]

Spain is a high-potential replicator with a lower demand in heating, but a higher cooling demand, which will increase in the coming years. The currently very low DHC market share holds the possibility to implement new low- or ultra-low-temperature RES DHC systems which can provide both heating and cooling (5th generation DHC).

Spain is a southern European country with a population of 46.94 million inhabitants. Spain's Mediterranean climate is characterised by hot and dry summers, and mild winters. Heating and cooling account for 41% of Spain's final energy demand. 17% of the heat demand is provided by renewable energy. Of the total heat demand, 37% goes towards space heating, with process heat making up the largest share. This is unlike most EU countries, where space heating normally accounts for the largest share of the overall heat demand. Cooling, both process and space, takes up less than 10% of the heating and cooling demand but is expected to increase 18% by 2050.

As of 2017, there are 348 DHC systems in the country[2]. 60 of these systems produce both heat and cold. The share of renewables in Spain's DHC mix has increased significantly in recent years as a result of the development of systems in small and medium-sized municipalities, with the share of RES increasing from 26% in 2013 to 59% in 2017 (mainly biomass). Cooling (space and process) demand is growing rapidly in Spain and is expected to represent approximately 40% of the heating and cooling sector in 2050. A six-fold increase in the demand for space cooling is expected in the residential sector. There is high potential to meet this increased cooling demand using renewables-based district energy networks supplying both heat and cold.

Spain's very dense built environment is well suited to DHC. Heat Roadmap Europe expects the district heating market share to grow to 69%, compared to just 1% in 2015, with large scale heat

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[1] https://ec.europa.eu/energy/sites/ener/files/sk_final_necp_main_en.pdf

[2] ADHAC DH&C Census 2017. Due to the small amount of district cooling networks (systems that only generate cold) in Spain, the information refers to district heating and district heating and cooling systems.

pumps and biomass-driven CHP providing two-thirds of the heat. In certain regions, solar thermal and geothermal energy will be used to supply heat to DHC networks. By 2050, district cooling is expected to account for 6% of the cooling market, with cold being supplied from centralised chillers and sorption cooling[1]. Free cooling from water courses also offers a source of freely-available renewable energy.

[1] https://vbn.aau.dk/ws/portalfiles/portal/287932746/Country_Roadmap_Spain_20181005.pdf

11. ANNEX

Country	**Share of district heating in fuel consumption for space heating 2015** (Source: JCR 2019)	**Share of renewable energy in gross final energy consumption for heating and cooling 2018** (Source: Eurostat 2020)	**Share of renewable energy in generation of district heat.** (Source: EHP Country by country; IEA 2020)
Austria	23,0%	34%	47%
Belgium	0,5%	8%	/
Bulgaria	22,0%	33%	/
Croatia	7,0%	37%	15%
Cyprus	0,0%	37%	/
Czechia	20,0%	21%	8%
Germany	9,0%	14%	14%
Denmark	52,0%	47%	57%
Estonia	39,0%	54%	50%
Greece	1,0%	30%	/
Finland	43,0%	55%	46%
France	6,0%	22%	56%
Hungary	1,0%	18%	/
Ireland	0,0%	6%	6,9%
Italy	4,0%	19%	24%
Lithuania	42,0%	46%	69%
Luxembourg	8,0%	9%	/
Latvia	36,0%	56%	/
Malta	0,0%	23%	/
Netherlands	5,0%	6%	80%
Poland	25,0%	15%	9%
Portugal	2,0%	41%	/
Romania	15,0%	25%	/
Sweden	50,0%	65%	70%
Slovenia	12,0%	32%	13%
Slovakia	21,0%	11%	/
Spain	1,0%	17%	73%
Switzerland	7,0%	40%	57%
United Kingdom	1,0%	8 %	/
Norway	12,0%	34 %	/

Annex 1: Country-level data on the European heating and cooling sector

GRANTS	LOAN	GUARANTEE	EQUITY	SUBSIDIES	OTHER
Green Deal	LIFE Private Finance for Energy Efficiency (PF4EE)	CEF – Energy	European Investment Fund	URBACT III	CEF – Energy
H2020 / Horizon Europe	European Energy Efficiency Fund	European Fund for Strategic Investments (EFSI)	InnovFin		LIFE Private Finance for Energy Efficiency (PF4EE)
SME Instrument	European Investment Fund	Smart Finance for Smart Buildings	COSME		
Fast Track to Innovation (FTI)	InnovFin	European Energy Efficiency Fund	EIT InnoEnergy		
Future and Emerging Technologies (FET) Open	COSME	European Investment Fund			
EIT Climate-KIC		InnovFin			
GRANTS					
INTERREG: European Territorial Co-operation (ETC)	CEF – Energy	ELENA	Urban Innovative Action (UIA)	NER300 / Innovation Fund	EUREKA
LIFE Climate Action	LIFE Environment	Eurostars	EIT InnoEnergy		

Annex 2: European Funding Programmes for RES-DHC