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District heating in national Long-Term Strategies

Member States' visions for enabling low-carbon district heat networks

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Executive summary

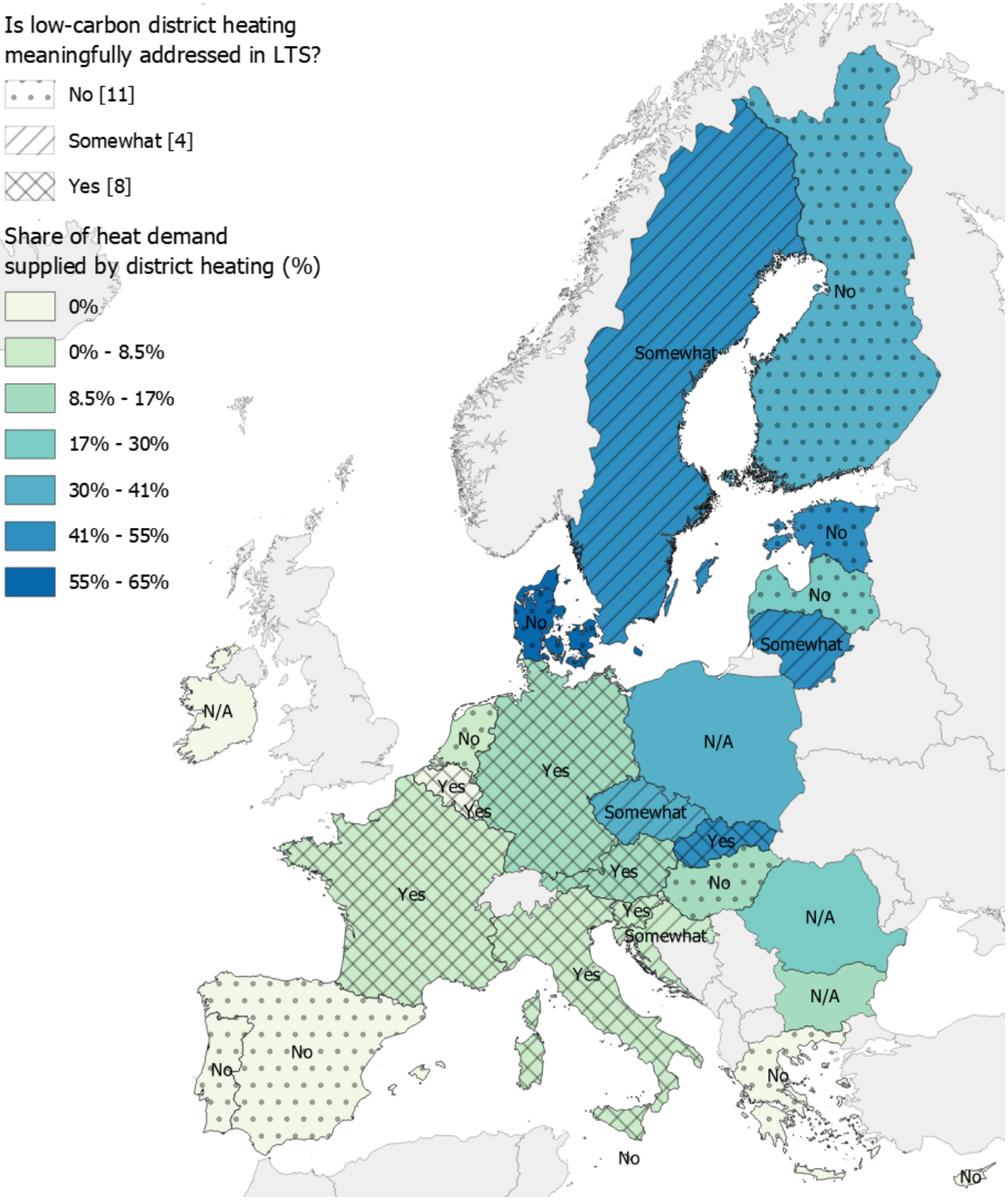
Modern, low-carbon district heating networks are important vectors for decarbonizing the European heating sector. However, they only supply 12% of residential heating demand in the EU, and face numerous challenges, including inefficiencies and fossil fuel dependency in legacy urban heating systems in Central and Eastern Europe. In the light of the recent Fit for 55 package and RePowerEU plan, efficient district heating systems are increasingly in focus as a tool for decarbonization as well as for energy savings.

The Long-Term Strategies for climate neutrality (LTSs) of Member States vary in the importance they assign to low-carbon district heating systems. Overall, **12 of the 23 Long-Term Strategies published at the time of writing mentioned district heating in a meaningful way**, with all 12 pinpointing the use of renewable or waste heat as sources of supply for these networks. Of the other 11 LTSs, some did not cover district heating simply due to it being irrelevant given geographic conditions, such warm climates, while others would benefit from including district heat networks in their long-term decarbonization pathways.

The main finding of this assessment is that, in general, **the LTSs provide little detail and few targets or milestones** for the penetration of district heating in heating supply or the fuel mix of future networks, even in Member States with significant needs for modernization of their existing legacy networks. The extent to which the role of district heating systems in LTSs is explored varies across these Member States, as well as across without legacy systems but where district heating is a feasible heating solution. Few strategies explore the role of 4th-generation district heating, thermal storage, or district cooling. Less than half propose financial instruments for enabling low-carbon district heating, and only two mention R&D. A key conclusion of this analysis is that **district heating is insufficiently explored as a measure for decarbonizing residential heating supply**, risking a gap in climate ambition particularly for Member States with existing extensive district heating networks.

The main recommendation of this analysis is for Member States with district heating potential to solidify a commitment to deploying district heating networks as decarbonization measures, **by putting forward clear commitments and targets in their LTSs**, based on an assessment of their national circumstances. These targets should be aligned with other national and European decarbonization strategies and integrated with clear support mechanisms for developing, modernizing and innovating district heating infrastructure. As visions for a climate-neutral future, Member States' LTSs can become credible launchpads for efficient, low-carbon and reliable district heating systems as part of a decarbonized residential heating system.

Graphical summary



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Abbreviations

CEE	Central and Eastern Europe
CHP	Combined heat and power
CO_2	Carbon dioxide
DHN	District heating network
DHS	District heating system
EU	European Union
EED	Energy Efficiency Directive
EPBD	Energy Performance of Buildings Directive
GHG	Greenhouse gas
Kt	Kilo-tonne
LTS	Long-Term Strategy
MS	Member State
Mt	Mega-tonne
NECP	National Energy and Climate Plan
nZEB	Nearly-zero energy buildings
RED	Renewable Energy Directive

1 Context

In line with the EU's Governance Regulation,[1] Member States (MSs) are required to create Long-Term Strategies presenting their economy-wide low-carbon transition plans to 2050. These strategies (LTSs) are, essentially, the strategies of MSs to achieve the EU's climate targets and are meant to cover greenhouse gas (GHG) emissions reductions as well as enhancements of removals for all sectors of national economies. They are now required to use projections to forecast their GHG emissions,[2] outlining potential measures to reduce emissions and reach climate neutrality by 2050. The LTSs were meant to be submitted to the European Commission by 1 January 2020 and must be updated every 10 years thereafter. Many countries submitted their strategies after the 2020 deadline, and four MSs had yet to publish their respective LTSs at the time of writing this assessment (October 2022) (Bulgaria,[3] Ireland, Poland, and Romania).

Within the framework for achieving climate neutrality, the residential heating and cooling sector is a priority for the decarbonisation of the EU's economy, making up 26% of the final energy demand of the EU (dominated by space heating[4]).[5] While electricity generation has been decarbonising at an accelerating pace, the heating sector is proving more challenging – not least due to traditionally cheap and widely available natural gas being piped into homes on the basis of well-developed pipeline infrastructure. Poor thermal efficiency in residential buildings further contributes to the decarbonisation challenge, as does the poor performance of centralized heating systems in countries in Central and Eastern Europe and the overall high investment costs and long timelines of deep building renovation.

Overview of district heating

Broadly speaking, district heating (DH) systems are a type of heating systems which distribute heat generated in a central location (for example, a co-generation plant or, more rarely, heat-only plants) to residential and commercial buildings through a network of pipes. Modern DH systems can integrate renewable energy resources as well as waste heat recovered from industry[6] and improve heating efficiency compared to decentralized heating systems. The potential of these low-carbon DH systems has been particularly highlighted for European buildings, where heating and cooling demand accounted for over half of final energy consumption, and where DH systems supplied only 12% of the European heat market in 2019.[7] The situation is different across EU Member States[8] – for example, modern DH systems in Sweden significantly contribute to national emissions reductions, but many Central and Eastern European (CEE) countries have large-scale legacy DH systems in significant need of modernization, which are mostly supplied with heat generated in old fossil fuel plants. This means that **utilizing the potential of DH systems** to help decarbonise the

[1] Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action (or Governance Regulation).
[2] European Commission, 2018. Regulation on the Governance of the Energy Union and Climate Action. Accessed online [16/08/2022].
[3] At the time of writing, the LTS of Bulgaria was in final drafting stages following public consultation and had not been submitted to the European Commission.
[4] European Commission, 2018. In-depth analysis in support of the Commission Communication Com (2018) 773. A Clean Planet for all: A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy. Pp. 91. Accessed online [16/08/2022].
[5] Odysee Mure, 2021. Final energy consumption by energy sector in EU. Accessed online [16/08/2022].
[6] Delmastro, C., 2021. District Heating. IEA, Paris. Accessed online [16/08/2022].
[7] Euroheat and Power, 2021. District Heating % Cooling Market Outlook. Accessed online [16/08/2022].
[8] W.E. District, 2021. A new interactive map "Share of District Heating and Cooling across Europe". Accessed online [16/08/2022].

European residential heating sector **involves both building new low-carbon, efficient DH systems as well as decarbonising and modernizing existing DH systems.**

Although mostly addressed in the context of the buildings sector, DH can also play a role in decarbonising industry. While much of the reduction in industrial GHG emissions to date has been the result of improved energy efficiency, linking industrial enterprises to DH networks can achieve further improvements, alongside the recovery and use of industrial waste heat (the surplus of which can also be supplied to buildings connected to DH networks). However, such optimisation measures on their own are insufficient to meet long-term GHG reduction targets and must be accompanied by industrial heat electrification and fuel switching (biomass, and in the longer-term hydrogen and e-fuels).[9]

The role of district heating in EU decarbonization

In the residential sector, where their potential is highest, DH systems are only one of a large portfolio of decarbonisation measures, including energy efficiency measures, renovation, and electrification (e.g., the use of heat pumps). In the European Commission's scenarios for net zero GHG emissions by 2050[10], energy efficiency is the key driver of decarbonisation in the buildings sector, mainly due to an acceleration of building renovation rates and the penetration of near-zero energy buildings (nZEBs), as mandated by EU standards. Given the relative ease of decarbonising electricity, a rapid growth in the electrification of heating is also projected, mainly achieved through heat pumps in residential buildings. In these scenarios, DH systems are foreseen to maintain a stable share of total energy demand, equivalent to a reduction in absolute distributed heat supply given the projected increases in energy efficiency and electrification. However, one of the benefits of DH networks is that they are particularly applicable to dense urban areas where, if properly planned, they can lead to reduced investment costs and thermal losses compared to individual heating systems.[11] Regardless of their share in final heating demand, they will need to use clean energy sources (such as electricity, biomass, or geothermal heat) to align with climate neutrality targets.

In addition to the more significant projected impact of electrification and building renovation on reducing heating demand, DH systems also face several barriers to widespread deployment in the EU. First and foremost, they have a natural limit for feasibility, directly correlated to the population density of the residential areas they supply – after this limit, individual heating solutions become more feasible.[12] DH systems are thus not suitable for meeting the dual challenge of decarbonisation and improved energy access faced in the rural areas of some MSs, and will compete with individual solutions such as highly efficient heat pumps. Another challenge facing DH systems is that they are large infrastructure projects requiring significant investment costs and lead time – resources which may be increasingly difficult to justify in the context of the lower energy demand generated by building renovation and energy efficiency measures. In CEE countries, the development and decarbonisation of DH networks is also plagued by significant existing thermal losses from old pipe systems, requiring investment for upgrade and modernization as well as an effort to capture or re-capture customers.

[9] European Commission, 2018. In-depth analysis in support of the Commission Communication Com (2018) 773. A Clean Planet for all: A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy. Accessed online [20/03/2022]
[10] These "net zero emissions" scenarios refer to the 1.5TECH and 1.5LIFE scenarios outlined in the "A Clean Planet for all" communication of the European Commission (2018).
[11] Joint Research Centre, 2019. Decarbonising the EU heating sector: Integration of the power and heating sector. Accessed online [20/03/2022]
[12] Ramboll, 2020. District Heating and Cooling Stock at EU level. Accessed online [20/03/2022]

Aim of this paper

This analysis aims to understand what role MSs envisage for low-carbon DH systems in their contributions to EU climate neutrality, based on their LTSs. It is objective in the sense that it does not promote a particular pathway for decarbonisation of DH systems, nor the wider residential heating sector. Rather, it reviews the approach to DH systems adopted in individual LTSs and outlines how this approach might be improved in further LTS updates. It should be noted that, given the loose framework requirements for developing LTSs in the Governance Regulation, there is significant variation in structure, content, and level of detail between the published national strategies. Furthermore, given the recent proposals of the EU for intermediate decarbonisation targets (the Fit for 55 package), some LTSs may present visions and plans that have not been updated in line with the renewed objectives. Finally, for the four MSs that had not, at the time of writing, yet submitted their LTSs, their National Energy and Climate Plans (NECPs) were analysed instead. While richer in detail, the NECPs are focused on the 2030 climate objectives and can offer scarce information on emissions trajectories until mid-century.

2 District heating systems in the EU

DH systems are key to the decarbonisation of the heating sector at a global level, given their ability to integrate flexible and low-carbon energy sources (including renewables and excess heat) to heat dense urban areas. Despite a growing global market, the International Energy Agency (IEA) considers progress on low-carbon district heating to be “not on track”, given that 90% of DH systems worldwide are still being fuelled by fossil energy sources.[13] In the EU, DH systems today supply heat to around 60 million Europeans[14] and most are fuelled by natural gas and, to a certain extent, coal – primarily through combined heat and power plants (CHPs).[15] However, there has been a progressive shift towards low-carbon heat sources, and with a heightened focus on heating brought about by the European Green Deal and a concern around the prolonged use of natural gas driven by Russia’s invasion of Ukraine, low-carbon DH systems could be at the forefront of efforts to decarbonise heating services.

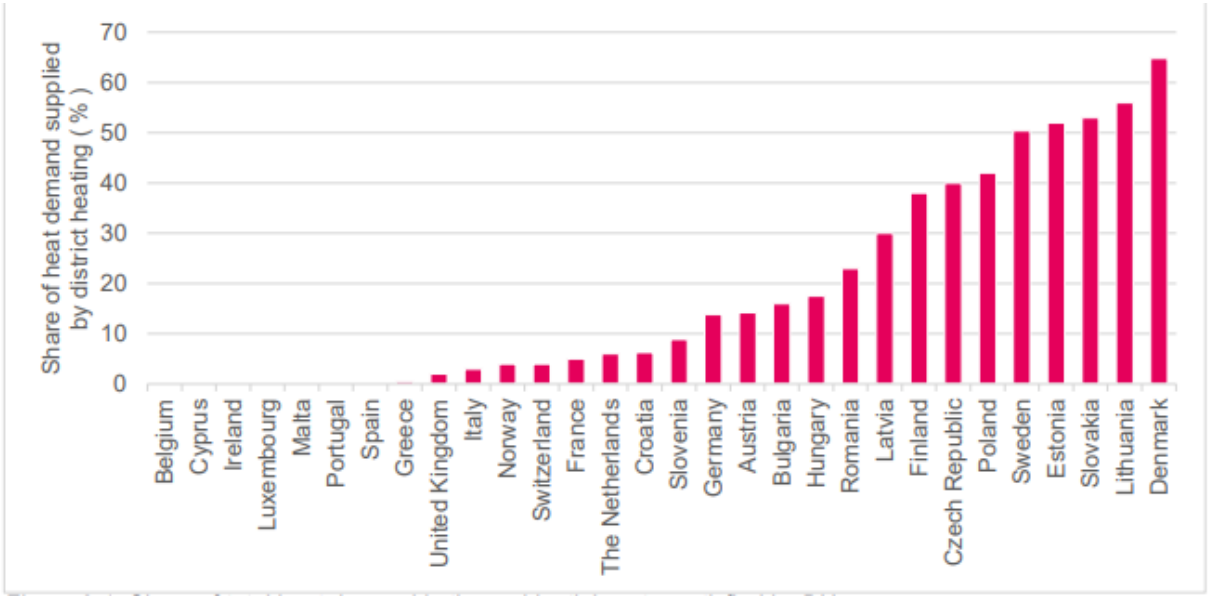
The share of DH systems in residential sector heating varies across EU countries, from over 60% in Denmark to negligible levels in Belgium, Ireland, and Spain, among others (see Figure 1).[16] In general, DH systems are more developed in countries with colder climates, which tend to have a higher share (over 50%) of DH in residential heating, modern systems and well-established political and market structures to support further improvements. On the other hand, countries with medium shares (between 10% and 50%) of DH in residential heating tend to have legacy systems in need of renovation and improvement, in some cases to the extent that residential customers choose to disconnect from DH systems in favour of individual heating solutions.[17] Indeed, the particularities of DH systems in different EU MSs mean that **planning, decarbonizing or using DH systems,**

[13] Delmastro, C., 2021. District Heating. IEA, Paris. Accessed online [16/08/2022].
[14] Energy Post, 2022. District Heating Roundtable: Policy across RED, EED and EPBD "must take account of conditions in all Member States". Accessed online [20/03/2022]
[15] Europe Beyond Coal. Combined heat and power and district heating. Accessed online [18/03/2022]
[16] Ramboll, 2020. District Heating and Cooling Stock at EU level. Accessed online [20/03/2022]
[17] Europa Libera, 2021. București | Firmele de debranșări nu fac față cererilor. „Reveniți în 2022!” Accessed online [20/03/2022]

will often depend on local and regional conditions, which should be acknowledged in policy and regulatory frameworks at EU level.[18]

DH systems in **low-share MSs** tend to rely significantly on fossil fuels and are challenged by a relative lack of planning and regulatory frameworks for further development. Many of these countries tend to be in warmer climates, creating investment risks due to lower expected utilization.[19] **Medium-share MSs** mainly use either fossil fuels or biofuels for heat production in DH systems and are generally plagued by a serious need for refurbishment of existing infrastructure. They also tend to be less competitive as heating solutions than individual boilers, especially if not accounting for climate and environmental externalities.[20] Finally, MSs with saturated DH markets (i.e., those with **high shares** of DH systems in residential heating) focus more on implementing new, low-carbon technologies in existing networks, rather than expanding them. In some cases, there is even the possibility of network contraction, given competition from individual heating solutions sustained through support schemes - for example, in Germany and the Czech Republic, DH operators pay emissions taxes, while individual heating solutions do not.[21]

Figure 1: Share of total heat demand in residential sector satisfied by district heating



Source: Ramboll, 2020. District Heating and Cooling Stock at EU level.

The policy landscape around DH systems has gained considerable momentum in light of the Fit for 55 package. The proposed revisions or recasts of the Renewable Energy Directive (RED II), Energy Efficiency Directive (EED) and Energy Performance of Buildings Directive (EPBD) all have provisions related to DH systems. At the time of writing, all proposals are still subject to negotiations and agreement between the European Parliament and the Council of the EU. Additionally, the RePowerEU plan for reducing dependence on imports of Russia fossil fuels further increases the ambition of the Fit for 55 package and highlights a role for DH systems in ensuring security, sustainability and affordability of energy in the EU.

Firstly, the European Commission's RED II and RePowerEU proposals introduce a significant upwards revision of the target for increasing the use of renewable and waste heat in DH systems

[18] Energy Post, 2022. District Heating Roundtable: Policy across RED, EED and EPBD "must take account of conditions in all Member States".
[19] Ramboll, 2020. District Heating and Cooling Stock at EU level. Accessed online [20/03/2022]
[20] Ramboll, 2020. District Heating and Cooling Stock at EU level. Accessed online [20/03/2022]
[21] Ramboll, 2020. District Heating and Cooling Stock at EU level. Accessed online [20/03/2022]

(from 1% to 2.1% per year in RED II, later increased to 2.3% in RePowerEU, with a strong focus on large-scale heat pumps and biogas[22]). RED II also introduces a requirement to ensure connection of third-party suppliers of renewable and waste heat to DH plants with a capacity above 25 MW_{th}. The upward revision of targets on renewable and waste heat shares will be particularly challenging to meet for some countries with legacy, fossil-fuelled DH systems, and European funding will likely be needed to ensure these targets are met.[23]

Secondly, the EED revision proposal establishes definitions of efficient heating and cooling systems, based on minimum shares of low-carbon energy sources which increase progressively to 2050 – by when only DH systems using renewable and/or waste heat (with a minimum share of 60% renewable energy) will be considered "efficient". The short-term definition of efficient heating systems means that by 2026, only DH systems using a minimum of 50% renewable energy, waste heat or a combination of these two, or 75% cogenerated heat, will be considered efficient. Other provisions of the EED affecting DH systems include an encouragement of for municipalities with over 50,000 inhabitants to carry out heat mapping, including assessing the potential for DH systems.[24]

Finally, the EPBD recast proposal also highlights DH systems as key to ensuring energy efficiency in buildings, encouraging MSs to enable architects and planners to consider them as part of an optimal portfolio of energy efficiency improvements. The proposal provides a new definition of "zero-emission buildings", which would require sourcing the low amount of energy still required either from on-site or community renewable energy generation, or from a DH system defined as efficient according to the EED. The proposed legislation also requires that MSs outline existing and planned policies on district heating as a method of decarbonising heating in their National Building Renovation Plans.[25]

The developments in the EU's climate agenda (embodied by the Fit for 55 Package), the invasion of Ukraine by Russia and the resulting energy shortage (which was addressed through the RePowerEU Plan) will have medium- and long-term implications for the fuel mix of DH systems by redirecting DH operators away from natural gas. Indeed, the RePowerEU plan highlights the development and modernization of DH networks as a way to accelerate the deployment of heat pumps, solar energy and geothermal energy in a cost-effective way. Fuel replacement choices will vary based on national or local circumstances; the RePowerEU plan particularly highlights large-scale heat pumps, solar and geothermal energy, and biogas. However, a significant additional volume of electricity would be required for a complete switch to heat pumps and other electricity-based solutions such as green hydrogen, as well as storage solutions to manage the intermittency of renewable energy resources.[26] As such, demand reduction, energy efficiency improvements and the use of recovered waste heat will also be key in delivering a more cost-efficient move away from natural gas and decarbonisation of the economy.

The current landscape of DH systems in the EU shows potential for their effective contribution to the decarbonisation of the heating sector and the reduction of dependence on Russian gas. However, as a country-specific approach is required (due to the differences in

[22] European Commission, 2022. Commission staff working document. Implementing the RePower EU action plan: investment needs, hydrogen accelerator and achieving the bio-methane targets. Brussels, May 2022. Accessed online [18/08/2022].
[23] Energy Policy Group, 2022. Renewable energy directive revision impact on the Romanian energy sector. Accessed online [15/03/2022]
[24] Energy Policy Group, 2022. Energy Efficiency Directive Revision Impact on the Romanian Energy Sector. Accessed online [15/03/2022]
[25] European Commission, 2022. Proposal for a Directive of the European Parliament and of the Council on the energy performance of buildings (recast) Accessed online [15/03/2022]
[26] EURACTIV, 2022. Industry chief: District heating sector looking at 'other options' than gas. Accessed online [20/03/2022]

national heating systems, the age of DH infrastructure and the fuel sources available), the following section describes the main similarities and differences between the LTSs of EU countries, regarding their approaches to using DH systems to decarbonise their heating sectors.

3 Comparative analysis

3.1 Overview

A first characteristic, noticeable across many MSs, is the high-level nature of LTSs. By their nature, many of these strategies present the vision and ambition of their respective countries, rather than a more detailed action plan for implementation. Some strategies point to their National Energy and Climate Plans (NECPs) or other operational documents for further detail and concrete measures. Given that DH are a rather specific measure of broader heating decarbonisation strategies, significant detail on advancing low-carbon DH networks was missing from many LTSs. Nevertheless, it is insightful to highlight those strategies which do pinpoint specific measures and targets for low-carbon DH networks as drivers for climate neutrality.

A second aspect of the LTSs is their significant variation in length and depth, running from just 8 pages (Estonia) to nearly 200 (France). This is a feature of the relatively loose requirements imposed on the documents' design by the Governance Regulation. In some cases, the LTSs are equivalent to national strategies or plans – for example, Germany's LTS is its Climate Action Plan 2050 (published in 2016), and Czechia's is its Climate Protection Policy (published in 2017). Given the commitment to the European Green Deal and associated Fit for 55 package as well as the implications of the war in the Ukraine, updates to these LTSs will be necessary to incorporate new emissions reduction and energy targets and the policy changes under REPowerEU.

Some MSs have still not submitted their first LTSs, despite the submission deadline of 2020 (Bulgaria, Ireland, Poland, Romania). For these MSs, their NECPs were reviewed instead for the purposes of this report. By their nature, the NECPs do not have the long-term vision of the LTSs, covering mainly the 2021-2030 period. Furthermore, given the more operational and detailed nature of NECPs compared to LTSs, they are allocated separate sections in the following assessment.

To assess the LTSs or NECPs, the following characteristics were evaluated:

- General objectives of the LTS: a high-level overview of the vision of the LTS
- Role of DH: an evaluation of whether the LTS discusses DH to the extent that its envisaged role in the country's future energy mix (2030 or 2050) can be deduced
- Fuel mix of DH: an evaluation of whether the LTS presents specific energy sources to be used by DHs and includes
- Technologies: an evaluation of whether the LTS discusses technologies for increasing the efficiency, sustainability, or integration of DH networks (see Box 1 for details):
    - 4th generation (low temperature) DH networks;
    - Thermal energy storage coupled to DH networks;
    - The use of cogeneration to power DH networks;
    - The use of district cooling.

- Support: an evaluation of whether the LTS presents support measures for advancing low-carbon DH networks, outside of building or expanding networks or fuel switching – for example, modernisation or innovation of existing networks, support for research and development, or financial support.
- Specific measures: an evaluation of whether the LTS presents specific measures for advancing low-carbon DH (rather than stating their importance, for example); these are split into "residential" (measures to decarbonise the residential sector using DH), "industry" (measures to decarbonise industry through DH, mostly by virtue of waste heat recovery for use in heat networks), "infrastructure" (measures related to the construction, expansion or modernisation of DH networks and associated technological systems) and "support" (measures related to the non-technical enabling of DH networks, for example research and development, financing and policy or planning).

The full list of assessment criteria is provided in Annex I - methodology.

Box 1: Technologies for low-carbon District Heating systems

4th generation DH networks

Over time, successive generations of DH systems have decreased their flow temperatures (i.e., the temperature of the piped and returned water supply), enabling greater efficiency of fuel use. The newest generation (4th generation, or low temperature, DH networks), in addition to higher efficiency, can integrate more renewable energy sources (such as low-temperature waste industrial heat), as well as enable two-way DH (for example, a commercial building producing its own solar thermal energy can be supplied by a 4th-generation DH network, as well as inject its own produced heat into the network).

Thermal storage

Short-term or seasonal heat storage is an important component of demand management as well as an enabler of integrating intermittent renewable energy sources (RES) and of inter-sectorial coupling. They can generate significant energy savings by preventing the waste of thermal energy in periods of low demand – as high as 1,400 TWh per year in Europe (IRENA, 2013). Thermal storage systems can also support the integration of intermittent RES, by storing energy in periods of high renewables output and discharging it in low-output, high-demand periods.

Co-generation

Co-generation (combined heat and power, or CHP) plants simultaneously produce electricity and heat, are more efficient than electric- or heat-only plants. Large CHP plants are the main energy sources for European DH networks, and the EU has a major focus on high-efficiency cogeneration, i.e., CHP plants that achieve primary energy savings compared to the separate production of heat and electricity. The share of DH supplied through CHP plants varies across MSs.

District cooling

Based on the same principles as DH, district cooling delivers chilled water to meet the cooling needs of buildings and industry. It currently has a very low market share in Europe, but has been developed in countries such as Sweden and Denmark, based on the relative economic attractiveness of large heat pumps and RES.

3.2 Main findings

The following sections discuss the main aspects related to DH in the analysed LTSs: 1) their envisaged role for achieving climate neutrality, 2) associated fuels and technologies, and 3) support and specific measures assigned. The full assessments of LTSs and NECPs of individual MSs are available in Annex II – Details of district heating in individual national LTSs .

3.2.1 The envisaged role of DH for decarbonisation

Extent of coverage and vision

The extent to which district heating is covered in the existing national LTSs varies. DH systems are mentioned significantly (i.e., discussed to an extent that allows an assessment of their envisioned role in a climate-neutral 2050) in 12 out of the 23 LTSs submitted (see Table 1). Some MSs whose LTSs did not significantly address DH were warm-climate countries (Greece, Malta, Portugal, Spain) or cooler-climate countries where shares of DH are currently negligible (the Netherlands). However, other countries with negligible current shares of DH (such as Italy, France, Belgium, and Luxembourg) placed a significant importance on district heat networks for decarbonisation, while some countries with high shares of DH in their heating mix did little to address the issue in their LTSs (Denmark, Estonia, Finland and Latvia). In the latter category, in some cases the LTS simply does not seem to be an adequate document for discussing heating decarbonisation through DH. For Denmark, more targets and commitments around DH are outlined in the country's 2018 Energy Agreement (an cross-party agreement on the future of the Danish energy sector), while in the case of Latvia specific measures around DH are outlined in the country's NECP). On the other hand, Sweden's modern DH networks already use mostly waste and biofuels, and the LTS presents few measures for their decarbonisation– and where it does, these measures are highly specific (for example, pricing incentives for fuel switching and encouraging prosumerism for heat production).

The main roles envisaged for DH in national LTSs are for decarbonisation of the residential sector. Some (for example, Belgium – particularly Wallonia[27] - and France) also highlight the role of DH in industrial decarbonisation, as a potential user of industrial waste heat. In many cases, DH is seen as complementary to other solutions, but in some instances, it is presented as a cost-effective alternative to other solutions for dense neighbourhoods (for example, heat pumps in Luxembourg)'s LTS. Some LTSs use DHs as part of a wider effort for district-based approaches to decarbonisation (for example, the testing of decarbonisation solutions in "model neighbourhoods" in Germany and district-centred approaches in the Netherlands). In countries where DH systems are not significantly mentioned, decarbonisation pathways for the buildings sector are often based on electrification. Some interesting advantages of DH systems are highlighted occasionally – in the Croatian LTS, where DH is significantly mentioned, buildings with cultural heritage are highlighted as potential beneficiaries of DH systems, in lieu of individual heating systems "blighting" their facades.

As for countries which have not yet submitted their LTSs, DH systems are mentioned significantly in the NECPs of those with legacy DH systems (Bulgaria, Romania, and Poland). Poland, with its 40% share of DH in residential heat demand, outlines a vision of DH systems being the primary heat supplier to households – aiming to meet all residential heating needs through DH systems and zero- or low-carbon heat sources. By 2030, the objective is to have 70% of urban households connected to DH systems (up from 61% in 2015). DH systems bring with them a significant public health component as well, replacing inefficient boilers which contribute to air pollution in Polish cities. Interestingly, despite its negligible current share of heat networks, Ireland also outlines a role

[27] The LTS of Belgium is comprised of the LTSs of Flanders, Wallonia, and Brussels-Capital.

for DH systems in its NECP. Proposed measures include identifying sources of waste heat for use in DH, such as data centres.

Table 1: Inclusion and role of DH systems in national LTSs.

Country	DH mentioned?	Role of DH
Austria	Yes	Role mostly envisaged for **residential sector**, although waste heat frequently mentioned (including industrial); decarbonisation through **switching** to renewable heat, waste heat or geothermal energy (locally produced or stored); **sector integration** through coupling with thermal storage (seasonally stored geothermal energy)
Belgium	Yes	Role for both **industrial sector** (using waste heat) and the **residential sector** (particularly in Flanders); decarbonising Flemish buildings **relies primarily on low-carbon DH** and heavily prioritises waste heat use supported by intelligent spatial planning; role of DH in decarbonising Walloon buildings is **primarily for multi-family buildings** and using renewable or waste heat; DH also highlighted as important for decarbonisation of Walloon industry, to maximise heat recovery
Croatia	Yes	DH will meet heating needs of **10% of households** by 2050; DH anticipated to contribute to electrification using **electric boilers**; DH anticipated to be installed in residential areas with **cultural heritage value**
Czech Republic	Yes	Modernisation of DH networks envisaged to bring **significant heat savings** **Heat recovery** briefly mentioned for industry, but not explicitly linked to DH networks
Cyprus	No	Not mentioned
Denmark	No	Assessment of DH potential highlights a potential role for **renewable-based DH networks**; associated with specific measures and objectives in the Energy Agreement
Estonia	No	Not mentioned
Finland	No	Decarbonisation by DH switching to **low-carbon fuels**, but consumption covered by DH expected to decline
France	Yes	DH plays a role in decarbonisation of **buildings sector, industry and energy** decarbonisation plans
Germany	Yes	DH presented as a **priority for decarbonisation**, using heat from CHP, heat pumps, solar thermal systems or waste industrial heat; seen as contributing to **increased sector coupling**
Greece	No	Not mentioned
Hungary	No	Not mentioned
Italy	Yes	Decarbonisation of the residential sector through **high- and low-temperature DH networks**; DH networks will contribute to the **diversification of energy sources and use of waste heat**; DH networks will contribute to optimising energy management and increasing

Country	DH mentioned?	Role of DH
		system flexibility through **thermal storage**; **district cooling** will be integrated; additional **low-carbon fuels** will be used in low-temperature DH networks
Latvia	No	DH is sparsely addressed in the LTS, with more detail being provided in Latvia's NECP
Lithuania	Yes	DH systems seen as contributing to alleviating Lithuania's high rates of **energy poverty**; integrating renewable energy into DH supply seen as decarbonisation measure
Luxembourg	Yes	DH systems seen as a contributor to the **renewable heat action area** DH systems are seen as a **cost-effective alternative to heat pumps** for dense neighbourhoods
Malta	No	Not mentioned
Netherlands	No	DH systems seen as one of the measures for **sustainable heating;** DH systems seen as central to a **"district-centred"** approach
Portugal	No	Not mentioned
Slovakia	Yes	DH systems are receivers of **fuel switching and efficiency** measures; measures to encourage only efficient DH systems and build new low-carbon DH networks are outlined
Slovenia	Yes	Decarbonisation and expansion of DH systems seen as key to achieve climate neutrality; **renewable energy** at the heart of heat decarbonisation, with biomass only acknowledged in areas where RE is not feasible
Spain	No	DH only mentioned as contributing to a "circular economy solution" and not detailed
Sweden	Yes	DH perceived as instrumental to achieve energy efficiency and climate neutrality; **prosumerism** outlined for small-scale heat producers

Targets and milestones

The “vision-like” nature of LTSs means that few targets or commitments are explicitly outlined around DH networks. Table 2 outlines specific commitments made in 7 LTSs of MSs which significantly mentioned DH as part of their 2050 climate neutrality vision. These countries have varied shares of DH in their national heating supply, ranging from around 5% in France to 55% in Lithuania.[28]

Many of these LTSs outline relatively high-level ambitions for the share of DH networks in national heating systems, but three also set specific targets. Slovenia and Lithuania aim to double the share of households connected to DH networks by 2050, while France aims for a threefold increase in this share between 2017 and 2050.[29] All 7 countries outlining specific DH commitments include at least one commitment related to the fuel mix of their DH networks, aiming to transition to using renewable energy, waste heat, or both.

Five LTSs present commitments which are not just related to the share and fuel mix of DH networks, but rather to building, upgrading or repairing low-carbon DH networks. Croatia and the Czech Republic, present a commitment to repairing and upgrading their existing DH networks; it should be noted that both these countries are eligible for the Modernisation Fund (which finances the modernization of DH networks, among other areas)[30]. Luxembourg and France, two of the MSs with the most significant inclusion of DH in their LTSs, also address urban planning in their DH commitments, outlining a need to identify areas feasible for heat networks – in the case of France, coupled with local waste heat sources as part of mapping heating needs. Slovakia specifies a commitment to building new DH systems in valley and basin areas.

Table 2. Targets and commitments on DH systems in national LTSs.

Country	Targets/commitments for DH
Croatia	Repair and upgrade DH networks in view of transitioning to 4th-generation networks Replace current units in buildings with efficient cogeneration or diesel heating units DH systems fuelled by efficient cogeneration units highlighted as key for decarbonisation
Czech Republic	Increase share of waste and low-carbon heat Optimise distribution systems and change insulation and pipe layouts
France	Increase share of DH in residential heating sector from 3.4% (2017) to 5% in 2030 and 11% in 2050 (based on interpretation of figures) Decarbonise by fuel switching to renewables and waste heat Use of waste heat briefly mentioned as decarbonisation lever for industry, including incentives for waste heat recovery Identification of local waste heat sources and identifying heating and cooling needs in planning
Lithuania	Achieve 90% renewable energy in DH systems by 2030 and 100% by 2050 Double number of households connected to "environmentally friendly" DH network
Luxembourg	Develop low-carbon heat networks Establish "sustainable and energy-positive dense neighbourhoods" including DH networks Develop planning instruments to identify areas suitable for DH networks

[28] Ramboll, 2020. District Heating and Cooling Stock at EU level. Accessed online [30/03/2022]
[29] Note that the targets quoted for France are based on the authors’ interpretation of the graphics presented in the LTS.
[30] The Modernisation Fund is an EU financing instrument aiming to support lower-income MSs to decarbonise and improve the efficiency of their energy systems.

Country	Targets/commitments for DH
Slovakia	Institute national policy to optimize DH systems, including shift to natural gas and biomass and CHP units installation Build new DH systems in valley and basin areas
Slovenia	1% year on year increase in share of RE and waste heat and cold in DH and district cooling networks Double share of buildings heated and cooled by DH systems by 2050 Support connection of industrial companies with DH systems by using waste heat

As expected, due to the different nature of the documents, the NECPs of Bulgaria, Ireland, and Poland are much more specific in their commitments and targets on DH than the LTSs. Bulgaria commits to promoting efficient DH and district cooling, including expansion and construction of new networks, as well as modernisation and supporting customers forced to discontinue the use of their traditional stoves. Ireland sets a key objective to develop a policy framework for supporting DH in dense urban areas. Poland commits to expanding connections to DH networks, as well as constructing new networks, modernising existing ones and encouraging cogeneration as an energy source (something that Poland has already received financing for under the Modernisation Fund).[31] Romania's NECP, which mentions DH several times, does not include targets or indicators for low-carbon DH network.

3.2.2 Fuel mix of DH

Few LTSs presented quantitative intermediate (2030) or final (2050) shares of specific fuels in the fuel mix of their future DH systems. This is in line with the "vision-like" nature of LTSs, as opposed to the concrete action plans presented in NECPs or energy-specific strategies. Only Lithuania assigns specific targets for the share of renewable energy in its future DH fuel mix (90% by 2030 and 100% by 2050) but does not specify what renewable fuels will be used. Slovenia outlines a commitment to increase its share of renewable energy in its future heating mix from 11% in 2017 to 26% in 2050. This includes a 1% year-on-year increase in the share of renewable energy in DH networks, but a target share of renewable energy in DH networks is not specified.

However, nearly all MSs which significantly address DH in their LTSs highlight the need to transition to low-carbon fuels in their DH networks (Table 3). The exception is Sweden, where the fuel mix of existing DH systems is already extensively supplied by renewable energy sources, and where residual fossil fuel used by DH producers is proposed to be targeted through pricing incentives in the LTS. The Swedish LTS also highlights a potential concern around emissions from waste incineration, which is widely used for energy recovery and supply in Sweden.[32] Denmark, although it does not significantly address DH in its LTS, outlines a commitment to achieve 90% renewable energy share in its DH fuel mix by 2030.[33] Other countries which do not significantly address DH in their LTSs do outline some sector-wide commitments to certain fuels for the overall heating sector, but these are not explicitly linked to DH networks (Finland, Latvia, and the Netherlands).

The main energy sources quoted are renewable energy and waste heat, with the former including biomass, heat pumps, solar energy and, in some cases, a burgeoning interest in shallow geothermal energy (Slovenia and Austria). The Czech Republic and Slovakia both outline natural gas as a fuel in the future mix of their heating and DH systems, respectively – an unsurprising fact

[31] Modernisation Fund, 2022. Investments - Modernisation Fund. Accessed online [21/03/2022].
[32] New York Times, 2018. In Sweden, Trash Heats Homes, Powers Buses and Fuels Taxi Fleets. Accessed online [30/03/2022].
[33] In its Energy Agreement, Denmark does outline specific fuel sources for future low-carbon DH networks, targeting an increase in the uptake of heat pumps and waste heat for use in heat networks.

given the legacy coal dependency and coal phase-out plans of these countries. However, given the current extremely high dependence of these countries on Russian gas imports (87%[34] and 86%,[35] respectively), it is unclear what effect the Russian war on Ukraine will have on planned future use of natural gas. In both these cases, it is likely that natural gas for DH networks would be used in combined heat and power (CHP) plants, given that these already account for 70% of the Czech Republic's total gross heat production in large and medium-sized combustion units, and their mention as potential future fuel sources for DH networks in Slovakia.

Table 3. Envisaged fuel mix for DH systems in national LTSs. Only countries with significant mention of DH are shown.

Country	Fuel mix proposed?	Fuels proposed
Austria	Yes	Biomass, heat pumps, solar thermal energy, waste heat (industrial and municipal), local or stored geothermal energy
Belgium	Yes	Renewable and waste heat Walloon LTS mentions biomass, solar thermal energy and cogeneration, although not specifically for DH
Croatia	No	Electric boilers, cogeneration and diesel units mentioned for DH networks, but no actual fuel mix proposed
Czech Republic	No	Gas, biomass, waste heat and other low-carbon heating sources (for whole heating sector rather than explicitly for DH)
France	Yes	Renewable or waste heat will fuel DH systems by 2050 (biomass, heat pumps, waste heat, joule effect systems, solar thermal energy)
Germany	Yes	Increased use of CHP, large-scale heat pumps or solar thermal systems for fuelling DH networks Waste heat also considered
Italy	Yes	Solar thermal, biomass, waste heat (industrial and low-enthalpy), centralized heat pumps
Lithuania	No	Overall target of 90% renewable energy share in 2030 and 100% in 2050 in DH systems
Luxembourg	Yes	Decentralised renewable energy and waste heat from industry
Slovakia	Yes	Transition from "fossil fuels" (coal) to biomass, natural gas and waste heat in DH systems
Slovenia	Yes	Solar energy, heat pumps using shallow geothermal energy, industrial waste heat, CHPs, "climate-neutral synthetic gas"

[34] Heinrich Böll Stiftung, 2022. How to break Czechia's dependence on Russian gas. Accessed online [30/03/2022].
[35] EURACTIV, 2022. Slovakia yet to plan solution to lower dependency on Russian energy. Accessed online [30/03/2022].

The NECPs of Bulgaria, Ireland, Poland, and Romania address the fuel mix of their future DH systems, although the level of specificity is not much higher than in the LTSs. In Bulgaria, the use of biomass from waste and geothermal energy are highlighted as potential fuel sources for DH and district cooling systems. Ireland pinpoints industrial waste heat, solid and gaseous biofuels and geothermal energy as potential fuel sources for DH networks. The latter has recently generated significant interest for use in Ireland. In Poland, natural gas is foreseen to play a transitional role, and biomass and waste heat are outlined as particularly suitable to fuel future DH networks. Romania proposes the use of heat pumps, based on an increasing share of renewable electricity, as well as geothermal energy (projected to increase from 31 to 45 ktoe by 2030 in the "with additional measures" scenario) and industrial waste heat. However, only natural gas combusted in CHP plants to fuel DH networks is presented as a priority for financing for the 2020-2030 period.

3.2.3 Technologies

In nearly all LTSs which significantly mention DH, the decarbonisation of heating through the use of DH involves a range of measures, including the expansion of low-carbon networks, the modernisation, or upkeep of existing infrastructure to improve efficiency, or the replacement of fossil fuels with renewable or waste energy. All LTSs which significantly mention DH networks also highlight at least one specific technology to be coupled to low-carbon DH networks, even if in most cases the mentions are brief (in line with the overall lack of detail in most LTSs). The most mentions are related to the use of cogeneration (CHP) units as fuel sources used for DH networks and 4th-generation (low temperature) DH networks, while district cooling is sparsely mentioned.

Croatia, Finland, Germany, Lithuania, and Slovakia explicitly associate **cogeneration units** with advancing low-carbon DH systems. Most such mentions are brief (e.g. in the case of Finland, which does not elaborate on the role of DH in climate neutrality, and Lithuania, where CHPs are seen as a longer-term measure for improving heat generation efficiency), but Croatia, Germany and Slovakia all draw strong links between cogeneration and advancing low-carbon DH networks as climate neutrality measures.

On next-generation networks, only Austria, Croatia, Germany, and Italy specifically mention **4th-generation (low temperature) DH networks** in their LTSs. All have relatively low current shares of DH in their residential heat supply (at most ~15% in Austria). While in the case of Croatia and Germany, 4th-generation DH networks are mentioned only briefly, the LTSs of Austria and Italy tout them as significant decarbonisation measures. Italy's LTS, in fact, splits high-temperature and low-temperature DH networks in terms of their contribution to decarbonisation (for example, low-temperature networks can be coupled with low-enthalpy waste heat sources). Austria's LTS outlines low-temperature DH networks as enabling thermal storage, efficient heat distribution and the integration of renewable and waste heat sources.

Austria, Belgium - Wallonia, Italy, Luxembourg, and Slovenia are the only countries which mention **thermal storage** in conjunction with DH networks, mostly to optimise the networks and increase system flexibility by enabling sector coupling. It is noted that while Austria mentions thermal storage systems in conjunction with low-temperature heat networks, Italy associates them with high-temperature (traditional) networks.[36]

Little attention is paid to **district cooling** in the LTSs. Denmark's Energy Agreement includes an agreement to promote district cooling initiatives, while in the LTSs of France and Slovenia, district cooling is often mentioned in conjunction with DH but not specifically addressed. As one of the few

[36] In general, thermal storage units are seen as an enabler for low-temperature DH networks, this being the possible rationale for their association with current traditional networks in the Italian LTS. Source: Kuosa et al, 2022. Optimisation of district heating production by utilising the storage capacity of a district heating network on the basis of weather forecasts. Results in Engineering 13.

countries with higher cooling needs and specifically tackling DH, Italy only mentions district cooling as being possible to integrate in high-temperature networks.

As for countries without LTSs, the NECPs reveal the following: Romania draws a strong link between DH systems and high-efficiency cogeneration, as well as district cooling, while Ireland hints at 4th-generation DH networks by focusing on the use of low-temperature heat sources (waste heat from data centres). Poland names high-efficiency cogeneration as a key measure for advancing efficient DH networks, as well as an expansion of district cooling (heat storage is only briefly mentioned). Bulgaria only mentions district cooling in conjunction with DH as part of its decarbonisation efforts.

3.2.4 Other support for district heating

A final review shows relatively vague commitments on the provision of modernisation, research and development (R&D) and financing measures in national LTSs. Hungary, Croatia, the Czech Republic, and Slovakia all address modernisation of DH networks in their LTSs, with varying levels of concreteness in their commitments. Some of these MSs refer to using the Modernisation Fund for modernising their DH networks (Hungary, Czech Republic and Slovakia). Only Slovakia makes a concrete commitment to using this Fund for modernisation of its networks; it should be noted that both Hungary and Slovakia applied for and received financing from the Modernisation Fund in 2021 to upgrade their DH networks.[37] Although Croatia does not state a financing source for its proposed network repair and upgrade measures, it may also use the Modernisation Fund for this purpose, given it is a beneficiary state of the Fund.

Only two countries mention R&D around DH as part of their LTSs. Germany's LTS outlines support for R&D and commercialisation of low-temperature heating systems which can be integrated with renewable energy sources. It also commits to the establishment of "model neighbourhoods" to pilot innovative solutions, including smart networks. Slovenia aims to support pilot projects also in integrating renewable energy into their DH supply. In France's LTS, support for R&D is not explicitly outlined, but a performance indicator on the number of studies on the future of heat networks is presented.

Regarding the financing of low-carbon DH systems, five MSs suggest financial instruments for decarbonising the DH fuel mix: Austria's LTS foresees a mix of financial, fiscal, and legal instruments to support the replacement of individual oil-fired heating systems with connections to efficient DH networks and renewable heat. France's LTS suggests incentives for promoting on-site waste heat recovery from industrial entities (for further use in DH systems), and Slovenia outlines financial support to integrate renewable energy into DH systems as a key measure (but does not quantify the investment needs). Both Sweden and Denmark (in its Energy Agreement) suggest price incentives to support the transition from fossil-based to renewables-based DH systems.

Other countries address financing more vaguely: several Central and Eastern European countries mention the Modernisation Fund (see above), the LTS of Flanders (Belgium) outlines that climate policy revenues will be used to finance the development of heat networks, while the Luxembourgish LTS simply highlights public investment and financial instruments that are already available to public authorities for DH investments. Finally, as mentioned in Section 3.2.3, the Czech Republic, Hungary, and Slovakia highlight the Modernisation Fund for upgrading their DH networks.

A variety of other support measures are presented, ranging from incorporating DH feasibility assessments into urban planning (Austria) to tackling emissions of fluorinated GHG by using natural cooling agents in DH networks (Germany). In general, these additional measures can be

[37] Slovakia received €65 million for state aid to rehabilitate and extend its DH networks, while Hungary received €14.2 million to support renewables-based DH systems.

classified as technological, regulatory, and planning measures, and they are mentioned even in some LTSs which do not significantly address DH systems (see Table 4).

Table 4. Support measures envisaged for low-carbon DH systems in national LTSs.

Technological measures	
Austria	Urban planning to incorporate DH or local heating and make best use of waste heat potential
Germany	Integrative concept to tackle emissions of fluorinated GHG through use of natural cooling agents in DH networks.
Latvia	LTS vaguely mentions that innovative technologies and efficiency operations will be introduced in centralised and local heat supply systems
Regulatory measures	
Denmark	Restructuring of regulations on surplus heat to incentivise its use (although not explicitly linked to DH networks)
Estonia	Vague mention of a goal for improving the legislative framework, aiming to facilitate efficient and sustainable heat networks
Germany	Measure suggested to use "an appropriate mix of instruments" to address barriers for the use of waste heat.
Luxembourg	LTS also calls for a revision of EU aid guidelines to support investments in heating and cooling networks
Planning measures	
France	Measure suggested to identify potential for heating and cooling networks in territorial development policies and planning
Hungary	Measure suggested to integrate considerations of climate risk into DH network planning, but no specific measures outlined.
Luxembourg	The use of thermal cadastre planning instruments
Netherlands	The LTS highlights the development of heating plans as central to a district-oriented approach to building sector decarbonisation
Slovenia	Recommendation to include climate resilience assessment in design of new DH networks Indicators for emissions reduction success include DH-related indicators (share of buildings connected, share of RES and waste heat, average specific emissions per unit of DH)

As for countries where the NECPs were analysed, Poland presents an array of additional support measures to facilitate the advance of low-carbon DH networks. These include simplifying investment procedures, financial and market incentives, “popularising” smart networks and heat storage and modernising and expanding DH and district cooling systems. Ireland aims to create a national policy framework to support regulation, planning, financing, and research related to DH, as well as using two existing pilot schemes to develop and transfer knowledge. The Bulgarian NECP lists support offered to households to connect to existing DH systems as well as expanding new connections and highlights the modernisation and upkeep of infrastructure as a necessary measure. Romania does not outline any additional support measures connected to DH in its NECP.

3.2.5 Specific measures to advance low-carbon DH

Given their “vision-like” nature, there is a large variation between LTSs in the level of detail regarding support measures outlined for DH systems. Some LTSs (even some which significantly mention DH systems) do not detail concrete measures, while others outline measures which are fairly high-level, lacking specific context or implementation details. Table 5 presents the specific measures, where they exist. For conciseness, it does not include the high-level measures (e.g., “increase share of renewable heat”) – these can be found in the country-specific assessments in Annex II – Details of district heating in individual national LTSs Several key takeaways from this table are discussed below.

Firstly, the bulk of measures to support low-carbon DH systems focus on the residential sector and are presented as ambitions rather than concrete steps or plans. Some MSs also outline measures for industry to advance low-carbon DH, more specifically addressing the supply of waste heat to these heat networks (Belgium, the Czech Republic, France, Germany, Slovakia, and Slovenia).

Secondly, specific measures related to the infrastructural aspects of low-carbon DH networks are rare. Only Belgium, the Czech Republic, and Slovakia concretely outline the construction or expansion of heat networks, while this is implied in the French and Lithuanian LTSs by virtue of their targets to increase the share of DH-supplied households, and the Luxemburgish LTS through its commitment to implement new DH networks in dense urban areas.

Finally, the variation in the specificity and reach of support measures does not seem to correlate with the current share of DH in national heat demand. For example, France outlines the most measures to support DH systems focused on implementation of heat networks in residential areas, while Luxembourg lists the most measures to support research, innovation, and financing of low-carbon heat networks. Neither of these countries has a share of DH in their national heating sectors of more than 5%. On the other hand, countries with legacy DH systems in Central and Eastern Europe are relatively vague in specifying support measures for low-carbon DH, with the notable exception of Slovakia.

Table 5. Specific measures outlined for supporting low-carbon DH systems in national LTSs.

Country	Residential sector	Industry	Infrastructure	Support
Austria	Replace oil-fired heating systems with RES and efficient DH		Integrate thermal storage using geothermal energy	Mix of legal, financial, and fiscal instruments for replacing oil-fired heating systems with efficient DH
Belgium			Construction of heat and cold networks (no targets mentioned)	Use climate policy revenues to finance large investments
Croatia	Repair and upgrade DH networks with a view of moving towards 4th generation DH			
	Upgrade building “boiler rooms” to cogeneration and/or diesel heating units			
Czech Republic			Optimise distribution systems	
			Changes to insulation and pipe layouts	
France	Increase heat supplied through DH systems from approx. 25 TWh in 2015 to 30 TWh in 2030 and 50 TWh in 2050; connect collective dwellings to low-carbon DH networks as a priority	Encourage the identification of waste heat sources in the vicinity of DH networks and implement heat recovery	No specific mention of infrastructure development, although the increase in energy supply to buildings via DH networks suggests the need for new connections	Identify needs and potential for heating and cooling networks in territorial policies and plans
		Incentivise the development of on-site waste heat recovery, including for feeding into DH networks	Suggested future infrastructure development for connecting waste heat sources to nearby DH networks	

Country	Residential sector	Industry	Infrastructure	Support
Germany	Increase the use of CHP plants, large-scale heat pumps and solar thermal systems for fuelling DH networks	Improve waste heat recovery to use in DH networks		Support research, development and commercialization of low-temperature heating systems coupled with renewable energy sources
				Evaluate “model neighbourhoods” including testing smart networks
Italy	Develop high-temperature (traditional) DH networks, integrated with thermal storage and possibly with district cooling, and low-temperature (4th generation) DH networks, running on low-enthalpy waste heat, solar thermal systems, and heat pumps			
Lithuania			No specific mention of infrastructure development, although the increase in energy supply to buildings via DH networks suggests the need for new connections	
Luxembourg	Within dense urban neighbourhoods (existing or planned), implement low-carbon DH networks		No specific mention of infrastructure development, although the implementation of new DH networks suggests the need for infrastructural development	Implement thermal cadastres to identify DH potential and opportunities
	Explore the coupling of DH networks to heat storage			Mobilize financing instruments such as energy and climate funds for DH infrastructure investments

Country	Residential sector	Industry	Infrastructure	Support
Luxembourg				Call for revision of EU State Aid guidelines
Slovakia		Incentivise the use of industrial waste heat in heating networks	Modernise DH pipeline networks	
			Introduce new, RES-based DH systems in valleys and basins	
Slovenia		Support the connection of industrial enterprises to DH networks		Support pilots of new technologies for integrating RES into DH
Sweden				Energy and CO_2 taxes to incentivise fuel switching by DH producers

For countries for which the NECPs were analysed instead of the LTSs, the level of detail regarding support measures was higher - as expected given the different nature of these documents. This was the case for Bulgaria, Ireland, and Poland. Bulgaria and Poland outline infrastructure-related measures for advancing low-carbon DH, with Poland lists market and financial measures to incentivise heat network expansion and decarbonisation. Ireland does not outline specific infrastructural measures, however their target of increase in energy supplied by DH networks implies an expansion of existing systems or construction of new ones (more likely the latter, given the current negligible share of DH in the country). Romania does not outline any specific measures to advance low-carbon DH, despite having a significant share of legacy DH. This further reinforces the fact that despite being more short-term, operational plans than LTSs, the level of detail on decarbonisation measures varies across NECPs as well.

4 Conclusions and recommendations

DH systems can be important vectors for decarbonisation, given their superior efficiency, their ability to use low-carbon fuels and their potential for coupling with thermal storage capacities and industrial waste heat. Their potentially significant contribution to decarbonising the residential sector (and somewhat the industry), has led to an increase in policy interest at EU level, evidenced through the Fit for 55 legislative proposals and the RePowerEU plan. Major barriers to the advancement of low-carbon DH continue to be high upfront investment costs and the significant need for repair and modernisation in countries with legacy DH systems such as Central and Eastern European states.

The LTSs of Member States exhibit a great diversity in the importance assigned to low-carbon DH systems and the detail outlined on measures to support them. This variation does not seem to be always correlated with the current share of DH in national heating mixes, nor with the differences between LTSs and NECPs as “vision” documents (the former) and action plans (the latter). Some MSs with a high share of DH, that are advanced in their decarbonisation (such as Denmark and Sweden) do not devote significant attention to low-carbon DH in their LTSs, which could be linked to their current (relatively) low-carbon status. However, others with a similarly high share of legacy DH, mostly using fossil fuels, also fall short of specifying a pathway for decarbonisation of existing DH systems, incl. addressing existing issues such as lagging upkeep and a need for modernization (for example, Romania and the Czech Republic).

Where they are specified, **measures for advancing low-carbon DH systems tend to focus on transitioning to low-carbon fuels and increasing coverage in the residential sector**, with some interest shown in the enabling of waste heat recovery from industry for use in heat networks. There is a limited focus on opportunities for coupling DH systems with thermal storage or advancing towards 4th-generation networks - many LTSs do propose high-efficiency cogeneration units as energy sources for their heat networks, which are generally quite common for DH systems in the EU. Research, development, and financing are also rarely addressed. Some financial incentives are mentioned in countries such as France, Luxembourg, Sweden and Denmark, and connections to the Modernisation Fund are made in some Central and Eastern European countries’ strategies.

The advancement of low-carbon DH systems, capitalizing on their potential for decarbonisation of the residential and industry sectors, could be better embedded into future LTS updates in several ways.

Firstly, **MSs should integrate DH systems into their LTSs as key decarbonisation measures.** These systems will not always be suitable to local circumstances (for example, warmer climates), but as the analysis shows, the paucity of detail in addressing DH systems is not confined to countries with lower heating requirements. Additionally, district cooling should also be explored particularly to countries with higher cooling needs.

Secondly, **countries including DH systems in their LTSs should be more concrete on their projected development**, including better quantifying the target share and fuel mix of low-carbon DH networks in future heating mixes, as well as the projected share in the overall residential heating demand. Indicative intermediary targets should also be provided. Specifying a future fuel mix for DH networks is particularly important considering the previously envisaged role of natural gas in some countries, which in the context of the current geopolitical situation should be revised. Where available, MSs should refer to specific heating or cooling strategies, their NECPs or other strategic plans and make sure these are integrated with their ambitions for developing low-carbon DH.

Finally, **more attention should be paid to support mechanisms for DH systems**. These systems are capital-intensive and require heavy infrastructure development, requiring a mix of legal, fiscal, and financial incentives. Beyond the cost aspect, the planning challenges around DH systems must be consistently addressed, by inclusion in district, city or regional-level policies and territorial planning instruments. To boost innovation for efficient DH networks, MSs should commit to enabling more R&D on low-carbon DH systems.

To conclude, fulfilling the decarbonization potential of low-carbon DH systems could be significantly advanced by integrating them into national LTSs in a meaningful way, with associated targets and milestones as well as adequate support mechanisms. In the context of the numerous challenges faced by Member States' energy systems, it is vital that low-carbon and efficient DH networks become the backbone of a sustainable and secure future heating system. This can be embodied in ambitious LTSs, integrated with national and European strategies for heating, cooling and industrial decarbonization, and overseen by European policy which accounts for national specificities and circumstances.

5 Annex I - methodology

Assessment criteria

The treatment of district heating in LTSs was analysed based on several assessment criteria:

- Whether the issue of district heating is covered to an extent that allows the assessment of the role of DH in the country's energy system to 2050. If it is not, it is assumed that there is "no significant mention" of district heating in the LTS.
    - A sub-criterion for this measure is whether plans for low-carbon DH systems include intermediary targets (e.g., share of residential heating provided by DH systems)
    - Countries which have significant contributions of DH to their heating sectors, but which do not address DH in their LTS, are highlighted.
- Whether the future fuel mix of DH systems is outlined in the LTS, and what proportions (if any) of different fuel types are assigned to future DH systems. Where possible, the assessment is based on numeric data, where the share of a given fuel is to increase, replacing fossil fuels.
    - A sub-criterion for this measure is whether the evolution of the fuel mix of DH systems includes intermediary targets to 2050, or just a 2050 objective
- Whether or not the proposal for DH systems specifically addresses 4th generation (low-temperature) DH networks
- Whether or not the proposal for DH systems includes a proposal for coupling with thermal storage, combined heat and power or district cooling
- Whether or not the LTS addresses the needs or investment plans for DH measures of a supporting nature (i.e., outside of the construction or expansion of DH networks, or the replacement of fuels):
    - Infrastructural, e.g. network modernization, smart DH technologies e.g., demand management systems or smart heating controls, to improve the performance of the system by reducing pressure on the network
    - Research, innovation and knowledge creation, e.g., heat mapping, innovation in smart DH management systems
- Whether financing for low-carbon DH systems is addressed in the strategy

As a general remark, many LTSs either lack specific figures for the above indicators, or objectives are only vaguely defined. Hence, the assessment is sometimes based on conclusions drawn from the general picture presented in each LTS and not on precise data.

6 Annex II – Details of district heating in individual national LTSs

6.1 Austria

General objectives

In 2017, the Austrian Federal Government developed a series of scenarios for decarbonisation of the Austrian economy, including a "transition scenario" to achieve maximal emissions reduction with domestically available energy supplies. Within this scenario, "a switch to electricity and district heating generation based on renewable energy and the systematic use of waste heat potential" is highlighted as a key action, as is evolving DH systems for heat supply and distribution to become "highly efficient and renewable". Austria currently has a relatively low level of penetration of DH systems in residential heating (approx.15%),[38] and according to the LTS, 3% of final energy consumption in the manufacturing sector came from DH.

Austria's aim for 2050 is that "[d]istrict heating plays a central role in urban areas with a high density of heat consumers and in the vicinity of efficient suppliers of waste heat. Local, bidirectional (low-temperature) networks improve the possibilities of heat storage, energy-efficient heat distribution, efficient integration of renewable heat and the use of a wide variety of waste heat or locally of geothermal energy and seasonally stored geothermal energy." However, it sets no specific targets and also mentions heat pumps as accounting for a significant share of energy needs for space heating, hot water provision and cooling.

The following specific objectives related to DH systems are highlighted: the need for renewable and waste heat as a fuel for DH systems, the need for heat storage, the need for incorporating DH into urban planning, and support measures.

Role of DH systems

DH systems are significantly mentioned in the Austrian LTS (covered to an extent that allow a qualitative but not quantitative assessment of the role of DH in the country's energy system to 2050). Intermediate targets do not exist.

DH systems are most extensively mentioned in connection with the supply of heating to the residential sector. Alongside renewable heat systems, they are the most-mentioned alternatives for the decarbonisation of residential heating, in particular the phase-out of oil-fired heating in residential buildings. Although currently 3.5% of industrial energy consumption is provided by DH systems, no specific objectives are outlined for DH in industry.

Fuel mix

The future fuel mix of DH systems is outlined in the LTS, but no specific proportions of fuel types are assigned. Renewable (biomass and ambient heat, and solar thermal energy) and waste heat (operational[39] and municipal), as well as local or stored geothermal energy are mentioned as fuel types in the vision for 2050 of Austria's buildings sector. No intermediate targets are presented.

Technology

[38] Ramboll, 2020. District Heating and Cooling Stock at EU level.
[39] Although it is not clear what "operational" refers to, it is assumed to mean industrial in this context.

The Austrian LTS specifically addresses 4th generation (low temperature) DH networks and an aim to couple DH systems with thermal storage systems. Overall, the Austrian LTS highlights the need for seasonal heat storage to prevent supply shortages during the heating season, and for an increase in the generation of renewable heat. It also highlights the "world's first high-pressure and high-temperature storage facility" at Vienna-Simmering, integrated into Vienna's DH system and enabling the decoupling of energy generation from consumption. Seasonal heat storage is even highlighted as having the potential to replace heating plants.

CHP units and district cooling are not addressed in the LTS.

Support

Austria's LTS does not specifically address the need for infrastructure development or research/knowledge creation for low-carbon DH systems, but outlines a short series of legal, financial, and fiscal measures which could support investments in DH. According to Austria's Mission 2030, starting in 2025 half of existing 700,000 oil heating systems for buildings will be replaced by either renewable energy systems or efficient district heating by 2030, transitioning to full replacement with renewable alternatives by 2040. To achieve the phase-out of oil-based heating, the LTS lists a mix of long-term legal, financial, and fiscal instruments.

It also outlines the implementation of spatial, zoning and development planning to incorporate DH or local heating and make best use of waste heat potential.

Specific measures

No specific measures are outlined in the Austrian LTS for decarbonising DH systems, at a level more granular than those outlined in the general objectives of the Strategy.

Table 6. The measures to decarbonise DH systems in the Austrian energy system.

Sector	Measures
Residential	Transition to DH fuel mix based on renewable and waste heat (high-level)
	Replace oil-fired heating systems with RES and efficient DH
Infrastructure	Integrate thermal storage using geothermal energy
Support	Mix of legal, financial, and fiscal instruments for replacement of oil-fired heating systems with efficient DH

6.2 Belgium

General objectives

Given the sharing of power between the federal state of Belgium and its three regions (Wallonia, Flanders and Brussels-Capital), the LTS of Belgium incorporates three regional strategies for climate neutrality. DH systems are addressed separately in the three regional strategies, and brought together in the LTS's introduction, where the role of these systems is stated for industrial sectors, as a method for improving energy efficiency by maximum recovery of waste heat ("both within the installation and via heat networks"), and for the residential sectors of Wallonia and Flanders (particularly the latter).

In Wallonia, the main source of carbon-neutral energy for space heating and hot water production is foreseen to be heat pumps, as well as renewable thermal energy sources and DH networks in cities. In Flanders, the 2050 decarbonised building energy supply relies primarily

("as much as possible") on DH networks supplied with waste or renewable heat. Brussels-Capital relies mainly on solar thermal and PV energy combined with heat pumps.

Flanders, whose target for buildings is to reduce emissions by 75% by 2050 relative to 2015, places a significant emphasis on the use of waste heat, stating that it "will make maximum use of existing waste heat potential", in addition to electrification of heating and cooling. By 2050, the region is aiming for maximum recovery of waste heat from industrial installations, for use in industry and, where not possible, in DH networks. For residential buildings, to meet the ever-present "residual demand for energy", Flanders relies on heat networks supplied by waste or renewable heat sources. The development of low-carbon heat networks is supported by "intelligent spatial planning which encourages […] clustered housing in the right places."

The Walloon LTS includes DH networks in its lever for decarbonisation of the energy system, highlighting the use of biomass, solar thermal energy, and cogeneration, "pooled through heat networks", where appropriate. The recovery of waste heat is also mentioned. In its guidelines for developing a renewable energy mix, the LTS states that "heat and cold networks will be developed to supply cities. In concrete terms […] for multi-family buildings, connections to renewable or waste heat networks […] should be a priority", whereas for individual buildings heat pumps, solar thermal energy and geothermal energy are prioritized. A link is made to the re-evaluation of the role of the natural gas network, considering the decrease in natural gas consumption for residential heat production. The role of heat networks in urban areas is repeatedly mentioned throughout the LTS, apparently with varying levels of importance assigned.

The Walloon LTS also emphasizes the need for developing heat networks for industry, to maximise the use of industrial heat as a recovery resource. It also mentions sector coupling based on the integration of electricity, gas and heat networks to supply energy to all consumption sectors, while providing storage solutions.

Finally, the LTS of Brussels-Capital, despite owing 54% of its emissions to buildings (primarily residential buildings), does not outline a role for DH networks- only Brussels Airport is connected to a heating network.[40]

Role of DH systems

DH systems are significantly mentioned in the Belgian LTS (covered to an extent that allow a qualitative but not quantitative assessment of the role of DH in the country's energy system to 2050). In Flanders, the role of DH systems is mostly envisaged in the residential sector, while in Wallonia it is also outlined as a solution for achieving maximum waste heat recovery in industry. The role of DH networks is not mentioned in the LTS of Brussels-Capital. Intermediate targets do not exist.

Fuel mix

Both at federal level and in the Flemish and Walloon LTSs, the fuels for low-carbon DH networks are either renewable sources or waste heat. The Walloon LTS mentions as renewable heat sources for buildings (although not specifically for DH networks) biomass, solar thermal energy and cogeneration.

Technology

The Walloon LTS links DH networks to sector coupling, including storage solutions, and aligns the development of heat and cold networks with the re-evaluation of the role played by natural gas networks, given the reduction in consumption of natural gas for residential heating

[40] Vlaams Energie- & Klimaatagentschap, 2021. Heating in Flanders.

Support

The Flemish LTS states that climate policy revenues (such as revenue from auctioning EU ETS allowances), in combination with co-financing, will be used to finance large investments such as the development of heat networks.

Specific measures

Table 7. The measures to decarbonise DH systems in the Belgian energy system.

Sector	Measures
Residential	Use renewable and waste heat in DH supply (high-level)
Industry	Maximise waste heat recovery for surplus use in heat networks (high-level)
Infrastructure	Construction of heat and cold networks (no targets mentioned)
Support	Use climate policy revenues to finance large investments

6.3 Bulgaria

General objectives

At the time of writing, Bulgaria had not yet submitted its Long-Term Strategy, but it did address DH systems in its National Energy and Climate Plan (NECP). The country has a significant share of DH in its residential heating mix (approx. 16%)[41] with 22 DH systems that supply heat to buildings and industry. Bulgaria's DH systems suffer from similar issues around lack of maintenance and refurbishment of its DH systems. Heat losses from existing DH systems are high (17% in production and 20% in transmission[42]), partly due to the age of the infrastructure, leading to high energy bills and a resulting drop in customer volumes, with some choosing to switch to individual boilers, in theory a less efficiency heating choice than a well-maintained and efficient DH system.

In 2021, the US Trade and Development Agency offered its support for upgrading and refurbishing Sofia's DH system, including a roadmap for phased upgrade to its DH plants (no mention of fuel replacement is made).[43] Similar projects in Sofia have been supported by the European Bank for Reconstruction and Development, and by the World Bank more widely in Bulgaria.

Role of DHS

DH systems are significantly addressed in Bulgaria's NECP. Overall, the low-carbon transition of Bulgaria's heating and cooling sector is foreseen to be supported by energy efficiency and fuel switching. In the former category, increases in energy efficiency are envisaged to have a positive impact on losses from DH networks, expected to decrease by approx. 30% between 2020 and 2030. In the latter, the NECP projects a significant use of biomass in cogeneration (a huge increase of cogeneration from 4 to 2,497 GWh over the 2020-2030 period). No specific shares are provided for DH systems.

The NECP states that the use of efficient DH and district cooling will be promoted, including building new DH networks and expanding existing ones, estimated to save 52 kt CO_2/year. DH stations will be modernised, and the use of pre-insulated pipes will help reduce losses in DH

[41] Ramboll, 2020. District Heating and Cooling Stock at EU level.
[42] Alfa Laval, 2022. Warming Bulgaria
[43] USTDA, 2021. USTDA Supports Sustainable Heating in Bulgaria

systems. Furthermore, customers affected by a mandatory discontinuation of traditional stoves will be offered support to connect to DH systems.

Fuel mix

Although no specific fuel shares are provided, the use of biomass from waste and geothermal energy are highlighted as potential contributors to the renewable energy share in DH and cooling systems. A project to convert the DH system of Sofia (Bulgaria's capital) to use refuse-derived fuel is currently being implemented.

Technology

No mention is made of 4th-generation DH networks or thermal storage, but district cooling is packaged together with DH in its vision for decarbonisation of the heating and cooling sector.

Support

The Bulgarian NECP outlines that support will be offered to households to transition to DH systems, by offering reconnection to existing networks or expanding the systems. Modernisation and upkeep of existing infrastructure is also highlighted as a necessary measure.

Specific measures

Several measures are outlined to enable low-carbon DH systems in Bulgaria.

Table 8. The measures to decarbonise DH systems in the Bulgarian energy system.

Sector	Measures
Residential	Use secondary biomass, geothermal energy, and energy from waste in cogeneration for DH supply
Infrastructure	Modernise DH stations
	Replace piping in DH networks to reduce losses
	Expand existing DH networks
	Offer support for customers to reconnect to DH networks

6.4 Croatia

General objectives

Croatia's LTS, embodied by the country's Low-Carbon Development Strategy until 2030 with a view to 2050, is the first plan developed by the authorities in conjunction with European provisions for climate protection. The strategy has been adopted by the Parliament and is awaiting an action plan to be issued by the Government within the next 5 years.

In 2018, the electricity and heat production sector accounted for 13.8% of GHG emissions of the Republic of Croatia. These emissions are projected to decrease by around half by 2030 in the gradual and "powerful" low-carbon transition scenarios, and by 61% and 93% by 2050 in the gradual and "powerful" transition scenarios, respectively. Electricity consumption is projected to increase, with one of the drivers being an increase in the use of diesel for heating purposes – although the rationale behind this is not clear – and the use of electric boilers and/or heat engines in centralised heating systems.

Role of DHS

In its emissions projections, the Croatian LTS assumes that 10% of households' and commercial buildings' heating needs will be met by DH in 2050. Most households will instead be heated by biomass (35%), natural gas (41%) and heat pumps (14%) in the reference scenario, with higher shares for biomass and diesel heating in the gradual and "powerful" transition scenarios. DH systems are envisioned to contribute to an increase in the overall electricity consumption, due to the use of electric boilers as fuel sources, anticipated in a medium-term timeframe.

In one of its measures for decarbonisation of the energy sector, centralised heating systems are highlighted as one of the measures for decarbonising Croatia's electricity and heat production sector, using high-efficiency cogeneration based on natural gas (in combination with renewable energy) or biomass. They are also highlighted as one of the priorities of Croatia's energy policy, with potential for improvements in efficiency. It is assumed that centralised heat production refers to the use of DH networks.

Centralised heating and cooling systems are also highlighted as ripe for use in town centres and cultural heritage sites, to replace boilers installed on building facades which are a "blight" on the urban landscape.

Another concrete measure proposed in Croatia's LTS focuses on the repair and upgrade of DH networks, given their age and obsolescence, moving towards 4th-generation (low-temperature) DH. The measure also includes replacement of "boiler rooms" in buildings with highly efficient cogeneration units or diesel heating units.

More broadly, the LTS points to the necessity for improving heating and cooling efficiency and increasing the attractiveness of cogeneration plants using alternative fuels, including a stronger integration with the transport and heating systems.

Overall, the Croatian LTS does indicate a significant role of DH networks in the residential sector in 2050, given their higher efficiency, but provides little detail on advancing low-carbon DH networks. No role is outlined for DH in industry or the use of waste heat in DH networks.

Fuel mix

There is little focus on the future fuel mix of DHSs in Croatia. It is anticipated that electric boilers and heat pumps will be installed as fuel sources in the medium-term, contributing to an increase in electricity demand. The deployment of CHP is strongly linked to DH networks, and the LTS also mentions the use of renewable energy.

No final or intermediate targets for shares of alternative fuels in DHSs are presented.

Technology

As mentioned above, Croatia's LTS pinpoints the transition of DH systems to 4th generation DHS as a measure for decarbonisation. The use of advanced metering in DH networks is also highlighted, although little detail is given.

The deployment of CHP is strongly linked to heat networks. Thermal storage systems coupled to DH networks are not directly addressed, but energy storage is highlighted as necessary in buildings using a high share of renewable energy resources. District cooling is not mentioned.

Support

Generally, the Strategy suggests that Croatia's islands can serve as pilot sites for the development of integrated solutions, from example through energy production from waste or wind and increasing energy efficiency. No specific support is highlighted for financing low-carbon DH systems or encouraging research in low-carbon DH.

Specific measures

Vague measures are presented for advancing low-carbon DH systems, including modernisation and upgrade of existing networks and fuel sources.

Table 9. The measures to decarbonise DH systems in the Croatian energy system.

Sector	Measures
Residential	Repair and upgrade DH networks with a view of moving towards 4th generation DH
	Upgrade building "boiler rooms" to cogeneration and/or diesel heating units
	Improve the efficiency of DH networks (high-level)
	Use centralised heating systems in cultural heritage residential sites (high-level)

6.5 Cyprus

Cyprus submitted its Long-Term Strategy in September 2022.[44] The LTS does not mention DH, or indeed address heating and cooling decarbonization. The country has a very low share of DH systems in its residential heating supply, with an economic potential of high-efficiency cogeneration coupled to efficient DH and district cooling of around 50 MW in 2020.[45] The share of DH and district cooling in Cyprus's heating and cooling sector is very low in projections in its National Energy and Climate Plan (NECP), which highlights a higher economic potential of heat pumps and suggests "further study" for the potential for DH and cooling networks.

Despite this, Cyprus's NECP does highlight a potential role for DH systems in Cyprus's touristic areas is highlighted in the late 2020s, aiming alongside residential heat pumps to overcome the saturation of demand for solar water heaters.[46] A 2017 report on DH potential in Cyprus found only DH systems powered by waste or oil, combusted in cogeneration plants, to be cost-effective solutions. None of these are explored in the LTS.

6.6 Czech Republic

General objectives

The Czech Republic's LTS, as presented on the European Commission website, is the Climate Protection Policy of the Czech Republic, released by the Ministry of Environment in 2017. Emissions projections for the country find a reduction in residential heat consumption due to efficiency improvements, including savings on the heat distribution side. In the Czech LTS, DH systems are mentioned several times, both as having a high potential for generating heat savings as well as needing reconstruction, modernisation and optimisation.

Role of DH systems

DH systems are significantly mentioned in the Czech LTS, to the extent that they can be identified as an important contributor to heat savings in the country's energy profile. They are first mentioned in conjunction with the requirements for modernisation, reconstruction, and

[44] Cyprus national long-term strategy, 2022.
[45] Cyprus' Integrated National Energy and Climate Plan, 2020.
[46] Cyprus' Integrated National Energy and Climate Plan, 2020.

maintenance of heat distribution networks. The LTS highlights that the challenge is related to organisational conditions (conducting the necessary work in densely populated urban areas) as well as the high investment costs required by reconstruction of the networks and replacement of the obsolete [fuel] sources.

According to the LTS, the modernisation of distribution networks is seen to bring significant heat savings, including switching to heat networks in the first place, as well as optimising distribution systems, changes to insulation and pipe layouts, and higher contributing shares of renewable energy such as solar thermal energy. These measures are supported by operational programmes as well as the National plan for Investment in Equipment and Modernisation of Infrastructure and Clean Technologies of the Czech Republic.

For industry, heat recovery is only briefly mentioned as an option for reducing energy consumption in industrial production and is not linked to the supply of waste heat to a DH network.

Neither intermediate nor final targets for shares of low-carbon DH supply are presented.

Fuel mix

In the scenarios defined in the LTS, it is mentioned that domestic heating and hot water will be provided by gas and biomass boilers as well as heat pumps. For local heat supply, biomass energy is expected to play a central role in the renewable energy mix of the Czech Republic. Among the measures for reducing emissions from the energy system, the use of waste heat and low-carbon heating sources is mentioned, but no target shares are presented. Beyond this, neither intermediate nor final targets for a future fuel mix of DH systems are not presented.

Technology

The Czech LTS does not address DH networks in conjunction with CHP but does mention that cogeneration accounts for 70% of the total gross heat production in large and medium-sized combustion units. The Strategy does not address 4th generation DH networks, thermal storage or district cooling.

Support

The Czech LTS does not directly address investments for DH networks or supporting measures. The Strategy mentions that the Czech Republic should maximise the use of the Modernisation Fund, for which one of the priority investment areas is network modernisation, including heat networks.

Specific measures

No specific measures are presented for the residential sector or industry, however it is assumed that ambitions on the use of waste and renewable heat are applicable to both sectors. Infrastructure needs are not associated with specific measures.

Table 10. The measures to decarbonise DH systems in the Czech energy system.

Sector	Measures
Residential	Increase share of waste heat
	Increase share of low-carbon heat
Industry	Increase share of waste heat and heat recovery rates
	Increase share of low-carbon heat
Infrastructure	Optimise distribution systems
	Changes to insulation and pipe layouts

6.7 Denmark

General objectives

The Danish LTS was published in December 2019, shortly after the Danish Government reached an agreement on the country's new Climate Act. The LTS mostly covers Denmark's existing policies and targets under EU commitments, and is seen as "an evolving document", with the expectation to be updated even more frequently than the 5–10-year interval required by the Governance regulation. However, no updates to the 2019 LTS are currently available.

The Strategy calls attention to country's Energy Agreement, a cross-party agreement on key objectives for advancing Denmark's energy sector, signed in 2018.[47] Measures related to DH from this Agreement are highlighted in the relevant sections below.

Role of DH systems

The specific presence of DH systems in the Danish residential heating system is not outlined in the LTS. Only the results of an assessment of DH potential, delivered to the European Commission in 2015, are reported. This assessment highlights the role of DH networks using renewable fuels, as replacements for phased-out combined heat and power (CHP) units, estimated to be less feasible in Denmark's energy system due to their relatively high marginal costs compared to renewable energy sources.

The assessment also projects an increase in the technical and business of DH is expected to increase by 2035 and 2020, respectively, and "socio-economic potential" would increase to 2020 and decrease in the subsequent decade. No definition is provided for socio-economic potential.

Overall, DH systems are not considered to be significantly addressed in the Danish LTS but are associated with specific objectives and measures in the 2018 Energy Agreement.

Fuel mix

In the LTS, a target to use 90% renewable energy sources in DHSs by 2030 is presented. However, no specific fuel mix is outlined.

Within the 2018 Energy Agreement, the projected uptake of heat pumps and waste heat in DH systems is highlighted, as a result of reducing taxes on electricity-based heating. No specific targets are assigned to either of these alternative fuel sources.

Technology

[47] Danish Government, 2018. Energy Agreement.

There are no specific references to low-temperature DH systems in the LTS. Thermal storage is not referenced in association with DH systems. CHP is highlighted, but with DH networks acting as a replacement, rather than a complement, to these generation systems. District cooling is only highlighted in the context of its potential remaining the same to 2030, within the assessment of DH potential presented in the LTS.

Within the 2018 Energy Agreement, district cooling is highlighted as a "form of green energy" in demand by industry and businesses in Denmark. An agreement is reached to promote district cooling initiatives, including better options for cross-municipal district cooling projects.

No reference is made in the Agreement to thermal storage or CHPs in connection with DH systems.

Support

Denmark's LTS does not specifically address the need for infrastructure development or research/knowledge creation for low-carbon DH systems. It does provide an assessment of the general needs for financing and research on decarbonisation more broadly.

Within the 2018 Energy Agreement, an agreement is reached to remove production commitments in the form of CHP requirements and natural gas requirements the production commitments, as well as reducing taxes on electricity-based heating to incentivise the use of heat pumps. Production commitments for small DH systems are eliminated effective from January 2019, partially to mitigate the elimination of a base subsidy for these small DH providers. The Agreement cites an expectation that elimination of this subsidy will drive the uptake of heat pumps for small DH systems.

A restructuring of regulations for surplus heat is also presented in the Agreement, aiming to incentivise the use of surplus heat. Between 2020 and 2025, the public budgetary impact of this restructuring is estimated to be 100 million DKK (~€13.4 million) per year, while the adjustment of the tax on electricity-based heating is estimated at 325-350 million DKK per year between 2021 and 2025 (equivalent to ~€43-47 million).

Specific measures

No specific measures are outlined in the Danish LTS for decarbonising DH systems, at a level more granular than those outlined in the general objectives of the Strategy. Within the Energy Agreement, the specific measures relevant to DH systems are beneficial tax changes to incentivise heat pump and waste heat use in DHSs, and the investigation of the potential for district cooling.

6.8 Estonia

General objectives

Estonia's LTS, a very short (8-page) document, does not mention anything related to district heating. It vaguely mentions the goal of improving the legislative framework for heat generation and the use of domestic biomass and other renewable energy sources in the production of heat. This is surprising, given that DH is the most common heating type in Estonia (around 200 DH networks covering approx. 60% of heating demand).[48] Currently, the main renewable energy source used in DH systems in Estonia is biomass (mainly wood chips), also proposed as the

[48] Euroheat and Power, 2022. Promoting efficient district heating in Estonia.

main replacement fuel for natural gas and shale oil. Other DH networks use peat or industrial waste heat (for example, oil shale gases).[49]

Role of DHS

DH systems are not significantly mentioned in Estonia's LTS. No specific role is outlined for DH systems in the energy, residential or industry sectors of the Estonian economy, and it is impossible to assess the contribution of DH systems (low-carbon or otherwise) to Estonia's future heating supply. No final or intermediate targets for low-carbon DH systems are presented.

Fuel mix

In terms of fuel mix, the Strategy indicates that "a wide use of domestic biomass and other kind of renewable energy resources will be facilitated during the production of electricity and heat as well as the production of fuel for transport". No specific final or intermediate targets are provided for DH systems in the Strategy.

Technology

There is no mention of 4th-generation DH networks, thermal storage, CHP or district cooling.

Support

Estonia's LTS vaguely mentions the goal of improving the legislative framework for heat generation, aiming to facilitate the efficient and sustainable operation of heat networks, "on the basis of free market principles". No further information is provided regarding the necessary measures to achieve this objective.

Specific measures

No specific measures are presented for enabling low-carbon DH systems in Estonia's LTS.

6.9 Finland

General objectives

Overall, DH systems are sparsely mentioned in Finland's LTS, mostly in connection with emissions reductions in the buildings sector through the decarbonisation of district heating and electricity production.

Role of DHS

DH systems are envisaged to play a role in the decarbonisation of the buildings sector, by switching to low-carbon fuels. However, the Finnish LTS outlines that energy consumption by DH networks in its low-carbon scenarios is halved compared to current levels, due to energy efficiency improvements and the low availability of competitive, low-carbon DH production. This is mirrored across the heating sector, with final energy consumption for heating buildings declining by as much as 60% compared to 2010 levels. Even under the *business-as-usual* ("with existing measures") scenario, the energy consumption of DH systems is considerably reduced by 2050. Therefore, it is apparent that DH are not significantly addressed in Finland's LTS.

For industry, the key measures for emissions reduction are assumed to be electrification and the replacement of fossil fuels and peat with biofuels for heat generation.

[49] Volkova, A. et al, 2020. Planning of district heating regions in Estonia. International Journal of Sustainable Energy Planning and Management 27, pp. 5-16.

Fuel mix

A number of measures target the use of renewables in heating and cooling, including a quota obligation for biofuels in heating and the phasing out of oil heating. Heat pumps are also foreseen to be increasingly used for producing district heat and cold in municipalities. However, no specific target is provided.

No provisions are made for the use of waste heat in DH systems, but the Finnish LTS does state a need to explore the potential for emissions reduction by using industrial waste heat, as identified in its public consultation.

Technology

The Finnish LTS makes an association between combined heat and power (CHP) and DH systems but does not provide further detail on the use of high-efficiency cogeneration in existing and future DH networks.

Support

No support is outlined for Finland's DH networks in the LTS.

Specific measures

No specific measures for enabling or supporting DH networks are outlined in Finland's LTS.

6.10 France

General objectives

France's LTS, published in March 2020 as the "National Low-carbon Strategy" (Strategie Nationale Bas-Carbone), projects emissions from its buildings sector to reduce from 93 $MtCO_2e$ in 2015[50] to approx. 5 $MtCO_2e$ from its building sector by 2050, under the "With Additional Measures" scenario. The total decarbonisation of the energy mix for buildings by 2050 is partly reliant on the use of urban heat networks (DH systems), in addition to heat pumps.

Overall, the LTS envisages a reduction of 95% of emissions from buildings by 2050 relative to 2015. It should be noted that the buildings sector experienced the most overruns within the first carbon budget of France (2015-2018)- according to the LTS, this was due to low energy prices and the slow pace of building renovations.

Role of DH systems

DH systems are significantly mentioned in France's LTS, and are seen to play a role in the decarbonisation strategies for energy production, buildings, and industry. The role of DH systems in the final energy mix of the buildings sector is quantified, but the provided figures do not allow for an accurate identification of the contribution to final energy consumption of DH systems.

Under its buildings sectoral strategy, the French LTS outlines the connection of collective dwellings to heat networks using renewable and recovered waste energy for heat production. By our interpretation of the provided figures, in 2015 DH systems contributed approx. 3.1% of final energy consumption of the buildings sector[51] and in 2017 3.4% . Intermediate targets for 2030 are equivalent to approx. 30 TWh out of a total of 600 TWh, if our interpretation is correct.

[50] Other sources quote approx. 100 $MTCO_2e$ emissions from the buildings sector in 2019, although this figure covers "other" emissions as well. Source: Climate action in France: Latest state of play.

[51] These figures are based on the interpretation of bar charts in the French LTS, which lack an appropriate legend. Comparing with the actually quoted figure of 3.4% contribution in 2017, the contribution for 2015, 2030 and 2050 can be deduced (see page 24 of the LTS document).

In 2050, DH systems would provide approx. 50 TWh of energy, out of a total of approx. 450 TWh demand in the buildings sector.

Heat networks or the recovery of waste heat are briefly mentioned for industry, as one of the levers envisaged for the sectoral decarbonisation strategy for energy. Incentives are envisaged to allow the massive development of on-site waste heat recovery, including through heat networks.

DH systems are also referred to in the energy production sectoral strategy of France's LTS. Fossil fuel use is prevalent, with 37% of the energy supplied by France's 761 DH networks being provided by natural gas – and a main objective of the energy sector strategy is to increase by 5 times the amount of renewable heating and cooling in DH networks, relative to 2012. Identifying sources of waste heat in the vicinity of heat networks and implementing the recovery of this heat, as well as identifying needs and potential for heating and cooling networks in territorial policies and plans, are highlighted as two key actions in the strategy for decarbonisation of the energy sector. For the overall energy sector, a focus is placed on waste heat and renewable sources, including biomass. The share of renewable and recovered heat and cold is classified as a pilot indicator for the success of the sectoral decarbonisation strategy for energy.

Fuel mix

The fuel mix of DH systems is not quantified for 2050, however they are quoted as being fuelled by either renewable or waste heat sources. The energy sources listed include biomass, waste heat, heat pumps, alongside joule effect systems and solar thermal energy, where the geographical conditions permit it. It should be noted that France's decarbonisation strategy for its energy production includes an aim to "strongly develop the mobilisation of the biomass resource". Intermediate targets for the fuel mix of DHSs are not presented.

Technology

There is no specific mention of low-temperature (4th generation) DH networks. District cooling is mentioned in conjunction with district heating in several instances, but no specific measures or objectives related to district cooling are outlined. CHPs and thermal storage coupled to DH networks are not mentioned.

Support

A pilot indicator for France's energy decarbonisation strategy, outlined in the LTS, is the number of studies on options "to better inform long-term structuring choices", including the future of heat networks.

No financing schemes or incentives specific to DH systems are presented in the LTS, aside from the envisaging of incentives to develop on-site heat recovery for industry, partly feeding into DH networks. No detail is given on the type or structure of these incentives.

No measures for infrastructure development or modernisation are specifically outlined in the LTS – although the target increase in energy supply via DH networks indicates at least some infrastructure development for new connections. Additionally, the focus on incentivising waste heat recovery and identifying waste heat sources in the vicinity of DH networks suggests future infrastructure development for connecting waste heat sources to nearby DH networks.

Specific measures

Table 11. The measures to decarbonise DH systems in the French energy system.

Sector	Measures
Residential	Increase heat supplied through DH systems from approx. 25 TWh in 2015 to approx. 30 TWh in 2030 and approx. 50 TWh in 2050.
	Given the focus on renewable and waste heat energy sources for DH systems by 2050 and the current fuel mix of these systems, it can be assumed that a phase-out of coal, oil, and natural gas in DH systems will be required
	Identify needs and potential for heating and cooling networks in territorial policies and plans
	Connect collective dwellings to low-carbon DH networks as a priority
Industry	Encourage the identification of waste heat sources in the vicinity of DH networks and implement heat recovery
	Incentivise the development of on-site waste heat recovery, including for feeding into DH networks
Infrastructure	No specific mention of infrastructure development, although the increase in energy supply to buildings via DH networks suggests the need for new connections
	Suggested future infrastructure development for connecting waste heat sources to nearby DH networks

6.11 Germany

General objectives

Germany's LTS, embodied by its Climate Action Plan 2050, comprises principles and goals for decarbonisation as well as references to other adopted plans, strategies and tested programmes. The energy sector is envisaged to make a substantial contribution to overall emissions reduction targets, by cutting its GHG emissions between 175 and 183 million tonnes of CO_2-eq by 2030. DH is mentioned twice in context of sector coupling and is seen to have a substantial contribution to a climate neutral building stock by 2050.

Role of DHS

DH is developed in Germany and uses mostly combined heat and power (CHP) generation as a fuel source. Heat networks are presented in the LTS as a priority for decarbonisation, envisaging the use of waste heat from nearby industrial installations or heat generated by CHP plants, large-scale heat pumps or solar thermal systems. Overall, DH is significantly mentioned but vaguely described in the German LTS.

Through further implementation of advanced technologies, Germany also envisages increased sector coupling. Within this, Germany aims to support research into low-carbon heat, as well as a greater integrated of renewable energy in buildings and the evaluation of "model neighbourhoods" testing new forms of networking and sector coupling, including smart building control systems.

Fuel mix

In the future, the LTS envisages the increasing use of CHP plants, large-scale heat pumps or solar thermal systems for fuelling DH networks. Waste heat is also highlighted as an option to consider for use in DH networks, including addressing barriers to the use of Germany's significant amounts of waste heat through an "appropriate mix of instruments". No final or intermediate shares for the fuel mix of DH systems are presented.

Technology

The LTS highlights an important role to be played by 4th generation DH networks using a high share of renewable energy. The LTS also highlights an integrative concept to tackle energy-related CO_2 emissions as well as direct emissions of fluorinated GHG, through heating networks that use natural cooling agents. No further detail is provided on these natural cooling agents. No mention is made in the LTS of thermal storage coupled to DH networks or district cooling. CHP is mentioned in the context of being the primary energy source for DH networks in Germany today, and a major component of the long-term DH fuel mix.

Support

The German LTS outlines support for research, development, and commercialization of affordable, innovative technologies for low-carbon heat, including low-temperature systems that can be coupled to renewable energy sources. As mentioned above, it also addresses "model neighbourhoods" that can be used to test innovative solutions, including smart networks. No further specific support is outlined.

Broadly speaking, the German LTS also announces the phase out of funding for replacement of fossil-based heating technologies in buildings by 2020, and an increase in the availability of funding for renewable heating technologies. It is not specified whether this refers to individual heating systems, DH networks, or both.

Specific measures

A few specific measures to support DH networks can be extracted from the German LTS, outlined in Table 12. They mostly refer to high-level ambitions on fuel and technology use, and support for R&D as part of a broader package.

Table 12. The measures to decarbonise DH systems in the German energy system.

Sector	Measures
Residential	Increase the use of CHP plants, large-scale heat pumps and solar thermal systems for fuelling DH networks
Industry	Improve waste heat recovery to use in DH networks
Support	Support research, development and commercialization of low-temperature heating systems coupled with renewable energy sources
	Evaluate "model neighbourhoods" including testing smart networks

6.12 Greece

General objectives

Greece's Long-Term Strategy for 2050 is complementary to its National Energy and Climate Plan (NECP) putting forward a set of objectives and measures to implement beyond 2030. Central to the strategy are improving energy efficiency, uptake of renewable energy sources (especially for electricity generation) and changing the overall consumption pattern. The Strategy includes 2030 and 2050 provisions for heating systems in Greece's building stock.

Role of DHS

DH systems are not significantly mentioned in Greece's LTS and have a very small share of residential heating demand.[52] The electrification of heating in buildings is projected to dominate the LTS scenarios and lead to a near-zero emissions in the built environment, also supported by energy efficiency measures for heating and cooling. Heat pumps appear to be the main option for present and future renovated building stock in Greece, especially for non-residential buildings.

Fuel mix

Achieving climate neutrality in Greece is connected to eliminating the use of all solid and liquid fossil fuels in buildings, but the fuel mix of DH system is not outlined in any intermediate or final shares or targets.

Technology

There is no reference to preferred technologies for decarbonisation of DH systems and no mentions of 4th generation DH, thermal storage, CHP, or district cooling.

Support

No support for DH systems is outlined.

Specific measures

Concrete measures for advancing low-carbon DH are not presented.

6.13 Hungary

General objectives

Hungary's LTS, represented by the National Clean Development Strategy 2020 – 2050, was published in 2021 and is based on three modelling scenarios – business as usual, late action for climate neutrality and early action for climate neutrality. Electricity and DH emissions made up 29% of Hungary's energy-related emissions, or ~21% of total emissions. Since 2010, emissions from these sectors have stagnated, but are envisaged to necessitate additional investments for decarbonisation.

Role of DH systems

Hungary's LTS mentions DH networks, both in terms of the current impact on emissions and future investment needs, but little detail is given on exactly what the decarbonisation of DH networks would look like. It is impossible to assess the envisaged future role of low-carbon DH networks in Hungary's heating mix, and therefore DH systems are considered to not be significantly mentioned.

Reducing building-related emissions, with the key component of increasing household energy savings, are projected to primarily occur through refer to building retrofit, energy-efficiency appliances, and energy-efficient new dwellings, as well as a phase-out of coal and subsequently natural gas from the heating mix, being replaced with hydrogen blends as well as solar energy.

Fuel mix

Reaching climate neutrality requires significant changes in terms of the energy mix and starting with 2040 a decline in natural gas consumption and the blending of hydrogen into the natural gas grid are envisaged. However, no shares or targets related to the fuel mix of DH systems are presented in the Hungarian LTS.

Technology

[52] Ramboll, 2020. District Heating and Cooling Stock at EU level.

The Strategy does not touch on 4th generation DH networks, proposals for coupling with thermal storage or CHP. A list of innovative technologies and solutions for the energy sector only specify "efficient and green" DH systems, without indicating a timeframe or specificities.

Support

In the early-action scenario, additional investment costs in the electricity and DH sectors account make up 15% of total additional investments in the energy sector equivalent to 3,600 billion HUF (€9.7 billion) cumulative investment by 2050. Additional investments target both sectors to boost heating efficiency, as part of a broader set of energy efficiency measures. The modernisation of energy networks, including DH, is outlined as a priority for financing under the Modernisation Fund.

Considerations of climate risk should be integrated into overall infrastructure planning, including for DH networks, but no specific measures are outlined for the expansion or repair of DH infrastructure.

Specific measures

Efficient and green DH systems are highlighted as innovative technologies for the energy sector, but neither specific measures nor further details are not provided.

6.14 Ireland

General objectives

At the time of writing, Ireland had not submitted its Long-Term Strategy. The share of DH systems in the Irish heat supply is negligible, at most 0.8% of heating consumption, in a country challenged by dispersed settlements with an overall low population density.[53] However, Ireland's National Energy and Climate Plan (NECP) does outline a potential role for DH systems to contribute to the decarbonisation of heating.

Role of DHS

Ireland's NECP sets the establishment of a policy framework to support DH as a key objective, focusing on dense urban areas such as the cities of Dublin, Cork, Limerick and others. At the date of publication of the NECP, funding from the Climate Action Fund is supporting two DH projects in Dublin (one of which aims to use low-temperature waste heat from data centres), and future DH schemes, such as the Clongriffin DH network, are more ambitious than the existing small-scale networks, suggesting potential increased prominence of these heating supply systems in the future – including the use of waste heat and biomass combusted in boilers or CHPs, as well as heat pumps.[54] Only one district cooling network exists in Ireland due to low cooling demand.

In its Comprehensive Assessment of Potential for Efficient Heating and Cooling (required under Article 14 of the EU Energy Efficiency Directive), the Sustainable Energy Authority of Ireland identified suitable heat extraction or recovery sites (including 20 data centres) for potential future DH schemes. In the associated analysis, over 9,700 small areas are found to have economic potential for DH, amounting to 54% of total heating demand – of these, high economic potential is found in 311 small areas. An objective for additional DH supply of 0.12 TWh, growing linearly from 2023 to 2028, is set in the NECP.

Fuel mix

[53] Department of Communications, Climate Action & Environment. National Energy & Climate Plan.
[54] Sustainable Energy Authority of Ireland, 2021. Comprehensive Assessment of the Potential for Efficient Heating and Cooling in Ireland.

Ireland's NECP and Comprehensive Assessment on Potential for Efficient Heating and Cooling outline industrial waste heat, geothermal energy and biomass (solid and biomethane) as future fuel sources for DH systems. Geothermal energy for use in DH systems has generated interest in Ireland, producing a standalone assessment of potential in late 2020. No final or intermediate targets for the future fuel mix of DH systems in Ireland are presented.

Technology

The proposed use of low-temperature heat sources (waste heat from data centres) implies the use of 4th generation (low-temperature) DH networks, although these are not specifically mentioned. High-efficiency cogeneration is considered as a measure in the Comprehensive Assessment scenarios, but no target is set. No mention is made of district cooling or coupling of thermal storage with DH networks.

Support

In its NECP, Ireland sets the objective to develop a national policy framework for DH, covering regulation, planning, financing and research. It further proposes to use the two DH pilot schemes supported by the Climate Action Fund for developing experience and knowledge to facilitate a greater uptake of DH in self-financed heat networks, indirectly acting as a boost to research and knowledge generation.

Measures for reducing losses from DH networks are not included in Ireland's Comprehensive Assessment, given the assumed low economic potential and lack of data on existing losses.

Specific measures

A series of specific measures to advance low-carbon DH systems are outlined in the Irish NECP.

Table 13. The measures to decarbonise DH systems in the Irish energy system.

Sector	Measures
Residential	Increase DH supply by 0.12 TWh between 2023 and 2028 (high-level)
Research	Develop a national policy framework for DH
	Use two ongoing DH pilot schemes to facilitate a greater uptake of DH

6.15 Italy

General objectives

Between 2000 and 2018, final energy consumption in Italy increased, driven in the residential sector by population growth and an increase in the quality of life. However, since 2010 energy intensity per capita has decreased due to the implementation of efficiency policies. Derived heat[55] has penetrated the Italian energy mix in the last decade, thanks in part to the expansion of district heating in central and northern Italy.

Overall, the Italian LTS envisages the reduction of emissions from service and residential sectors by around 60% by 2050, compared to 2017. District heating is sparsely mentioned compared to the electrification of heating (which is seen as the largest-coverage decarbonisation option for the residential heating sector). DH systems are, however, listed as key decarbonisation measures for the residential sector, with their projected contribution being

[55] Derived heat is defined as the portion of heating sold on the market from CHPs or heat plants.

separated into high-temperature networks (including the use of thermal storage systems) and low-temperature networks (including the opportunity for using waste heat).

Role of DH systems

DH systems are significantly mentioned in the Italian LTS, with both high-temperature and low-temperature DH systems, as well as district cooling and thermal storage, being mentioned as decarbonisation measures for the residential sector. These systems are envisaged to contribute to the diversification of energy sources and the use of recovered waste heat, the optimisation of energy management through thermal storage, the integration of district cooling, and the use of additional low-carbon fuels in low-temperature DH networks (e.g. solar thermal systems, low-enthalpy waste heat and efficient centralised heat pumps).

DH systems are also envisaged to have a role in increasing flexibility in the electricity system, through coupling with seasonal heat storage systems whereby heat produced by surplus PV production in summer months can be dispatched during winter months, using power-to-heat technologies.

Intermediate targets are not presented.

Fuel mix

There is no quantitative assessment of the future fuel mix of DH systems in the Italian LTS, however the fuels mentioned in conjunction with these systems are renewable energy (e.g. solar thermal), biomass, waste heat (both industrial and low-enthalpy) and centralized heat pumps. Intermediate targets for the future fuel mix are not presented.

For the residential heat sector more broadly, both Italy's reference and decarbonisation scenarios (equivalent to "With existing measures" and "With additional measures", respectively) envisage a significant electrification by 2050, as well as a significant use of renewables. These two major decarbonised fuel sources (electricity and renewables used for heat production) are also mentioned in the future fuel mix for DH systems.

Technology

As mentioned above, the Italian LTS specifically mentions 4th generation (low-temperature) DH networks as a key measure for decarbonising the residential heat sector, outlining their potential to use low-enthalpy waste heat, centralized heat pumps and centralized solar thermal systems, as well as their efficiency advantages in terms of energy losses, compared to high-temperature DH systems.

The LTS also presents the opportunity for integrating thermal storage systems into high-temperature DH networks, offering added value for flexibility of the grid. District cooling is briefly mentioned as being possible to integrate with high-temperature DH systems.

The LTS does not mention combined heat and power (CHP) in combination with DH systems.

Support

The Italian LTS does not specifically address the support or investment for DH measures.

Specific measures

The Italian LTS does not outline many specific measures for decarbonising or expanding low-carbon DH systems. It only refers to high- and low-temperature DH systems as key measures for decarbonising the residential sector.

Table 14. The measures to decarbonise DH systems in the Italian energy system.

Sector	Measures
Residential	High-temperature (traditional) DH networks, integrated with thermal storage and possibly with district cooling
	Low-temperature (4th generation) DH networks, running on low-enthalpy waste heat, solar thermal systems and heat pumps

6.16 Latvia

General objectives

Latvia's LTS mentions energy efficiency as an essential factor for reducing GHG emissions but offers no details regarding modernisation of DH systems, despite the Latvian heating demand being 30% covered by DH.[56] However, attention is paid to the fuel mix of the heating sector, strongly implying that subsidies for fossil heating should be denounced completely, shifting towards support for renewable energy.

Role of DHS

The Latvian LTS outlines no significant role for DH systems in achieving climate neutrality, but it should be noted that its National Energy and Climate Plan (NECP) does provide more detail on plans for modernising and decarbonising DH systems. It plans to make DHS more appealing by building new connections to district and local systems, installing new boilers, raising overall efficiency, putting low tariffs on heat and switching to renewable energy sources.[57]

Fuel mix

No fuel mix is outlined for the future DHS of Latvia. However, a broader approach of the heating sector sees a reduction of GHG emissions based on energy efficiency measures as well as the switching of heating fuel from liquid and solid fuels to natural gas, as well as biomass and other renewable energy sources. The use of renewable energy sources in local heat supply is also highlighted as an emissions reduction as well as air quality improvement solution, and by 2050 the vision outlined in the LTS also include the electrification of heating (however, no detail is given as to the use of heat pumps for individual buildings or as central energy sources for DH networks).

Technology

No specific mention is made of 4th-generation DH networks, thermal storage or CHP. The LTS vaguely mentions that innovative technologies and efficient operations will be introduced in centralised and local heat supply systems.

Support

No specific support is outlined for DH systems in Latvia.

Specific measures

No specific measures are presented for enabling or improving low-carbon DH networks.

[56] Ramboll, 2020. District Heating and Cooling Stock at EU level.

[57] Bankwatch, 2021. District heating - the role of EU investments.

6.17 Lithuania

General objectives

The LTS is in fact Lithuania's National Climate Change Management Agenda focusing on climate adaptation policy. In it, Lithuania commits to attaining a carbon-neutral future through the uptake of renewable energy sources (RES), which are widely supported by the public. Ambitious targets are mentioned, such 100% RES share for heating by 2050, but it is lacking concrete measures, modelling scenarios and the necessary investments.

Role of DH systems

DH systems can contribute to a great extent to alleviating energy poverty, which in Lithuania is the second highest in the EU (27% in 2019). Nearly two-thirds of residential buildings have low energy performance scores, and there is no possibility for customers to change heating suppliers.

An intermediate target of 90% renewable energy share in DH supply systems by 2030 and 100% by 2050, as well as a commitment to double the number of households connected to an "environmentally friendly district heating network" (following the increase of RES in heating) by 2040, are envisaged to contribute to the decarbonisation of Lithuania's heating systems.

Despite DH systems being significantly mentioned in Lithuania's LTS, there is little detail on the specific measures for advancing low-carbon DH systems.

Fuel mix

Aside from its intermediate targets of 90% and 100% RES share in DH supply by 2030 and 2050, respectively, no specific shares or targets for alternative fuels are given.

Technology

No specific mention is made of 4th-generation DH networks or coupling of DH with thermal storage. CHP is mentioned only in the LTS's 2050 objectives, contributing to the reduction in energy consumption for heat and electricity production.

On a general note, Lithuania struggles with poor cooperation between business and research institutions, and research and experimental development for all sectors is insufficient. The importance of new technologies and the crucial role of R&D is acknowledged in the LTS.

The LTS of Lithuania does not address district cooling.

Support

The LTS mentions EU funding programmes but does not outline specific support for low-carbon DH systems.

Specific measures

A few specific measures, or more precisely targets, are outlined for DH systems in Lithuania in the country's LTS.

Table 15. The measures to decarbonise DH systems in the Lithuanian energy system.

Sector	Measures
Residential	Achieve 90% renewable energy share in DH supply by 2030, and 100% by 2050
	Double the number of households connected to „environmentally-friendly" DH networks by 2040

6.18 Luxembourg

General objectives

The LTS of Luxembourg, published in October 2021, sets out the transition to be achieved in the long term for reaching net zero by 2050. Among other lines of activity, the LTS aims to build sustainable and dense neighbourhoods to achieve decarbonisation of its building sector. It should be noted that Luxembourg has created a Climate Pact with its municipalities, to frame the active participation of local authorities, citizens, and local businesses in the transition to climate neutrality. The role of spatial planning policies and public finance in the green transition is also highlighted.

Overall, DH systems are evaluated in the LTS as having potentially important contributions to decarbonising the energy and buildings sectors. Heat networks are highlighted within the key policy area of "deep and sustainable energy renovations" of decarbonising Luxembourg's buildings sector. These contributions are not quantified – i.e. there is no indication of the share of energy production or final energy consumption provided by DH systems in 2030 or in 2050.

Role of DH systems

DH systems are significantly mentioned in Luxembourg's LTS - the issue of DH is covered to an extent that allows a qualitative assessment of the role of DH in the country's energy system in 2050.

A role for DH systems is outlined within the key action area of renewable heat. Within the highlighted "systematic development of renewable heat use in residential and functional buildings", the development of low-carbon heat networks (fuelled by decentralised renewable energy or waste heat from industry or data centres) is outlined. The development of planning instruments to identify areas suitable for DH networks is also presented as part of the renewable heat action area.

In the buildings sector, the role of DH networks is outlined as "a cost-effective alternative" to heat pumps, for relatively dense neighbourhoods. These DH networks would be fuelled by renewable (biomass, deep geothermal) or waste heat (from industry or data centres). They are a key measure of the action area of establishing "sustainable and dense energy-positive neighbourhoods" – connecting renewable energy resources or waste heat recovery with appropriate energy storage. In this respect, the densification of the building stock can lead to opportunities for decarbonisation, including the use of low-carbon DH networks, and measures to promote and finance densification are outlined.

The contributions of DH networks to decarbonising Luxembourg's energy and building sectors are not quantified, and intermediate or final targets are not presented.

Fuel mix

In the preamble to the LTS, it is outlined that "the systematic replacement of natural gas in […] DH networks by renewable sources" is responsible for declining emissions from Luxembourg's energy sector. It should be noted that Luxembourg imports most of in energy.

The future fuel mix of DH systems is/is not outlined in the LTS, and proportions of different fuel types are/are not assigned to future DH systems.

Intermediate targets for the future fuel mix are/are not presented.

Technology

The LTS mentions coupling of low-carbon heat networks with thermal storage as a potential action for decarbonising densely built neighbourhoods. Heat storage is specifically mentioned as a focus for Luxembourg for the expansion and optimisation of DH networks, within the decarbonisation of its energy sector. There is no mention of types of thermal storage technologies envisaged.

Low-temperature DH networks are not specifically addressed, with the LTS mentioning that "heat network projects (high or low temperature) will be developed by public and private actors" with low-carbon energy sources, within the key policy area of renewable heat development.

District cooling is not specifically addressed in Luxembourg's LTS.

Support

The LTS of Luxembourg specifically addresses financing for DH networks, outlining that municipalities are supported through climate and energy funds for investments including the establishment of low-carbon municipal heating networks. The LTS overall has a significant focus on financing the transition, given the assets and history of Luxembourg in this area. Public investment and financial instruments such as climate and energy funds are highlighted as financing sources available for public authorities, including for DH network investments. However, the differentiation of these investments between modernization of existing networks (including fuel replacement) and expansion of new ones is not clear.

The LTS also calls for a revision of EU aid guidelines, including support awarded to investments in efficient heating and cooling networks, to better support the decarbonisation of businesses.

Although not detailed, the use of thermal cadastre planning instruments is highlighted as a measure under Luxembourg's "renewable heat" action area for decarbonising its energy supply.

Specific measures

The Luxembourgish LTS presents several specific measures to enable low-carbon DH networks (Table 13).

Table 16. The measures to decarbonise DH systems in Luxembourg's energy system.

Sector	Measures
Residential	Within dense urban neighbourhoods (existing or planned), implement low-carbon DH networks
	Explore the coupling of DH networks to heat storage, for expanding and/or optimising networks
	Implement thermal cadastres to identify DH potential and opportunities
Support	Mobilize financing instruments such as energy and climate funds for DH infrastructure investments
	Call for revision of EU State Aid guidelines

6.19 Malta

General objectives

Malta's LTS outlines an ambition for decarbonisation of heating mainly based on individual heating sources powered by solar energy. The Strategy does not touch upon DH or district cooling systems, given their absence from the country's heating and cooling supply and the primary use of electricity for space and water heating and space cooling. Instead, a high priority is given to solar water heaters and solar water heat pumps, and the use of waste heat in Malta's industrial sector is also highlighted.

Role of DHS

No role for DH systems is envisaged in Malta's Long-Term Strategy.

Fuel mix

Not applicable.

Technology

Not applicable.

Support

No support is outlined for DH systems in Malta's Long-Term Strategy.

Specific measures

No specific measures are presented for enabling DH systems in Malta's Long-Term Strategy.

6.20 Netherlands

General objectives

Within the LTS of Netherlands, DH is mentioned in conjunction with the necessity to decarbonise the built environment. At the centre of this plan is a district-oriented approach under the supervision of the municipalities and the development of heating plans. The LTS outlines that as part of this approach, individual homeowners will be supported with and given access to government subsidies, loans with advantageous terms and comprehensive information.

Role of DHS

DH networks are envisaged to be one of the measures for the provision of sustainable heating in the Netherlands, alongside heat pumps and (occasionally) "green gas" and hydrogen. They are seen to be central to a district-oriented approach for decarbonising the Dutch built environment but cannot be said to be significantly addressed in the Netherlands' comparatively short LTS (22 pages long).

Fuel mix

No specific fuel mix for DH systems is presented in the Dutch LTS. However, industry is envisioned to provide heat to the built environment, presumably through the dispatch of waste industrial heat into DH networks. No final or intermediate targets are presented.

Technology

There is no mention of 4th generation (low temperature) DH networks, thermal storage or CHP.

Support

The development of heating plans (it is unclear if for whole municipalities or for districts) are emphasized as focal points of the Netherland's district-oriented approach to decarbonising its building sector.

Specific measures

Aside from the development of heating plans, no specific measures are highlighted for enabling low-carbon DH in the Netherlands.

6.21 Poland

At the time of writing, Poland had not submitted its Long-Term Strategy. Given the country's high penetration of DH systems in residential heat supply (approx. 40%),[58] it could be expected that Poland's LTS will have a focus on DH networks as a decarbonisation measure for the heating sector. Within its National Energy and Climate Plan (NECP), published in 2019, Poland does address DH as a contributor to its energy transition.

General objectives

Quoted in the NECP, a main objective of Poland's Energy Policy until 2040 (PEP2040) is the development of DH and cogeneration. It sets a target for efficient DH and district cooling systems: by 2030, 85% of installations with a capacity higher than 5 MW would meet the EU's energy efficiency criterion[59] (in 2018, this proportion was 20%). A suite of measures is presented to achieve this, including the development of co-generation, an increase in the use of renewable energy, natural gas and energy from waste incineration, modernisation and expansion of DH networks, the "popularisation" of heat storage and enabling a friendly investment environment for DHS.

Role of DHS

Poland's vision, outlined in the NECP, is that meeting its heat demand should be done primarily using DH systems. By 2040, Poland aims to meet all residential heating needs through DH systems and zero- or low-carbon heat sources, with an intermediate target of 70% of urban households connected to DH networks by 2030 (up from 61% in 2015). By replacing fossil-fired boilers with high-efficiency cogeneration and alternative fuels, DH networks are seen to have a significant potential contribution to reducing CO_2 emissions and raw material intensity of Poland's economy.

DH systems are also seen as conducive to the improvement of air quality, by displacing inefficient local boilers. Financial support, through grants or soft loans, is envisaged to develop DH networks, increasing their coverage and enabling the connection of new heat consumers, as well as investing in the replacement of heat pipes with pre-insulated ones and the modernisation of heat transfer stations.

The construction, expansion and modernisation of DH networks is also envisaged to contribute to the reduction of energy poverty and improvement in public health.

[58] Ramboll, 2020. District Heating and Cooling Stock at EU level.

[59] At the time, the definition of an efficient district heating and cooling systems was "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". Source: Directive 2012/27/EU on energy efficiency.

Fuel mix

Biomass and waste heat from industry are outlined as particularly suitable fuel sources for increasing the renewable energy share for DH system supply. Within the "transitional period" of moving away from coal, natural gas is highlighted as a key transformational fuel for heating – both DH and individual heating systems. Given Poland's recent efforts to wean itself off the 55% share of gas demand originating in Russia,[60] it is unclear whether the role of gas in Polish heating will be revised.

Technology

One of the key measures for reaching its targets for energy-efficient DH systems is the development of high-efficiency co-generation (combined heat and power, or CHP) to replace heating boilers. The expansion of district cooling, and the development of technologies for producing cold from district heat, are highlighted as key measures within PEP2040 for the advancement of low-carbon heating and cooling in Poland. Heat storage is briefly mentioned, as a measure requiring "popularisation" and associated with DH networks.

Support

Support measures for the development of low-carbon DH systems in Poland include improving ease of access to financing (by simplifying investment procedures and changing the heat market model and tariff policy), as well as "popularising" smart networks and heat storage and modernising and expanding the DH and district cooling systems. The development of smart grid infrastructure is also cited as being a significant issue requiring regulatory intervention in the near future.

The NECP also foresees the introduction of instruments to support connection to DH networks and improving the efficiency of heat supply to consumers (although it is not explicitly stated whether this refers to DH networks). A so-called "thermo-modernisation bonus" is planned to be made available to investors, homeowners, housing communities and local governments for improvements to DH sources. A support mechanism is also envisaged to be applied to the development of cogeneration units replacing older sources powering large DH systems.

Specific measures

A suite of measures is proposed in Poland's NECP (and in PEP2040) for enabling low-carbon DH systems.

Table 17. The measures to decarbonise DH systems in the Polish energy system.

Sector	Measures
Residential	Achieve 85% target for energy-efficient DHS with capacities over 5 MW
	Increase DH coverage to 70% of all urban households by 2030
	Replace fossil-fired boilers with high-efficiency cogeneration and alternative fuels (e.g. biomass, waste incineration and natural gas)
	Expand district cooling and technologies for production of cold from DH
	Popularise DH networks (including smart networks) and heat storage
Industry	Incentivise the use of industrial waste heat in heating networks

[60] Politico, 2022. Poland tries to wean itself off Russian energy.

Infrastructure	Modernise DH and district cooling systems, e.g. through pipe replacement
	Subsidise new connections to DH systems
	Simplify investment procedures for DH networks
	Change the heat market model and tariff policy
	Financial assistance for DH modernisation and fuel replacement projects

6.22 Portugal

General objectives

Portugal's LTS elaborates a path towards carbon neutrality and identifies guidelines for policies and measures required to achieve this goal. Significant attention is given to increasing energy efficiency in all sectors and promoting decarbonisation in the residential sector through urban regeneration, progressive electrification and combating energy poverty.

Role of DH systems

DH systems are not mentioned in Portugal's LTS, and the current share of DH in covering heating demand is negligible.[61] The LTS assumes that the decarbonisation of buildings will rely on an almost complete electrification of energy consumption, further supported by large energy efficiency gains.

Fuel mix

The future fuel mix of DH systems is not outlined in the LTS, and no targets are presented.

Technology

The LTS does not specifically address 4th generation (low temperature) DH networks, coupling with thermal storage, CHP, or district cooling.

Support

Not applicable.

Specific measures

Specific measures are not outlined.

6.23 Romania

At the time of writing, Romania had not submitted its Long-Term Strategy. As a country with significant legacy DH systems in its heating supply, linked to recent public disappointment in heating services and a push for financing the upgrade of heat networks, Romania could be expected to focus on DH systems in its heating decarbonisation plans. A national programme for financing investments in the modernisation, refurbishment and expansion of DH systems is currently being implemented over the 2019-2027 period by the Ministry of Development, Public Works and Administration.[62]

[61] Ramboll, 2020. District Heating and Cooling Stock at EU level.

[62] ro_final_necp_main_ro_0.pdf (europa.eu)

Role of DHS

In the Romanian NECP, DH systems are mentioned several times, but no intermediate or final targets for low-carbon DH networks in the national heating supply are presented.

Fuel mix

In the context of fuel sources, the use of heat pumps in DH networks is highlighted as part of increasing the share of renewable electricity in Romania's energy mix, while the share of geothermal energy in DH systems is projected to increase from 31 to 45 ktoe by 2030 (in the "with additional measures" scenario). However, only the use of natural gas in CHPs for fuelling DH networks is outlined as a priority for financing in the 2020-2030 period.

As part of cross-sectoral measures for GHG emissions reduction, the use of waste industrial heat in DH networks is presented, outlining a pilot project in the city of Cluj-Napoca, and touting its "substantial emissions savings" and contribution to industrial symbiosis and a circular economy.

Technology

In terms of DH system technologies, the potential for high-efficiency cogeneration in DH and district cooling is highlighted for high-density urban areas, resulting in a total of 80.3 PJ of efficient heating both through re-connecting buildings to the DH networks and establishing new connections.

Support

No policies or measures are outlined for building new DH networks in Romania. No financing measures or targets are committed, but the NECP does outline financing opportunities through the Modernisation Fund and InvestEU.

Specific measures

No specific measures for enabling low-carbon DH networks are presented in Romania's NECP. Only the potential for use of waste and geothermal heat as well as heat pumps in DH networks is outlined.

6.24 Slovakia

General objectives

The LTS of Slovak Republic, which relies on "with existing measures" (WEM) and "with additional measures" (WAM) models and scenarios, stresses that additional measures (defined as "neutral") must be implemented for achieving climate neutrality by 2050. According to the WAM scenario, Slovakia would achieve a 47% reduction in GHG emissions by 2030, and 70% by 2050, compared to 1990 levels. A key programmatic priority for the upcoming Multi-annual Financial Framework cycle is the promotion of renewable heat and cold, as well as efficient DH systems. The strategy relies on a previous study conducted in 2016 in cooperation with the World Bank.

The optimization of DHSs is among mitigation measures and the reduction of GHG emissions, with estimations provided in the LTS for emissions reductions achieved in certain scenarios. The current level of emissions from DH systems is not contextualised. Even within the WEM scenario, fuel switching in DH systems and other measures to improve DH efficiency are considered, and measures to encourage only efficient DHSs and build new DH networks with a high share of renewable energy are outlined.

Role of DH systems

DH systems are significantly mentioned in Slovakia's LTS. Within the WEM scenario, a national policy to optimize DH systems is outlined, including a shift from "fossil fuels" to biomass and natural gas, installing CHP units and making use of industrial CHP units either for heating in DH networks or as a secondary use of steam, improving efficiency and installing innovative technologies. No specific targets or measures are outlined in the Strategy. New DH systems in valley and basin areas are also proposed for cost-effective implementation, including an increased share of renewable energy. No timeframe or specific targets are mentioned.

Fuel mix

Without presenting specific intermediate or final targets, Slovakia's LTS envisions a transition from fossil fuels to biomass, natural gas and waste heat in DH systems. More broadly, the electrification of heating, for example through the uptake of heat pumps, is envisaged. An argument for "localization" is suggested in the WAM scenario, outlining that the development of heating installations should be aligned with local development concepts in the thermal energy field.

Technology

No mention is made in the Strategy of 4th-generation DH networks, thermal storage, or district cooling. CHP plants are mentioned as fuel sources for DH networks as well as potential sources of industrial steam that could be used for DH, however no detail is provided.

Support

The Slovak LTS envisages the modernisation of DH pipelines using financing available through the Modernisation Fund, and efficient DH networks are a priority under the next cycle of the Multi-annual Financial Framework.

Specific measures

Several specific measures, albeit high-level, are outlined in the Slovak LTS for supporting low-carbon DH networks.

Table 18. The measures to decarbonise DH systems in the Slovak energy system.

Sector	Measures
Residential	Transition from solid fossil fuels to biomass, natural gas and waste heat (high-level)
	Promote CHPs for DH supply (direct or via industrial steam production) (high-level)
Industry	Incentivise the use of industrial waste heat in heating networks
Infrastructure	Modernise DH pipeline networks
	Introduce new, RES-based DH systems in valleys and basins

6.25 Slovenia

General objectives

Slovenia's Long-Term Energy Strategy is the country's vision document for climate neutrality, with the main guiding document, including for intermediate targets, remains its National Energy and Climate Plan (NECP). The Strategy places at the heart of emissions reduction efforts measures of energy efficiency, climate justice and environmentally friendly technological developments. By 2030, coal use in Slovenia will be reduced by 30% compared to 2005, with

nuclear power plants being considered as viable options for replacement. In accordance with the NECP, a specific strategy for the decarbonisation of heating and cooling will be developed.

Role of DH systems

DH systems are significantly mentioned in Slovenia's LTS, with their decarbonisation and expansion being a key driver for achieving climate neutrality. The increase in DH systems in densely populated areas is quoted as a factor leading to the decrease in residential emissions of 55% between 2005 and 2018. The Strategy approaches the decarbonisation of heat production with renewable energy sources (RES) at its heart, acknowledging the use of biomass only in areas where RES is not feasible. DH systems are seen as very important for decarbonising heating and cooling and increasing the share of RES in DH systems is seen as a key driver of achieving climate neutrality by 2050.

The Strategy quotes targets established in Slovenia's NECP, including accelerating the development of DH and district cooling systems and a 1% year-on-year increase in the share of RES and waste heat and cold in DH and district cooling systems. No information is provided on the current share of RES and waste energy in DH and district cooling networks in Slovenia. The Strategy also sets a target for doubling the share of buildings heating and cooled by DH systems by 2050.

Slovenia also envisages a role for DH systems in its industrial sector, proposing to support the connection of industrial companies with DH systems, using excess heat to supply the buildings and agricultural sectors. This is proposed to be further addressed in a DH strategy, being prepared at the time of submission of the LTS (July 2021).

Among the proposed indicators for emission reduction, the LTS includes: the share of buildings connected to DH systems, the share of RES and excess heat in DH and cooling systems, and the average specific emissions per unit of DH produced.

Fuel mix

According to the Strategy, the use of RES in DH and district cooling systems will be promoted as a priority, with biomass only targeted in areas where RES availability is low. Large-scale heat pumps to exploit shallow geothermal energy, solar energy as well as sources of industrial waste heat, are listed as potential energy sources for DH supply.

CHPs using "carbon neutral sources" are listed as part of the solution for meeting winter demand for heating in the wake of closure of Slovenia's coal-fired power plants. The Strategy also mentions climate-neutral synthetic gas as a potential fuel source for DH systems.

Slovenia will significantly increase the share of RES in the heat industry, by 11% in 2017 to 26% in 2050. Increasing the direct use of RES for heating purposes will be based in particular on the exploitation of wood biomass in boilers and CHP systems, the use of low-temperature heat from geothermal energy and the use of energy from waste. For sparsely populated areas, efforts are focused on heat pumps and biomass boilers.

Technology

Perceiving DH systems as allowing for greater flexibility and inter-sectoral connectivity, Slovenia aims to develop its short-term and seasonal storage systems, by interconnecting electricity grids with DH systems. District cooling is often mentioned in conjunction with DH, and the measures and targets for DH are often packaged together with those for district cooling. 4th generation DH networks are not mentioned, and CHPs are listed as potential sources for covering unmet heating demand following the closure of coal-fired power plants.

Support

Financial support is outlined as a key measure, including for DH systems to integrate more RES into their supply. Investment needs are not specifically quantified, and the modernisation or upgrade of DH systems is not addressed.

In terms of research and development, Slovenia aims to support pilot projects focused on new technologies for integrating RES into DH supply.

Although not specifically a support measure, the Slovenian LTS does outline that the design of new DH networks will need to account for climate resilience, as demand for cooling is expected to increase, and climate change may impact the availability of biomass as a fuel.

Specific measures

Several specific measures are outlined in the Slovenian LTS for supporting low-carbon DH networks.

Table 19. The measures to decarbonise DH systems in the Slovenian energy system.

Sector	Measures
Residential	Accelerate the development of DH and district cooling (high-level)
	Increase share of RES and waste heat/cold in district heating/cooling systems by 1% per year
Industry	Support the connection of industrial enterprises to DH networks
Support	Support pilots of new technologies for integrating RES into DH

6.26 Spain

General objectives

Spain's LTS commits to a reduction of at least 90% in total GHG emissions by 2050 compared to 1990 and defining a path that will enable an almost completely renewable-based energy system. Its components include mitigation actions related to energy efficiency and renewable energy, as well as measures for the decarbonisation of different sectors, including industry and buildings. The strategy is centred on the massive development of renewable energy, energy efficiency, electrification, and renewable hydrogen. The LTS projects that the electrification of the economy will be over 50% by 2050, with 250 GW of new renewable energy capacity.

Role of DH systems

DH systems are not significantly mentioned in Spain's LTS (i.e., the issue of district heating is not covered to an extent that allows the assessment of the role of DH in the country's energy system to 2050). District heating is only mentioned once, alongside renewable self-consumption, efficient appliances and improved insulation, as contributing to "circular economy solutions". Intermediate targets are not presented.

Fuel mix

In the heating and cooling sector, renewable energy is expected to account for 97% by 2050 due to the use of heat pumps, biomass, renewable hydrogen, and solar energy. However, these fuels are not assigned to future DH systems, and intermediate targets are not presented.

Technology

The LTS does not specifically address 4th generation (low temperature) DH networks or include a proposal for coupling with thermal storage, combined heat and power or district cooling.

Support

The LTS does not address the needs or investment plans for DH measures of a supporting nature, or financing for low-carbon DH systems.

Specific measures

Further measures that can enhance the role of DH are not highlighted.

6.27 Sweden

General objectives

The LTS defines a clear goal for Sweden, aiming to be climate neutral by 2045.

Swedish climate policy is robust and started since the early 1990, with broad policy instruments supplemented by sectoral measures and urban planning. On top of that, DH expansion was methodically planned and implemented in conjunction with climate and energy-related research and market introduction of new technologies.

Sweden's heating and cooling system is already largely electrified, with an electrification share of 69%, and building energy demand is mostly covered by to electricity and district heating. The LTS brings forward the management of peak power and the reduction of emissions from waste incineration as key challenges for energy and DH sectors.

Role of DH systems

DH is significantly mentioned in Sweden's LTS, as instrumental for achieving high rates of energy efficiency and a climate neutral future. Energy use in existing buildings will reduce, but the Strategy outlines the potential for buildings to become energy-positive. This means that small-scale electricity and heat producers can cover part of their own needs in energy-efficient buildings and sell any surplus to the grid. Intermediate targets are not presented.

The transition to renewables in DH is well advanced in Sweden, and biofuels account for the largest share of the fuels that are currently used.

Fuel mix

Sweden has a low share of fossil fuels in electricity and heat production. The production of DH has increased by about 50% since 1990 but its emissions have remained relatively stable, as the expansion has largely been achieved through increased use of biofuels and wind power. However, the future fuel mix of DH systems is not outlined in the LTS, and proportions of different fuel types are not assigned to future DH systems. It is worth noting that the Swedish LTS highlights as potentially problematic the emissions from waste incineration plants, often used for energy recovery and injection into DH networks.

Technology

The LTS does not specifically address 4th generation (low temperature) DH networks or coupling with thermal storage, combined heat and power or district cooling.

Support

Sweden's LTS highlights that the country's DH systems are well-developed and advanced in their transition to renewables. A series of pricing incentives are outlined, aiming to encourage the switch from fossil fuels to renewables by DH producers. However, the current share of fossil fuels in DH production is low.

Fuels used for heat production, except for biofuels, are subject to both energy and carbon dioxide taxes. Fuel used for heat production in CHP and other heating plants within the EU ETS is subject to 91% CO2 tax and full energy tax. For CHP plants, this is a significant increase since August 2019, when these fuels were previously subject to only 11% carbon tax and 30% energy tax.

Specific measures

Only the incentives for fuel switching in DH systems are presented in the Swedish LTS as potentially new measures.

Table 20. The measures to decarbonise DH systems in the Swedish energy system.

Sector	Measures
Support	Energy and CO_2 taxes to incentivise fuel switching by DH producers

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