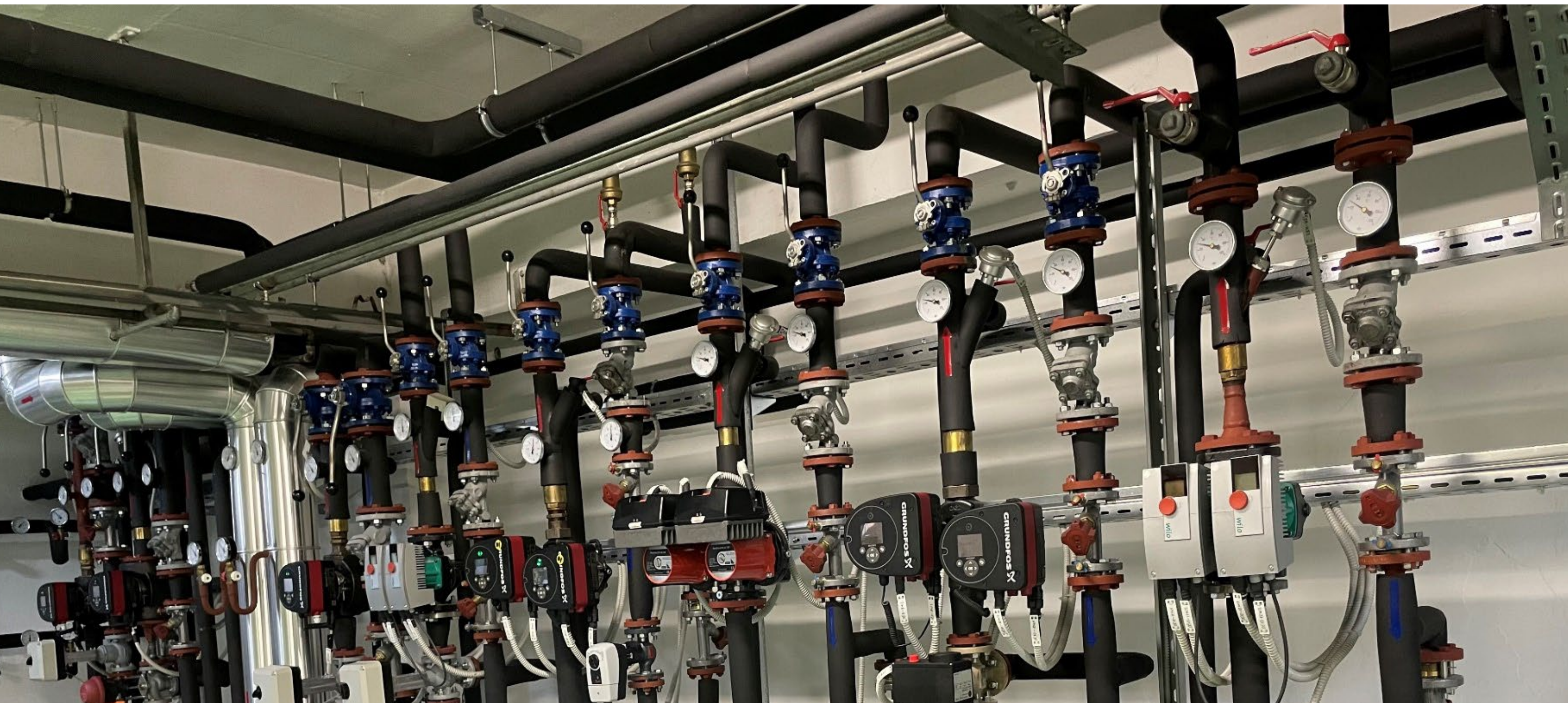
JASPERS guide to

decarbonisation of district heating systems



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1. Introduction

Half of the energy produced in the European Union is used to heat (95%) and cool (5%) commercial and industrial buildings. Much of this energy is still produced from fossil fuels.

District heating systems currently cover around 10% of heat demand in the European Union, with significant differences between EU Member States[1]: central-eastern and northern European countries have traditionally relied much more heavily on district heating systems than western and southern Europe, where these systems are few and far between.

Major district heating systems exist in Kyiv, Warsaw, Berlin, Hamburg, Helsinki, Stockholm, Copenhagen, Paris, Prague, Sofia, Bucharest, Vienna and Milan. The largest district heating system in operation in the European Union is located in Warsaw.

There are some 10 000 district heating systems in the European Union, covering a network stretching 150 000 km and with installed capacity of around 247 GW_{th}, serving 70 million people. The total energy supplied by district heating amounts to 580 TWh. At an EU level, the main fuel used in district heating is natural gas (40%), followed by coal (29%), with biomass (16%) only in third place, followed by renewable waste (5%), non-renewable waste (4%), fuel oil (3%), other fossil fuels (2%), electricity (1%) and other renewables.

Assuming that half of energy use in the European Union is for heating and cooling, and that 10% of that amount goes to district heating, leads to the conclusion that district heating addresses about 5% of final energy needs in the European Union. The total greenhouse gas emissions from the district heating sector may therefore be estimated at around 160 $MtCO_2$ per year on the basis of the district heating generation mix and average plant efficiency values. This corresponds to approximately 5% of total greenhouse gas emissions associated with energy use in the European Union.

District heating systems are an asset, since – if upgraded to technical state-of-the-art levels and correctly maintained – they outperform any individual boiler system in terms of energy efficiency and environmental impact and help the European Union to achieve its environmental targets.

Numerous existing district heating systems still need to be upgraded to ensure compliance with EU energy policy objectives. For this reason, one of the key actions targeted by the EU Strategy for Energy System Integration is the acceleration of investment in smart, highly efficient, renewable-based district heating.[2] The current district heating market context is not favourable to systems that have thus far used fossil fuels, as EU emission standards are being tightened and the emissions costs under the Emissions Trading Scheme (ETS) are increasing. This means that fossil fuel-based district heating systems face significant cost increases, affecting the competitiveness of their tariffs and undermining the long-term viability of district heating companies.

Substantial investments are required to transform existing networks into efficient district heating systems, reduce their carbon intensity and secure their environmental and financial sustainability. A representative example is Poland, where around 90% of district heating systems do not meet the definition of an efficient district heating system. As a result, substantial efforts and funding are required in the 2021-2027 Multiannual Financial Framework (MFF). Across the European Union, around €2.4 billion of EU funds (from the European Regional Development Fund, Just Transition Fund and Cohesion Fund) are allocated to

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[1] European Commission, "EU Strategy for Heating and Cooling," COM (2016) 51 final.

[2] European Commission, "Powering a climate-neutral economy: An EU Strategy for Energy System Integration," COM(2020) 299 final.

district heating investments in various cohesion policy programmes for 2021-2027, with total planned investment (including national co-financing) of €3.2 billion.[3]

District heating funding allocations under Cohesion Policy 2021-2027		
€	**EU financing (ERDF/CF/JTF)**	**Total financing (including national co-financing)**
Belgium	12 217 506	27 522 759
Bulgaria	24 864 187	30 418 724
Czechia	4 999 426	6 387 877
Germany	119 629 860	224 429 815
Estonia	20 000 000	32 994 709
Greece	56 485 200	67 910 256
Spain	199 573 255	274 594 961
France	88 478 898	152 180 460
Croatia	30 000 000	35 294 118
Hungary	110 513 958	130 016 421
Italy	47 108 728	103 365 409
Lithuania	27 000 000	31 764 706
Latvia	48 067 500	56 550 000
Netherlands	7 380 427	18 092 720
Poland	1 294 962 802	1 618 958 709
Romania	217 300 000	301 537 983
Slovenia	51 104 604	68 529 847
Slovakia	44 185 233	63 121 762
Interreg	5 402 055	9 133 768
Total	**2 409 273 639**	**3 252 805 005**

In addition to EU cohesion policy, public financing for investments in decarbonising district heating systems and making them more efficient is also available under other EU instruments, such as the Modernisation Fund, the Recovery and Resilience Facility and the Instrument for Pre-accession Assistance (IPA) III.

The challenge for district heating decarbonisation projects is frequently the allegedly complex project preparation in order to benefit from EU funding. JASPERS drew up this guide with a view to addressing this challenge, promoting a systematic approach to the preparation of district heating decarbonisation projects and encouraging the launch of more projects of this kind. It is based on experience from numerous district heating projects in various EU Member States, and includes systematic practical advice covering areas in which JASPERS most frequently receives requests for assistance from beneficiaries, namely:

[3] Cohesion Open Data Platform, aggregating funding allocations to codes “054 High efficiency co-generation, district heating & cooling” and “055 Low emissions, high-efficiency co-generation, district heating & cooling.” Data extracted in June 2024.

- analysis of the existing situation;
- objective setting;
- options analysis;
- definition of measures;
- determination of an optimised set of measures.

This guide primarily targets regions, municipalities and district heating companies planning to undertake district heating decarbonisation projects under the 2021-2027 Multiannual Financial Framework. It reflects JASPERS' experience, best practice and EU regulations as of June 2024, and may be reviewed and updated in view of changes in EU policies and regulations.

2. Policy and legal background

The European Union aims to be climate neutral (an economy with net-zero greenhouse gas emissions) by 2050.

In 2021, the European Union adopted the first EU Climate Law[4] and introduced a legally binding requirement for it to reach net-zero emissions by 2050, while at the same time setting the interim 2030 target of achieving a minimum 55% reduction in emissions compared to 1990 levels. To reach the 2030 climate and energy targets,[5] the Regulation on the Governance of the Energy Union obliges EU Member States to develop integrated national energy and climate plans (NECPs) based on a common template. The NECPs address five dimensions of the energy union: decarbonisation, energy efficiency, energy security and the internal energy market, as well as research, innovation and competitiveness. Every two years, each country must submit a progress report in line with the structure, format, technical details, and process set out in the implementing regulation. Heating and cooling (including the district heating subsector) are part of the Member State NECPs, and interim targets for achieving decarbonisation are reflected in these plans.

EU Member States are also required to develop national long-term strategies and ensure consistency between these strategies and their NECPs. The first national long-term strategies were submitted to the European Commission by January 2020, with subsequent rounds of strategies being due in January 2029 and every ten years thereafter.

The EU Green Deal – a package of policy initiatives aiming to set the European Union on the path to a green transition, with the goal of reaching climate neutrality by 2050 – underlines the need for a holistic and cross-sectoral approach.

Relevant EU legislation

The Fit for 55 package included proposals to revise and update EU legislation. Revisions affecting the energy sector and relevant to the district heating sector were made to the Energy Efficiency Directive (EED), Renewable Energy Directives (RED) and Energy Performance of Buildings Directives (EPBD).

The Energy Efficiency Directive 2023/1791[6] sets out a common framework of measures to promote energy efficiency improvements in EU Member States. It refers to an overreaching energy efficiency first principle that should be considered across all sectors – including district heating – and defines the concepts of efficient district heating and high-efficiency cogeneration.

[4] http://data.europa.eu/eli/reg/2021/1119/oj
[5] http://data.europa.eu/eli/reg/2018/1999/oj
[6] https://eur-lex.europa.eu/eli/dir/2023/1791/oj

Article 25 of the directive calls for NECPs to include a comprehensive heating and cooling assessment using cost-benefit analysis to identify the most resource- and cost-efficient solutions to meet heating and cooling needs, considering the energy efficiency first principle. The potential application of efficient district heating and cooling systems should be assessed with waste heat, high-efficiency cogeneration, and renewable energy sources taken into account. The directive also introduces a requirement for regional and local authorities to prepare local heating and cooling plans involving local stakeholders in municipalities with a total population over 45 000. Article 26 sets out criteria for efficient district heating and cooling systems, as summarised in the table below.

Energy sources to achieve EDHC criteria Periods	Renewable energy	Waste heat	Renewable energy and waste heat	Combined supply from renewables, waste heat and (high-efficiency) cogeneration	(High-efficiency) cogeneration
Until 31.12.2027	50%	50%	50%	50%	50%
1.1.2028 - 31.12.2034	50%	50%	50%	50%(1)	80%(2)
1.1.2035 - 31.12.2039	50%	50%	50%	80%(3)	
1.1.2040 - 31.12.2044	75%	75%	75%	95%(3)	
1.1.2045 - 31.12.2049	75%	75%	75%		
After 1.1.2050	100%	100%	100%		

Notes:

(1) Only high-efficiency cogeneration can be counted towards the threshold. At least 5 % of the heating and cooling supply going into the network should be from renewable energy.

(2) Only high-efficiency cogeneration can be counted towards the threshold.

(3) Only high-efficiency cogeneration can be counted towards the threshold. At least 35 % of the heating and cooling supply going into the network should be from renewable energy or waste heat.

Source: Commission Recommendation (EU) 2024/2395 of 2 September 2024 setting out guidelines for the interpretation of Article 26 of Directive (EU) 2023/1791 of the European Parliament and of the Council as regards the heating and cooling supply

Alternatively, EU Member States can also define efficient district heating systems using sustainability performance criteria based on greenhouse gas emissions per unit of delivered heat, progressively declining from 200 g/kWh in 2025 to 0 g/kWh in 2050 (see Article 26(2)).

Criteria for high-efficiency cogeneration are set out Annex III of the directive. One important criterion is that direct emissions of the carbon dioxide from fossil fuel-driven cogeneration production by cogeneration units built or substantially refurbished after the transposition of Annex III must be under 270 gCO_2/kWh.

Heat pumps are important for decarbonising the heating supply, including in district heating systems. The methodology established in Annex VII to Directive (EU) 2018/2001 provides rules for counting energy captured by heat pumps as energy from renewable sources, and prevents double counting of electricity from renewable sources. For the purposes of calculating the share of renewable energy in a district heating network, all the heat originating from the heat pump and going into the network should be counted as renewable energy, provided that the heat pump meets the minimum efficiency criteria set out in Annex VII to Directive (EU) 2018/2001 at the time of its installation.[7]

In addition to the efficient district heating criteria, EU Member States must ensure that when a district heating system is built or its supply units are substantially refurbished, there is no increase in the use of fossil fuels other than natural gas in existing heat sources compared to the annual consumption averaged over the previous three calendar years of full operation before refurbishment; and any new heat sources in that system do not use fossil fuels, except natural gas, if built or substantially refurbished until 2030.

The directive also requires adequate metering, cost allocation mechanisms and billing information to be available to customers.

The Renewable Energy Directive (EU) 2018/2001, **as amended by Directive (EU) 2023/2413 (RED III),**[8] aims to increase the share of renewable energy in the European Union's overall energy consumption mix to 42.5% by 2030 (binding at EU level), with a further indicative target of 2.5% (aiming for 45%). The directive defines renewable energies and waste heat. It requires EU Member States to increase the share of renewable energy in the heating and cooling sector at an annual average at least 0.8% for the period from 2021 to 2025 and by at least 1.1% for 2026-2030, starting from the share of renewable energy in the heating and cooling sector in 2020. EU Member States must endeavour to increase the share of energy from renewable sources and from waste heat and cold in district heating and cooling by an indicative 2.2% as an annual average calculated for the period from 2021 to 2030, starting from the share of energy from renewable sources and from waste heat and cold in district heating and cooling in 2020. The directive calls for EU Member States to consider measures to promote the installation of highly efficient renewable heating systems in buildings, the connection of buildings to efficient district heating systems, renewables-based district heating and cooling networks and renewable energy communities. EU Member States should ensure that the relevant district heating and cooling systems customers' rights are respected and that information about renewable heating and energy performance is provided to final consumers in an easily accessible manner.[9] The directive also reinforces sustainability criteria and greenhouse gas reduction requirements for biomass, and woody biomass should be used according to its highest economic and environmental added value following the cascading principle.

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[7] Recital (107) of the Energy Efficiency Directive.

[8] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018L2001-20240716

[9] A Joint Research Centre study presents reporting approaches for presenting information on the sustainability and efficiency of district heating systems in line with the Renewable Energy Directive requirements. See https://op.europa.eu/en/publication-detail/-/publication/d0d195ab-3733-11ee-b134-01aa75ed71a1/language-en/format-PDF/source-323274100

The Energy Performance of Buildings Directive Recast (EPDB) (EU/2024/1275)[10] requires national building renovation plans (NBRPs) to describe how EU Member States will transform their existing private and public buildings into zero-emission buildings (ZEBs) by 2050. All new buildings should be designed to optimise their solar energy generation potential. This is to be achieved through EU Member State[11] national building renovation plans. The EPDB requires all new residential and non-residential buildings to have zero on-site emissions from fossil fuels (making them zero-emission buildings) as of 1 January 2028 for publicly owned buildings and as of 1 January 2030 for all other new buildings, with the possibility of specific exemptions. Subsidising stand-alone fossil fuel boilers will be prohibited as of 2025, but financial incentives will still be possible for hybrid heating systems that use a considerable share of renewable energy, such as those combining a boiler with a solar thermal installation or a heat pump. In their NBRPs, EU Member States must outline how they will adopt measures to decarbonise heating systems, with a view to phasing out fossil fuels in heating and cooling by 2040.

The directive presents district heating as one of the options enabling the improvement of building energy performance. It encourages EU Member States to ensure that the use of district heating and cooling is carefully considered when buildings are planned, designed, built and renovated. Efficient district heating is explicitly put forward as an option for meeting a building's heating needs while respecting zero-emission building requirements. After 2030, new buildings can only be connected to an efficient district heating system.

European Union Emission Trading System (EU ETS) Directive 2023/959[12] works on the cap-and-trade principle,[13] and has been in force since 2005. The EU Emission Trading System operates in trading phases and is now in its fourth trading phase (2021-2030). Combustion installations with a rated thermal capacity exceeding 20 MW are covered under the system, meaning that many larger district heating network heat suppliers are part of it. It has been proven an effective tool for redistributing CO_2 emission costs. The Modernisation Fund[14] is financed by revenues from the auctioning of emission allowances under the EU Emission Trading System, supporting clean energy projects in various sectors, including district heating.

As part of the 2023 revisions of the ETS Directive, a new emissions trading system named ETS2 was created, separate from the existing EU Emission Trading System. This new system will cover and address the CO_2 emissions from fuel combustion in buildings. The carbon price set by the ETS2 is expected to provide a market incentive for investments in building renovations. All emission allowances in the ETS2 will be auctioned, and a share of the revenue will be used to support vulnerable households and micro-enterprises through a dedicated Social Climate Fund. The ETS2 will become fully operational in 2027.

To incentivise and expedite the reduction of greenhouse gas emissions originating from district heating, the directive allows the Emission Trading System installations providing heat to district heating systems to apply for additional free allowances in the period from 2026 to 2030. Free allowance allocation is conditional on a specific climate neutrality plan being drawn up and submitted.

[10] https://eur-lex.europa.eu/eli/dir/2024/1275/oj

[11] The first draft building renovation plan should be submitted to the European Commission by 31 December 2025.

[12] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02003L0087-20240301

[13] In a cap-and-trade system, the government sets an emissions cap and issues a quantity of emission allowances consistent with that cap. Emitters must hold allowances for every tonne of greenhouse gas they emit. Companies may buy and sell allowances, and this market establishes an emissions price.

[14] https://modernisationfund.eu/

State aid rules

Public financing for district heating decarbonisation projects would typically involve the presence of state aid within the meaning of Article 107(1) of the Treaty on the Functioning of the European Union (TFEU). The supply of heat is an economic activity and its financing with public funds can favour selected undertakings, potentially distorting competition and affecting trade between EU Member States.

In JASPERS' experience, the European Commission **General Block Exemption Regulation** (EU) No 651/2014 (GBER) provides a useful framework enabling most district heating decarbonisation projects to make their public financing compatible with the EU internal market, without having to notify the European Commission about the aid. In particular, with the 2023 Green Deal GBER amendment:

- aid for district heating and/or cooling systems, as referred to in Article 46, is exempted from notification requirements up to €50 million per undertaking per project;
- supported district heating and/or cooling systems need to be or need to become ***energy efficient*** as defined in Article 2(41) of the Energy Efficiency Directive 2012/27/EU;
- when the district heating system is not yet efficient, it needs to qualify within three years of the start of the supported works on the distribution network;
- aid can cover district heating generation, storage or distribution;
- **eligible cost** is the *investment cost* for construction or upgrade of a district heating system;
- the **maximum aid intensity** is 30% of the eligible costs, plus an additional 20% for a small or 10% for a medium enterprise, plus an additional 15% for projects using only renewable energy sources and/or waste heat. Alternatively, the aid intensity may reach up to 100% of the investment's **funding gap.**

The provisions of Article 41 of the General Block Exemption Regulation can be used to finance renewable heat generation and high-efficiency cogeneration assets, making it possible to secure exemption from notification requirements for aid up to €30 million per undertaking per project, with maximum aid intensities ranging from 30% to 45%, depending on the technology being supported.

EIB lending criteria

The EIB energy lending policy was adopted in 2019[15] and confirmed in 2023 with an updated version of the technical annexes. The policy reflects the EIB's commitment to support the European Union in delivering the 2030 targets and to align with the Paris Agreement. The policy stresses that district heating networks can play an important role in certain markets both in the European Union and beyond, and can use decarbonised sources of heat supply. The Bank undertakes to continue to finance the refurbishment and construction of these networks under the conditions specified below.

The EIB Group Climate Bank Roadmap 2021-2025 was adopted in 2020.[16] The roadmap outlines our goals for climate finance that supports the European Green Deal and helps make Europe carbon-neutral by 2050. It maps the next stages in the journey to a sustainable planet and provides a framework to counter climate change. Annex 2 to the roadmap[17] specifies which activities will be eligible for EIB Group support and which will not, setting out the requirements for financing district heating network refurbishment and construction.

[15] https://www.eib.org/en/publications/20230164-eib-energy-lending-policy
[16] https://www.eib.org/attachments/thematic/eib_group_climate_bank_roadmap_en.pdf
[17] https://www.eib.org/en/publications/20230342-paris-alignment-framework-low-carbon-v1-1

EIB eligibility criteria support the refurbishment and construction of district heating systems if the project will not result in any annual increase in the combustion of solid or liquid fossil fuels or non-organic waste. Thermal storage facilities are considered to be part of a network investment.

3. Methodology

The methodological approach proposed by this paper is based on four steps:

The starting point is the analysis of the existing situation. Different dimensions of the district heating business need to be assessed, including technical, financial and socioeconomic viability, the institutional setup and current and forecasted heat demand. The information collected should feed into the identification of the district heating system's current strengths (S) and weaknesses (W), on the one hand, and the opportunity (O) and threats (T) for future development, on the other. This SWOT analysis should be used as a basis for identifying the local, specific decarbonisation objectives contributing to the policy objectives and the related national targets set out in the national energy and climate plans (NECPs), building renovation plans and local heating and cooling plans. Different options are then considered as alternative paths to reach the identified objectives. The options could be developed as decarbonisation scenarios (pathways). Analytical tools such as multi-criteria analysis (MCA) and simplified forms of cost-benefit analysis (CBA) can be used to compare scenarios and options. A set of concrete measures is eventually identified, including both investment and, where required, operational and organisational measures that would enable the targeted district heating decarbonisation.

More guidance on the general approach can be found in the JASPERS paper entitled General methodological guidance for strategy making.

If this methodology is applied in the framework of the preparation of a public plan or programme (such as a municipal heating plan), a strategic environmental assessment (SEA) should also be made throughout the planning exercise in line with the provisions of the SEA Directive 2001/42/EC.

4. Assessment of the existing situation

4.1 Technical viability

District heating systems consist of following components: production sources, transmission and distribution network piping and customer interconnections (end-users' systems). The viability assessment of the current system should therefore include all of its components, irrespective of the current organisational and institutional structure of the physical district heating assets.

<u>Heating sources</u>

The technical assessment of heat generation plants should basically focus on three key areas:

- the adequacy of the heat production capacity for meeting actual demand in an uninterruptable manner;
- in the case of cogeneration plants, the operating mode (heat demand driven or electricity market demand driven) and interaction with the electricity market;
- compliance of the heating plants with the environmental requirements;
- the energy efficiency of the heating generation plants.

Available heat supply capacity should be sufficient to cover the entirety of heat demand from customers during normal steady state operation and in emergency situations. Heat production costs and efficiency should be optimised to ensure that security of supply and quality of heat is acceptable and in accordance with the contractual and heat delivery requirements. The maintenance of the heating plants should be analysed keeping in mind the objective of minimise the supply interruptions.

Larger district heating production plants are usually regulated under the following EU legislation:

- Industrial Emissions Directive (IED) 2010/75/EU and its revision (IED 2.0)
- Medium Combustion Plant Directive (MCPD) 2015/2193/EU
- Ambient Air Quality Directives (AAQD) 2008/50/EC and its revision[18]

Production plant performance should comply with the requirements of the environmental permit issued by the national or local authorities. The permit conditions on large combustion plants are usually based on best available techniques (BATs), which are provided in BAT reference documents (EU BREFs). As of June 2024, there are 34 published BAT reference documents. For the energy production sector, the most relevant are WI BREF for waste incineration and LCP BREF for large combustion plants. The assessment of the heat production technology should therefore also include verifying that the plant complies with environmental performance criteria, including but not limited to air emissions, water, land, generation of waste, use of raw materials, energy efficiency, noise, etc.

[18] The revised AAQD was formally adopted by the European Parliament in April 2024. The revised directive had not yet been published when this document was drafted.

Plant operation should minimise environmental harm and follow the legal requirements in terms of air emissions and noise.

When assessing the current heat production efficiency, the following performance indicators should be calculated (as a minimum):

- the overall production efficiency calculated as fuel input/net heat production;
- the electricity consumption of the heat production plant/net heat production. This value includes the power use of the district heating network circulation pumps.

These indicators are dependent on the chosen fuel or energy source, heat production technology and operating mode of the production plant (base load or peak load, load variation).

For cogeneration plants designed for maximising the heat supply, overall annual fuel efficiency of 80-90% is considered a reasonable figure to achieve. Cogeneration plants should aim to meet the requirements for high-efficiency cogeneration, as defined in Annex III of the Energy Efficiency Directive.

<u>Network heat density</u>

As heat networks are very capital intensive, the heated area has to be densely built to minimise the required network length. The economic potential for district heating in less dense urban areas generally requires higher investments in distribution network infrastructure. The level of heat density (area heat density) is measured as heat demand per unit of area and could be expressed as heat demand per hectare or square metre, for example TJ/km^2. Heat demand could be shown in heat density maps (heat density atlases or cadastre). The higher the density, the more viable it is to use district heating systems to supply heat to buildings.

The overall economic viability of an existing district heating system depends, among other things, on the physical distances between heat production and customers. An important and suitable parameter for assessing the economic viability of an existing district heating network is its linear heat density, which is the ratio between heat delivered per year and heating network trench length (MWh/y-m).

As a rule of thumb, the heat load density for district heating should be higher than 2 MWh per metre of the network. The value is not automatically given for every urban context. Large cities tend to have a higher heat density than smaller ones.

District heating utilities should improve their competitiveness on the heating market by optimising district heating network density. If relatively low heat load density (indicated by long network branches and sparsely located small customers) prevails, an enhanced analysis should be carried out.

Local municipalities and district heating utilities should use all opportunities to expand district heating business with new services and new customer areas.

Heat density analysis should be part of any district heating system feasibility study.

<u>Heat losses</u>

Thermal transmission losses in pipelines are caused by pipes with poor or no thermal insulation, the absence or reduction of insulation in valves, pumps and compensators, and ventilation of chambers.

Heat losses for a state-of-the-art district heating network with pre-insulated bonded pipes range from 5% to 10% of the heat supplied. Heat losses in older district heating networks frequently stretch to between 10% and 15%.

The following points should be included in heat loss analysis:

- length of the district heating network;
- connected load;
- number of connection points;
- age of the network;
- type of district heating network (primary and secondary grid, grid configuration and layout);
- quality of the network (pre-insulated pipes, channel types, plastic/steel pipes);
- temperature levels (supply and return winter and summer operation);
- operating mode (variable or constant flow);
- network circulation pumps (number, location, type, capacity, age);
- main characteristics of the pipes (dimensions, pressure, flow);
- network hydraulics;
- use of network data such as differential pressures, temperatures, flows, use of SCADA);
- maintenance and repair of the network (inspection and its frequency, leakage detection system is place).

The analysis should end with a list of all the problems related to the district heating network. Reducing heat losses brings several significant advantages to the energy company engaged in the district heating business and to the environment. The most visible advantage in reducing the heat losses of the district heating network is the improvement of its energy efficiency level in line with the energy efficiency first principle. As the energy efficiency of the district heating network increases, the heat energy transferred from production plants to customers is used more efficiently. When the heat produced is used more efficiently, the need for heat production decreases. Reduced heat production means lower fuel and energy procurement and production costs for the energy company, with positive implications for profitability. Loss reduction also has climate and environmental effects. If a district heating system uses fossil fuels such as coal or natural gas, a reduction in heat production reduces carbon dioxide emissions. Efficient energy utilisation and the reduction of carbon dioxide emissions help curb climate change and promote the achievement of the goal of carbon neutrality.

Water management

Water losses

Water losses are caused by leaks in pipelines, heat exchangers and control equipment, and occasionally also by illegal tapping on the consuming side. It is possible to reduce district heating network heat losses by optimising the need for additional water (the amount of water leaving the network), because it has absorbed heat energy. Annual water annual loss can be seen in the water replenishment rate, which is calculated as the total annual make/up water volume in m^3 divided by the total volume of the pipe system in m^3. The rate is considered satisfactory in the range of 2-5, with a good replenishment rate being between 1 and 2. In addition to the replenishment rate, water losses can also be seen in the amount of make-up water consumption per time period, for example m^3/h.

Water quality

To avoid corrosion in boilers and in the steel service pipes, treated water must be used. The water treatment technology depends on the local conditions (such as source and quality of raw water used, the technology used for producing boiler feeding water and make-up water, and the size of the district heating network), but water quality should comply with the technical and equipment manufacturer's requirements and recommendations.

During the assessment of the present situation, current values should therefore be compared with the required and recommended values. The circulating and make-up water benchmarks from countries with good district heating experience could serve as examples. For international benchmarks, the Danish recommendations on water treatment and corrosion prevention seem appropriate.[19]

In addition to standard regular monitoring, periodic full samples and laboratory analysis of the make-up water and district heating circulation water are recommended.

The capacity and performance of the water treatment plant should be analysed in the context of make-up water demand on the district heating network.

The circulating water should be oxygen-free, oil free and sludge free, and pH should be between 9.5 and 10 (in some countries between 9 and 10).

<u>Substations</u>

There are several connection and control methods for end-user systems (including indirect connection and direct connection), with the prevailing method depending on the country concerned. Indirect connection has certain advantages in large district heating systems.

The most important requirement of the connection method and the secondary system design is to reduce the return temperature of space heating as far as possible.

The consumer district heating substation located in the basement of each building will usually be equipped with a water temperature controller. The controller automatically adjusts the supply temperature of the space heating circuit according to the outdoor temperature and the building's specific heating needs. The substation therefore takes as much heat from the network as is needed – no more, no less. In addition to district heating substations, the operation of the internal heating systems of the buildings should ideally also be briefly reviewed during assessment in order to identify ways to improve the cooling of the heating water. Cooling and temperature levels influence the overall energy efficiency of the heat production systems and are important, particularly when heat is produced from combined heat and power plants.

The analysis of district heating substations should include:

- the number of the substations;
- the size of the customers connected (capacity of the heat exchangers for space heating, domestic hot water and ventilation);
- a description of the types of different substations used in the district heating system, including presenting typical technological schemes and main equipment such as heat

[19] It is possible to access the document via registration, see https://www.eurowater.com/en/district-heating/download-dh-guide

exchangers, circulation pumps, control and automation equipment including heat metering and valves;
- the average age of substations;
- a description of the ownership of the substations, and a definition of the boundary between the district heating utility and building owners;
- required temperature levels (design temperature of the radiator or heating systems);
- operation and maintenance principles (including digital monitoring);
- the room where substation is located (overall condition, lighting, access to equipment and safety);
- an analysis of the overall technical conditions and needs for improvements compared to best practices.

In addition to the individual district heating substations located in each building, some district heating systems also have central heat substations whose function is to decrease the supply temperature and to prepare, distribute and deliver heat and domestic hot water to a group of buildings. In this case, the analysis should include individual and central substations.

International best practices should also be considered when assessing the substations. A good reference could be the Euroheat & Power Guidelines for District Heating Substations, but recommendations from experienced national district heating organisations (for example, those of Germany or Sweden) could also be considered for the design, installation and operation of substations.

Smart heat metering

Heat metering systems are used at the building and apartment level. Heat metering is a key factor in achieving energy efficiency benefits. Users only have an incentive to monitor and actively manage their heating use if they pay for it. The Energy Efficiency Directive (EU) 2018/2002 has strengthened the requirements for individual heat meters and heat cost allocators, requiring new meters installed after 25 October 2020 to be remotely readable devices and existing meters to be replaced by remotely readable devices by 1 January 2027 (except when a given EU Member State shows that this is not cost-efficient in its case).

If heat metering is technically not possible at the apartment level (such as in existing older buildings with radiator room heating), cost allocators could be used instead if they are considered a cost-effective solution.

Building-level heat meters are usually owned by the district heating utility and located at the connection point (in the district heating substation). Heat metering systems and their quality requirements are sometimes regulated by national legislation.

The analysis of heat metering systems should include:

- the types of heat meters used, including the share that are smart meters;
- meter accuracy and testing requirements;
- meter replacement practices;
- meter reading practices (for example, sharing of meters with the remote reading function);
- consumption monitoring practices.

The use of smart heat metering at the building level should be promoted, as it offers many benefits for the entire district heating system. Smart meters make it possible to measure and monitor the actual capacity of heat consumption, which provides insights and newfound transparency, turning the network into a smart district heating system. If metering is used at an apartment or business level, it provides full transparency of individual energy consumption to tenants, apartment owners and commercial companies. This transparency makes it easier to actively steer and reduce energy consumption – simply by changing behaviour and without further technical equipment. Individual metering (sub-metering) could help to reduce heating use and thus contributes to cutting CO_2 emissions. Heat cost allocators attached to individual radiators in residential buildings measure – within certain limits – the total heat output of the individual radiators.

Compliance with the efficient district heating system definition

When assessing the current situation, it must be ascertained whether the district heating network can already be qualified as an efficient district heating system, or rather if it is not in accordance with Article 26 of the Energy Efficiency Directive This means that the share of renewable energy sources, waste heat, cogenerated heat and high-efficiency cogenerated heat in the total heat supply of the district heating network must be calculated.

If the district heating system is already efficient within the meaning of Energy Efficiency Directive, it is important to evaluate whether this situation is likely to continue in the medium to long-term future, or whether there is a risk that the current favourable situation cannot be sustained and additional measures are necessary, such as additional supply of local renewable energy and waste heat.

Current carbon intensity

The following greenhouse gases can be relevant when assessing the carbon intensity of district heating activities: carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). In principle, greenhouse gases should be converted and expressed in CO_2 terms on the basis of the applicable global warming potential, in order to refer consistently to the relevant CO_2-equivalent.

It is necessary to distinguish between three conventional emission scopes:

- Scope 1: *Direct* greenhouse gas emissions: from own production activity (such as fuel combustion in heat and power plants).
- Scope 2: *Indirect* emissions associated with externally purchasing heat or power only.
- Scope 3: All *induced* CO_2 emissions, such as emissions from coal mining activities for district heating systems running on coal.

Direct and indirect emissions (Scope 1 and 2) should be considered when assessing the carbon intensity of the district heating system. The total CO_2 emissions (ktonCO_{2eq}), and specific CO_2 emissions (gCO_{2eq}/kWh of heat produced) of the district heating supply should be calculated for the most recent years of operation.

Further methodological details and unit emission factors can be found in the EIB Project Carbon Footprint Methodologies.

4.2 Analysis of the institutional setup

Ownership

The ownership of district heating systems typically varies by country and sometimes even by region. The possible ownership models and operational and financial procedures are usually specified in, depend on and are adapted to national legislation.

Municipal ownership is a common form of public ownership, and provides good opportunities for local businesses at the construction stage. However, municipalities with a poor financial situation and lacking specific sector experience could prevent the development and proper use of existing infrastructure. Where it is a justified way to address market failure, public ownership can achieve social goals more easily (with achieving the same goals in private ownership requiring extensive regulation and monitoring).

Other district heating network ownership models are typically long-term concession agreements with private operators for heat generation and distribution, unbundled networks with separate ownership of different network assets or private owner/operators, all of which directly interact with consumers.

It is important for any type of project that the district heating utility clarifies its domain of ownership – public (state or local), private or mixed (partly private) – and its primary objectives: private ownership models often focus on their own business objectives or benefits, whereas public ownership models often include social and local economic objectives; mixed ownership models typically target a win-win situation at the risk of increased transaction costs.

Many examples from European countries suggest that the initiative to develop *low or no carbon* heating systems may remain with the public sector. However, their typical challenges – poor maintenance, insufficient funds, poor planning and project selection, inefficient service delivery – could be resolved in alternative ownership and business models, potentially involving the private sector through public-private partnerships or private sector participation. The private sector may contribute to solving the challenges of the public-ownership model by providing long-term investment, private sector experience, and innovation. A public-private partnership is a long-term contractual agreement on private provision of services and includes models that reflect the increasing transfer of risk and responsibility from the public sector to private operators. There are multiple forms of public-private partnership, but they all include a private sector responsibility to design, build and operate the project.

The key models for private sector participation in district heating are:

- **Management agreements:** A company manages the system and is responsible for heat sales; minor upgrades are envisaged; duration is short term (up to five years).
- **Leasing:** A private party (lessee) operates, manages, and implements facility upgrades under a contract with a public party (lessor); duration is medium term (eight-15 years).
- **Concession agreements:** The concessionaire is responsible for investments in system upgrades under a long-term concession agreement; long term in nature (typically 25-30 years).
- **Privatisation:** A private investor secures financing and recovers it through heat sales; the government provides the framework conditions, particularly tariff regulation, energy planning, standards and norms.
- **Energy services companies (ESCOs):** Involves the provision of energy services to end-users, including the supply and installation of energy-efficient equipment and/or refurbishment of buildings; financing for the operation may be arranged and is usually tied to the energy savings achieved or to agreed performance criteria through energy-performance contracts.

There is no one-size-fits-all rule or recommendation for the best ownership model – options and risks should be carefully assessed on a case-by-case basis.

Legal framework

The completeness of the legal framework for district heating should be checked, considering, for example, the existence of an energy strategy, a separate district heating sector strategy, or a national legal document regulating key principles of the sector, including whether the framework is up-to-date and coherent at a national or local level, and what the consequences of this are. A distinct legal framework such as a separate district heating law, rather than general energy and competition laws, usually indicates specific awareness of the sector.

The assessment of the legal framework would normally address the following aspects:

- whether district heating and cooling are considered energy efficiency measures under the legislation;
- the legal framework in the country in accordance with international best practice;
- whether private sector participation is allowed in the sector in principle; former or ongoing public-private partnership project developments related to district heating;
- other existing laws associated with district heating (for example, public-private partnership law, concession law, lease law) and the lead agency responsible;
- separate laws at national, regional or local level; distribution of responsibilities (scattered or centralised) among relevant authorities;
- any comprehensive revision of energy sector legislation performed in recent years, including the harmonisation of legislation with the Third Energy Package and Clean Energy Package; for example, provisions for third-party access (to what extent), heat unbundling, etc.;
- particularly relevant for district heating decarbonisation is the transposition of Article 24 of the Renewable Energy Directive 2018/2001/EU on District Heating and Cooling and the option selected under Article 24(4) for supporting the increase renewable energy sources in district heating.

Furthermore, the applicable legislation should be checked for specific energy acts and/or its relevance and relation with laws, research or guidelines on (non-exhaustive list):

- renewable energy sources;
- waste heat;
- efficient cogeneration;
- energy efficiency;
- heat energy market;
- energy planning;
- regulation of energy activities;
- communal activities;
- local self-governance;
- other key guidance documents from relevant institutions, associations etc.

Pricing and regulatory framework

The basic pricing principles for district heating are either market-based or cost-oriented. Typically, private sector owners prefer competitive pricing against other heat supply alternatives, in order to maximise their economic benefit. Municipally owned utilities usually apply cost-oriented pricing, sharing the benefits of district heating with the end-users. Countries with significant district heating business often regulate pricing, with some exceptions (such as Finland).

Invoicing is typically split between metered and unmetered and household and commercial customers.

District heating prices vary considerably both between and within countries. Generally, district heating prices are lower or close to fossil fuel-based heating costs. It is therefore advisable to compare district heating prices to national natural gas and fuel oil prices including taxes. In addition, since district heating prices are frequently regulated, any adjustments may lag behind those for heating based on other fuels. Correspondingly, district heating companies are at risk of not being properly compensated, depending on the approved tariff-setting methodology. In any case, a comparison of district heating prices within the country should be performed in order to analyse possible differences at a national and regional level.

The tariffs of some district heating utilities do not cover full operating costs and investments, despite the fact that tariff-setting methodologies should allow the inclusion of all relevant costs. Affordability concerns are frequently behind lower-than-cost price setting. The role of the regulator is therefore important for enforcement of the appropriate tariff setting and the approval process. Key elements in this respect are the regulator's independence, the cost-recovery approach, social concerns and the development of social protection programmes. Regulators can design and approve tariff-setting methodologies, or define a common methodology (without setting specific tariff levels) and leave the approval with the municipalities in accordance with their responsibilities under laws on local self-governance.

In this respect, it should be ascertained whether heat (and in certain cases electricity) generation are commercial activities or rather public services.

The importance of the role of regulators is expected to increase with further integration of the natural gas market and an increased focus on renewable energy. However, local authorities may still have the final responsibility for tariff approval, and retain operations in the district heating sector.

Some key aspects for reconfirmation are:

- whether a regulatory structure is in place and the government officially supports it; whether there is a single regulator in each entity or a national regulator;
- if the methodology for tariff calculation allows full cost recovery, including the investment in district heating infrastructure and possible adjustments to it;
- whether the tariff methodology is established at municipal level, meaning that tariffs are calculated and approved by municipalities;
- if subsidies are allocated to district heating companies or directly to households; if subsidies are blanket (benefiting all connected households) or structured (benefiting mainly the poorest households) and performance-based;
- whether there are feed-in tariffs in place for electricity produced from cogeneration or renewable sources and sold to the grid; if there are any other financial support mechanisms in place; whether there are specific feed-in tariffs for heat production;
- if there are any interconnection policies, or consistent and transparent procedures for selling the generated electricity to the grid;
- what efficiency incentives there are in the tariff structure;
- whether there is household protection in place to support low-income users; if it is uniformly applied (across all municipalities); if there are support subsidies directly paid to targeted users with the invoice or allocated to utilities; what significant issues there are related to revenue collection; and how are they balanced in view of the financial viability of the company.

The most common tariff-setting methodologies in the district heating sector are:

- **Cost-plus**: The operator recovers the operating cost of the district heating system with a fixed profit used for system upgrades.
- **Return on investment**: The operator recovers operating expenses, depreciation on tangible assets and new investments; a return on invested capital is included.

- **Tariff indexation or price cap**: Prices are set to cover the approved costs of the preceding year multiplied by an index that reflects the new conditions (such as rising fuel costs), as well as an expected annual efficiency gain.
- **Benchmarking**: Prices are established upon review of peer heat suppliers. This incentivises more efficient suppliers and penalises those that are less efficient.

European institutional and regulatory framework best practice includes the following:

- Regulators should be independent from ownership and management.
- The regulatory and tariff approval process and decisions should be transparent and traceable in documents.
- The approved tariffs should allow for full cost recovery.
- Regulation should provide incentives for efficiency improvements.
- Policy instruments should be applied to support the use of district heating or combined heat and power (financial and fiscal support mechanisms, market-based mechanisms, interconnection policies).
- Social protection and support of district heating customers in the face of price increases should target only low-income households.
- Investment decisions should consider the interests of consumers (by promoting low-cost, reliable heat supply).
- The legislative framework should allow for private sector participation in the district heating sector.

The analysis of the regulatory framework should also cover:

- the process of granting eligible producer status for the issuing of licences for energy activities;
- the granting of permits for construction and operation of new generation capacities;
- general conditions for energy supply and required standards of service;
- the process for resolving potential disputes between customers and energy suppliers or operators;
- monitoring of compliance with standards, codes (including the grid and distribution code) and technical rules.

Some countries have established favourable legislative incentives, such as national heat planning and high fossil fuel taxes. Other key support incentives are:

- **Financial and fiscal support mechanisms**: Feed-in tariffs for electricity from renewables and cogeneration; similar incentives for heat production; for what fuel basis it is provided and how long do the feed-in tariffs last.
- **Regulatory mechanisms**: A requirement for new electricity generation above a certain level of installed capacity to allow for the recovery of heat by means of a high-efficiency combined heat and power unit to be located where heat can be used (Article 10, Energy Efficiency Directive 2018/2002/EU); certificate of origin of energy from renewables and combined heat and power; preferred energy generator status and access to feed-in tariffs.
- **Interconnection policies**: Priority access or connection, purchasing, dispatching incentives and priority for renewable or combined heat and power electricity and heat rather than equal access to all generators.

4.3 Financial and economic viability

Assessment of cost-recovery levels

Using the assessment of the applicable regulatory framework and the related tariff-setting methodology for the district heating network and, where applicable, the heat generation sources, the analysis must assess the system cost-recovery level. This can typically be broken down into three components:

- operating and maintenance costs (variable and fixed);
- depreciation, as a proxy for recouping investment outlays;
- return on capital, meaning the remuneration of equity (dividends) and debt (interest costs).
- Financially viable district heating systems are those that can consistently recover the above three components in full. However, cost recovery is sometimes only partial, such as when there are mismatches between the allowed revenue and the actual costs and/or the actual revenue collected (for example because of affordability issues). The full recovery of the (cash) operating costs is clearly vital to ensuring service provision. Systems that can only partially recoup and remunerate capital would, over time, have a tendency to underinvest in asset maintenance and replacement, thereby leading to a possible increase in operating costs (for example, because of higher losses) and reactive maintenance (repair), and a decline in service quality (for example, supply disruptions). This can in turn lead to disconnections from the district heating system and/or an inability to connect new buildings. A smaller customer base would further exacerbate the problem, as fixed costs would be shared among a reduced number of users.

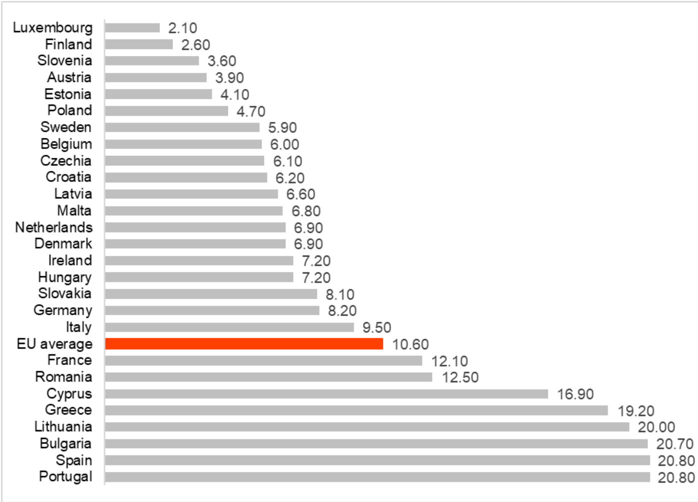
Affordability and competitiveness

Two key questions in terms of the SWOT analysis (see section 4.5 below) are to what extent the current district heating service is **affordable for households** and if the service is cost **competitive compared to other alternative solutions**.

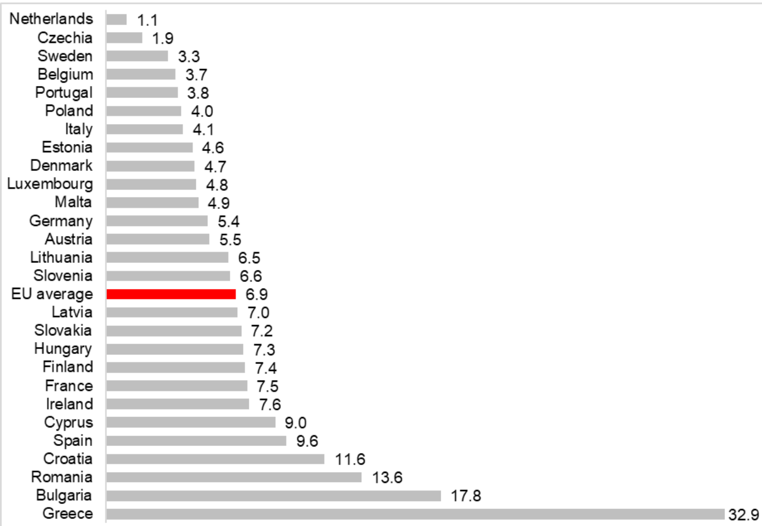
In this context, **affordability** can be defined as the ability of households to pay for the level of heating needed to keep their home sufficiently warm. At a national level, Eurostat monitors the percentage of population not being able to keep home adequately warm.[20] Another indicator monitored by Eurostat (and that can be used to assess possible affordability constraints) is the arrears on utility bills.

Share of population who are unable to keep home adequately warm 2023

[20] The indicator measures the share of population who are unable to keep their home adequately warm. Data for this indicator are collected as part of the European Union Statistics on Income and Living Conditions (EU-SILC) to monitor the development of poverty and social inclusion in the European Union. The data collection is based on a survey, which means that indicator values are self-reported.



Share of population unable to pay utility bills on time 2023



The following indicators can also be assessed, for example, depending on the availability of data at the municipal level:

- the share of heating costs in households' average or median[21] disposable income (or expenditure);
- the share of households whose expenditure on energy (heat and electricity) exceeds 10% of disposable income – this is a typical indicator for identifying households at risk of energy poverty;
- the share of households at risk of poverty (whose disposable income falls below 60% of median income) after consideration of expenditure on heating and electricity.

[21] As income distributions tend to be skewed, median values are better indicators of central tendency and should be preferred to average values when available.

While affordability relates the district heating costs against household income and expenditure, another important part of the assessment is how the district heating costs compare to the cost of alternative individual solutions – in other words, what the **competitiveness** of the district heating system is. For municipalities connected to the natural gas distribution network, individual condensing gas boilers are typically the lowest-cost alternative that would set the benchmark for the competitiveness analysis. However, in certain markets, individual solutions based on heat pumps may become increasingly economical (depending on climatic conditions[22] and the average size of buildings[23]), and could become the next-best alternative to district heating.

In addition to assessing the financial competitiveness of district heating, it is also important to analyse its socioeconomic benefits, taking into account the sustainability and security-of-supply dimensions of EU energy policy. In practical terms, this can be done by pricing certain external factors into the cost of district heating (and its next-best individual heat solution), such as:

- **Greenhouse gas emissions**. The shadow price to be used for the monetisation of the estimated changes in CO_2 emissions can be taken, for example, from the values used by the EIB.[24] When using this social cost of carbon, attention should be paid to excluding the possible cost for Emissions Trading System allowances in order to avoid double counting.
- **Emissions of air pollutants** (such as sulphur oxides, nitrogen oxides and particulate matter). Unit economic damage values (such as those from economic literature) can be used.
- **Security-of-supply costs**. Two aspects may be relevant here. The first relates to the fuel used to generate heat. In the case of natural gas, an external cost related to import dependency can be added to reflect possible risks of gas supply disruptions. A second aspects relates to the reliability of the district heating system and the possible economic cost associated with the use of individual electric heaters during periods of district heating disruptions.

4.4 Demand analysis

Demand for a district heating system should normally be justified by assessing:

- **current demand** (based on statistics provided by district heating service suppliers, regulators, ministries, or national and regional statistical offices for the various types of users);
- **future demand** (based on reliable demand forecasting models that consider macroeconomic and socioeconomic forecasts, alternative sources of heat supply, elasticity of demand to relevant prices and income, etc.).

The estimation of future heat demand is crucial for the identification and evaluation of district heating decarbonisation scenarios and options. Energy and cooling demand estimates are key parameters in both the financial and technical design of district heating systems, and thus impact their socioeconomic and environmental features.

[22] This would, for example, affect not only heat demand, but also the average coefficient of performance of heat pumps (the amount of heat output per energy input).

[23] As heat pumps are a high investment cost solution, installation in larger buildings allows for the sharing of the initial costs among a larger number of households.

[24] See Annex 5 of the Climate Bank Roadmap: https://www.eib.org/attachments/thematic/eib_group_climate_bank_roadmap_en.pdf

In order to derive a consistent target framework, knowledge of consumption patterns as well as localisation of energy sources and sinks is important. A detailed analysis of energy demand shows where and for what energy is consumed. Better geographic data availability includes data on buildings and related heating demand, excess heat potential and local renewable energy sources, as well as energy efficiency potential. However, access to geographical data can often be costly.

When developing a district heating system, it is necessary to identify the main users, their location and the intensity of the heat demand with a view to weighting which users could actually be connected to a system. The four main consumer groups by type of use are:[25]

- residential users
- public users
- tertiary sector users
- industrial users

When analysing consumer demand, the following points should normally be considered:

- heat demand per fuel type (for individual heating), per use (surface, water heating, etc.), per type of building (school, hospital, etc.) and per industrial process;
- population, population density, residential volume, floor area (at least at the scale of the municipality), number of employees, fuel consumption, quantity of product per specific sector (at least at the scale of the municipality) or number of employees per type of building (office, shopping centre, etc.);
- number of buildings, year of construction (age), volume or floor area (heated area), surface or volume ratio per type of building (at least at the scale of the municipality), climatic conditions (heating and cooling degree days per location) and overall energy performance.

For each source of data, the following aspects need to be taken into account:

- data structure
- data accuracy
- data availability (procedure, restrictions, waiting time, etc.)
- spatial resolution
- year and frequency of updating

<u>Service area</u>

Since district heating planning needs to be conducted locally, a binding target framework set by municipalities is a key driver for an effective and efficient decarbonisation of the district heating sector. Local authorities need to understand heating planning as an essential component of public service tasks. Heating planning requirements to decarbonise the local energy systems should be included as part of the urban planning framework.

Mapping heat demand is recommended to ensure that district heating system coverage is efficient. The mapping process is handled in three steps:

- mapping of building locations and surface areas
- identification of building heights,
- identification of building types

Each step contains one layer of information: A building's overall heating demand can be calculated by combining its surface area, height (number of floors) and type. The results obtained can be further complemented with the addition of several layers of information such as population density and energy certificates.

[25] Methodology for assessing and mapping the heat demand, Intelligent Energy Europe (February 2011).

The analysis of the potential for future developments of the current district heating system in a particular area should be based on an economic assessment to check if the operation of a district heating system can be justified in a certain city area. The following aspects should be taken into the account for this assessment:

- the existence of district heating network in the area;
- the availability of renewable energy sources and waste heat in the area;
- total heat demand in the area;
- heat density in the area;
- the levelised cost of heat (LCOH);
- potential revenue from the supply of heat;
- the cost of a new network development in the area.

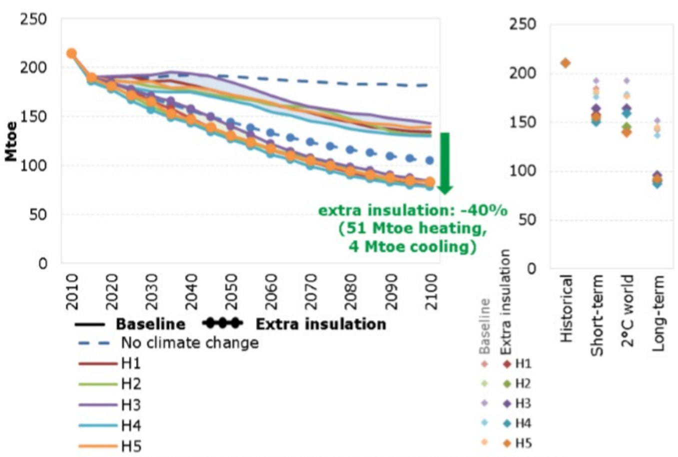
Energy efficiency improvements

Another factor to be considered in evaluating and forecasting district heating demand is increasing energy efficiency. Enhanced thermal insulation reduces buildings' heat consumption and therefore also the economic feasibility of district heating. However, it may also increase the feasibility of district heating systems by reducing the temperature levels required. This would have a positive effect on the feasibility of using renewable energy sources, waste heat and heat pump solutions, and may decrease heat losses in the district heating network.

The requirements for energy efficiency set in the Energy Efficiency Directive 2018/2002/EU and the Energy Performance of Buildings Directive 2024/1275/EU should be taken into account, together with the targets set in the EU Member State National Energy and Climate Plans and long-term renovation strategies.

The figure below illustrates the possible impact of better insulation on the total heating and cooling demand in the EU28 based on a study performed by the European Commission.[26]

Figure 10. Impact of a better insulation on the sum of heating and cooling demand in EU28



Source: POLES-JRC model (ADVANCE project version (ADVANCE wiki 2017))

Additional insulation can bring up to 40% of additional energy savings in heating demand.

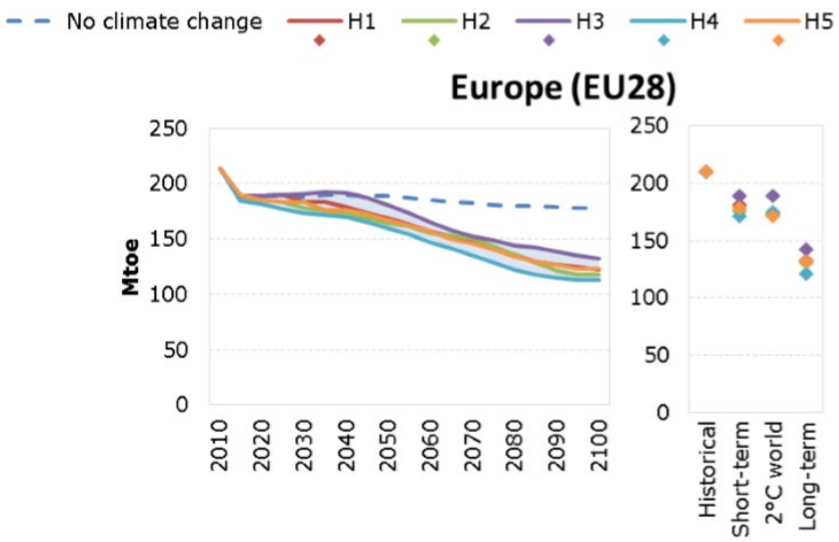
Climate change

[26] European Commission (2018), "Assessment of the impact of climate change on residential energy demand for heating and cooling" – see section 5.2, Impact of improved insulation.

District heating system operation depends on local climate conditions – temperature, solar radiation, wind, air humidity, etc. The energy demand for building or space heating is strongly correlated with outdoor weather conditions and temperatures in particular. In the longer term, global heating or climate change will affect district heating systems due to increased average outdoor temperatures, leading to reduced space heating usage.

The effects of the climate on energy needs for heating may be captured via heating degree days (HDD). This is an index designed to describe the heating energy requirements of buildings depending on the weather conditions. For each day in the year during which the mean air temperature does not exceed a given base temperature (15 °C, for instance) leading to indoor heating, the heating degree days index sums the difference between a set average room temperature (such as 18 °C) and the mean outdoor temperature.[27]

This paper uses a study from the European Commission entitled Assessment of the impact of climate change on residential energy demand for heating and cooling (see footnote 26) as a basis for empirical estimations of the impact of climate change on heating demand. The figure below illustrates the expected impact of climate change on residential heating demand for the EU28.



Source: POLES-JRC model (ADVANCE project version (ADVANCE wiki 2017))

The study also reports specific simulation results for different geographical areas in the European Union – potentially useful input for future demand analysis.

The results in picture above confirm that the decrease in heat degree days in all European countries leads to a decrease in heating demand. The continent needs 15% less heating energy in the short term (2021-2050) than in 2010, and 37% less in the long term (2071-2100). Compared to the no climate change scenario, climate change has effects of 5% in the short term and 27% in the long term (32% in 2100).

Population changes

[27] Eurostat uses the following formula for heating degree days (HDD):

If $T_m \leq 15$ °C Then [HDD = $\sum_i(18°C - T^i_m)$], Else [HDD = 0],

where T^i_m is the mean air temperature of day i.

For example, if the daily mean air temperature is 12 °C, for that day the value of the heating degree days index is 6 (18 °C-12 °C); if the daily mean air temperature is 16 °C, for that day the heating degree days index is 0.

District heating infrastructure follows building and population distribution. Heating demand within a country and for the residential sector is the function of available building area per capita and specific thermal demand per area. When these ratios are known, heat demand can therefore be mapped using building locations. A basic hypothesis is that district heating can be economically developed in every urban area with sufficiently high demand density. All demand below a given threshold could be supplied for a lower cost than individual heating and cooling solutions.

Geographical information systems (GIS) could be used to model and map heating demand as distribution functions of population, land use and soil sealing in a combined top-down and bottom-up manner. National energy statistics – combined with small-scale statistics at NUTS3 level – could then be used to calculate specific or absolute heating demand values on a per capita or per m^2 basis.

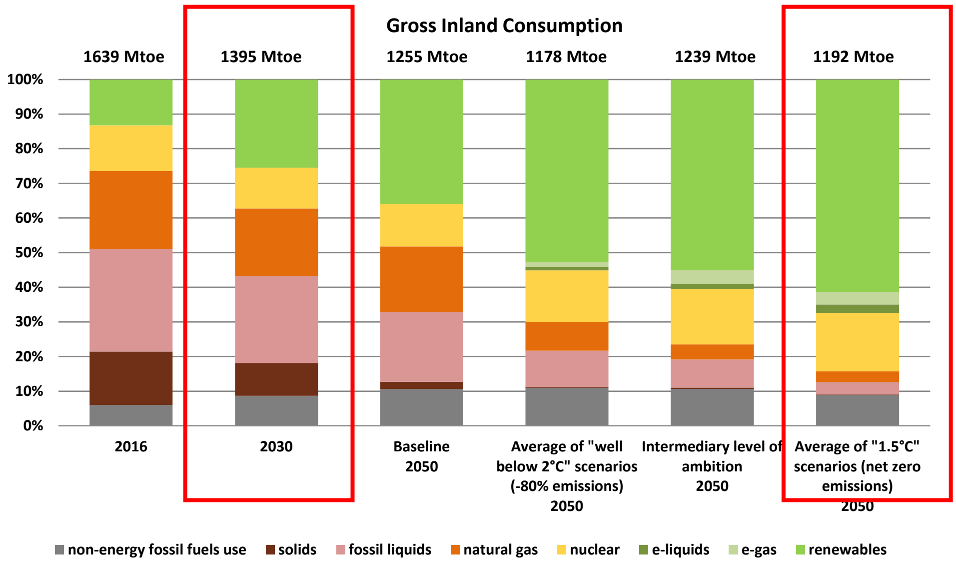
Future demand should take into account expected changes in population size and density.

GDP changes

Forecasts of district heating demand should also take account of expected gross domestic product (GDP) changes in the area in question. Though heating demand may be relatively inelastic with respect to income growth, the following aspects should be considered:

- In certain less-developed regions and areas, affordability constraints may limit households' heat demand. Growth in per capita GDP may therefore result in increased demand to the extent that heating bills constitute a lower share of household income.
- Growth in GDP and household wealth may, in the long term, lead to an increase in residential surface area to be heated, as bigger homes will be more affordable.
- Industrial heat demand (such as that for steam) or consumption from commercial buildings are typically more sensitive to changes in GDP.

The expected energy demand trend for the European Union – driven by the decarbonisation targets and the expected decoupling of energy demand from GDP – is illustrated in the figure below.[28]



[28] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773

4.5 SWOT analysis

Based on the analysis of district heating operational needs (demand), status of infrastructure (technical aspects), organisational and institutional setup and financial and socioeconomic viability, the district heating system's *current* strengths (S) and weaknesses (W) as well as the *future* potential opportunities (O) and threats (T) need to be presented in a SWOT analysis.

Examples of SWOT elements that might be applicable include:

- *Strengths:*
    - competitive district heating price (tariffs) compared to alternative heating sources;
    - high heat density in the service area;
    - high share of renewables, waste heat or efficient cogeneration in heat supply mix;
    - reliable service (very small number of unplanned interruption in recent years);
    - large market share in heating the buildings in an urban area.
- *Weaknesses:*
    - fossil fuel-based district heating system;
    - high level of CO_2 emissions;
    - high level of air pollutants emissions (air quality problem);
    - high district heating losses in networks;
    - high level of water losses;
    - high level of customer requests for disconnection;
    - low heat bill collection rate;
    - obsolete infrastructure that needs to be updated;
    - need for substantial capital for investments;
    - inability to finance district heating system transition;
    - lack of resources to develop district heating decarbonisation projects.
- *Opportunities:*
    - untapped waste heat from nearby industrial plants;
    - use of local renewable energy potential (from a geothermal source, for example);
    - national support schemes for operation of high-efficient cogeneration units and renewable heat;
    - possibility of receiving grant support for efficient district heating system feasibility studies and investments;
    - extending the district heating network coverage area;
    - connection of new buildings to the district heating network;
    - densification of the coverage area: connecting "missing" customers;
    - possibility of establishing local renewable energy district heating communities;
    - possibility of decreasing district heating prices compared to alternative individual heating solutions;
    - supporting decarbonisation of the buildings;
    - the expected introduction of the Emissions Trading System 2 might decrease the competitiveness of fossil-based individual heating solutions.
- *Threats:*
    - increasing price of Emissions Trading System emissions increases operating costs; possible application of Emissions Trading System 2 to smaller fossil fuel installations (such as natural gas boilers);
    - increasing cost of other environmental fees;
    - phasing out of subsidies for local lignite or coal extraction;

- declining costs of individual heating solutions such as heat pumps, which are competitors for the district heating system;
- lack of favourable financing (long-term low interest loans, grants);
- upcoming legal obligation to connect independent renewable energy source heat generators to the district heating system;
- decreasing heat sales as result of energy efficiency improvements and building renovation.

5. Setting the objectives

This step of the proposed methodology aims to define the objectives against which various decarbonisation measures will be screened and assessed at the option analysis stage. The needs assessment (regional and sectoral) builds upon the description of the context (such as a SWOT analysis as described in previous sections) and provides the basis for objective setting. The objectives must be set in compliance with the national or sectoral strategy of the EU Member States. The objectives should be defined in explicit relation to the identified needs, on the basis of the findings of the first step and the identified SWOT analysis. Objectives should address questions about the scale of the investment required and the prioritisation of investment needed to generate capability consistent with the interests of consumers.

Evidence should be provided demonstrating that the rationale of the objectives set responds to a priority for the region, meaning that the objectives should be in compliance with the regional or sectoral strategies prepared by the EU Member States and meet EU policy goals. Reference to these strategic documents should demonstrate that the problems are recognised and that there is a strategic approach in place to resolve them. The clearer the definition of the objectives, the easier the identification of the project and its effects.

General objectives (from EU or national policy, such as national energy and climate plans) can be associated with:

- **improving carbon efficiency and reducing greenhouse gas emissions** of district heating activities with the aim of reducing emission intensity. This objective could contribute to a target of improving carbon efficiency.
- **a low-carbon and resilient fuel basis of the district heating system.** The fuel basis should account for the incidence of individual fuels and any bridge solution to a low-emission future.
- **developing renewable energy sources and circular-approach initiatives.** This should consist of the promotion of renewables to reduce greenhouse gas and pollutant emissions produced by the district heating system by replacing fossil fuels with more sustainable energy sources.

The general objectives should be quantified with a system of indicators and specific targets comparing the situations with and without the identified decarbonisation measures. The project has to demonstrate how it contributes to the objective of improving overall carbon efficiency over the reference period. The project should contribute to the national compulsory target for energy share of renewable sources. Achieving the project's objectives and target values will directly contribute to the national energy objectives defined in relevant strategic documents.

Specific objectives (from the results of the SWOT analysis) could include, for example:

- increase the share of renewable energy -H to X TWh/y or X% of total mix;
- increase the share of efficient cogenerated heat to X TWh/y or X% total mix;
- introduce industrial waste heat use to X TWh/y or X% total mix;
- introduce/increase heat storage capacity for X MW;
- reduce the carbon intensity of district heating to X gCO_2/KWh or to X tonne/year;
- reduce average district heating water temperature to X °C;
- reduce district heating losses to below 10%;
- reduce supply disruptions to max X /year;
- reduce average length of supply disruptions to X hours;
- reduce the emissions of airborne pollutants (PM, SOx, NOx) by X% / to X tonnes/year;
- reduce/maintain average district heating generation cost to X €/MWh;
- reduce/maintain average district heating distribution costs cost to X €/MWh;
- reduce/maintain average district heating bills at max X% of average/median household income.

To the extent possible, specific objectives should be reflected in quantitative performance indicators against which the different options can be assessed. Other aspects that should be taken into account when setting up the project objectives are:

- shorter term vs. longer term;
- compliance with the national and European Union-level requirements (for example, efficient district heating system definition, zero energy buildings);
- geographical scope.

Timescale of the planned decarbonisation

The objectives set should also consider the timescale of the planned decarbonisation, in order to make a distinction between the long-term strategy and the short-term investment programme (project). The process of decarbonisation is a phased process, where the subsequent phases of decarbonisation involve gradually replacing heat sources with ones based on renewables and waste heat.

The long-term strategy should cover a period of around 15-25 years, in order to determine measures that would lead to the desired ultimate degree of decarbonisation in 2050. The shorter-term investment programme should be aligned with the long-term strategy and focus on the measures to be implemented on a five to ten-year time scale.

6. Approach for options analysis

The option analysis stage relates to the assessment and comparison of a series of potential measures that can meet the decarbonisation objectives set in the previous step. In JASPERS' opinion, a multi-criteria analysis (MCA) is the most appropriate and comprehensive analytical tool to compare options at a strategic level. The previously defined objectives will be translated into the relevant multi-criteria analysis criteria. For the evaluation of the financial and economic criteria of the multi-criteria analysis, the levelised cost of heat can be used as a simplified cost-benefit analysis tool to determine the related scoring.

The strategic options analysis should focus on identifying sustainable heat sources for the district heating system, covering a longer timescale of ten to 20 years. Different options for the decarbonisation of heat supply should be analysed and compared, with the options considered being aligned with the objectives defined in the previous step. Different options to be analysed may include a partial or full switch from the current heat source to a sustainable heat generation option such as high-efficiency cogeneration, renewable and waste heat sources, or an appropriate combination thereof. The analysis of options should include the following aspects in particular:

- possibility of using high-efficiency cogeneration considering the availability of a gas distribution network and clean gases;
- local waste heat sources:
    - potential to use excess heat from condensing thermal power and waste incineration plants;
    - potential to use industrial waste heat;
    - potential to use unconventional sources of heat such as wastewater treatment plants;
    - heat recycling from data centres;
    - waste heat from buildings with cooling demand, such as heat recovery from air conditioning systems.
- renewable energy sources:
    - availability of local geothermal heat sources of various temperatures;
    - availability of biofuels including forest, agricultural and industrial waste biomass;
    - availability of renewable gases such as biomethane, landfill gas and sewage gas;
    - potential for solar thermal sources such as annual available solar yield as kWh/m^2, availability of the local land area for solar thermal collectors close to the district heating network and rooftops in the district heating supply area.
- power-to-heat technologies such as electrical heat pumps and electrical boilers.

The strategic options analysis should also determine the optimal setup of different heat supply facilities and their operational arrangements. The aspects below may be studied as sub-options of the principal options identified above.

- Heat demand duration curves and heat supply duration curves should be analysed to optimise the operation of the heat production facilities (summer domestic hot water (DHW) load, base load, medium and peak load).

- Heat storage options such as short-term, medium-term and seasonal storage should be considered.
- Centralised vs. distributed heat production options, or a combination of both should be considered.

Where relevant and feasible, the assessment can be complemented with the deeper analysis of specific technological solutions. This should aim to define a short-term investment programme (project) to be implemented over five to ten years. In addition to further optimising the specific technological solutions for the predefined option selected at the strategic level, the analysis should also aim to optimise other improvement areas relevant for the sustainable operation of the district heating system, such as service area, energy efficiency, water management, operating regime and operational setup. The measures may include in particular:

- redefinition of a district heating network service area: analysis of options for extension and/or reduction of the service area;
- potential to connect smaller existing district heating systems and interconnecting them with the larger district heating system;
- potential for developing greenfield district heating grids;
- replacement of district heating transmission and distribution pipes, choosing optimal insulation thickness of the pipes, other measures aiming to reduce thermal losses, measures aiming to reduce power losses (for example, replacement of circulation pumps, application of variable speed drives);
- reduction of water losses, improved water management;
- optimisation of operating regime: supplying heat for space heating only rather than for space heating and domestic hot water, supply/return temperatures, pressure, hydraulic balancing, automation and control;
- replacement of substations and application of smart metering;
- reduction of supply and return temperatures of the district heating network;
- using a modular approach in adapting to the need for decarbonisation and thermal grid evolution;
- digitisation of the district heating system (metering, sensors, monitoring, data analysis, modelling and simulation)

For the analysis of specific technological solutions, JASPERS recommends the following procedure for the optimisation of measures, selection of measures and an optimal combination of measures:

Step 1. List any potential improvement measures that contribute to meeting the objectives.

Step 2. Optimise each individual measure using levelised cost of heat criteria.

Step 3. Rank individual measures starting with the measure that achieves the lowest levelised cost of heat.

Step 4. Check if measure number one alone meets the project objective set. If not, add measure number two, then number three, etc. Proceed until you identify the first set of measures making it possible to meet the objectives set.

Multi-criteria analysis

The suggested tool to assess and compare the performance of the different options is multi-criteria analysis (MCA[29]). This analysis enables the decision-maker chose the most suitable option from a number of possibilities, prioritising them based on a number of different criteria. Multi-criteria analysis methods have become increasingly popular in decision-making because of the multi-dimensionality of the goals, and the possibility of applying them to complex systems. This kind of analysis facilitates the comparison of different options, considering all the benefits (even those that cannot be monetised or quantified easily) and relating them back to the policies that the strategic and planning documents pursue in a direct visual way.

There are many different multi-criteria analysis methods available,[30][31] and it is sometimes not easy to find the right one for the specific task. The usability and possibilities of different methods for a particular task could be assessed using a number of criteria:

- number of exercises solved with the method;
- maximum amount of options to be assessed;
- maximum amount of criteria for the assessment of options to be used;
- possibility to evaluate the credibility of the results;
- time and other resources required to perform the analysis;
- clarity of the method and credibility of the results.

In the scientific literature, the following main steps of multi-criteria analysis have been identified as:[32]

- determining the main goal of problem structuring and goal setting (discussed in section 4 above);
- establishing system of objectives or criteria by which the options are to be judged;
- generating feasible options (a finite number of options) that can be implemented to achieve the goal (discussed in section 5 above);
- establishing the relative importance of criteria (such as by introducing criteria weights);
- normalisation of data (explained in the paragraph below);
- evaluation and interpretation of results.

Establishing system of the main objectives or criteria by which the options are to be judged

The specific objectives set in the previous step can be translated into criteria against which the different district heating decarbonisation measures considered above can be compared. Possible examples could be:

- capital expenditure;
- operating expenses;
- residual value of assets;
- district heating system supply security;

[29] Multi-criteria analysis (MCA) – also known in the literature under the names of multiple-criteria decision-making (MCDM), multiple-criteria decision analysis (MCDA), multi-objective decision analysis (MODA), multiple-attribute decision-making (MADM) or multi-dimensional decision-making (MDDM) – comprises various classes of methods, techniques and tools (with differing degrees of complexity) that explicitly consider multiple objectives and criteria (or attributes) in decision-making problems.

[30] Hwang, C. L.; Yoon, K. (1981). *Multiple attribute decision-making: methods and applications: a state of the art survey.* New York: Springer-Verlag.

[31] Podvezko, V. (2011), "The Comparative Analysis of MCDA Methods SAW and COPRAS." Engineering Economics, 2011, 22(2), 134-146. http://dx.doi.org/10.5755/j01.ee.22.2.310

[32] Zavadskas, E. K.; Turskis, Z. (2011). "Multiple criteria decision-making (MCDM) methods in economics: an overview." Technological and Economic Development of Economy 17(2): 397–427.

- district heating service quality;
- local environmental impact (such as airborne pollutants);
- CO_2 emissions;
- resource efficiency, including the energy efficiency first principle;
- social acceptance;
- heat price (the financial levelised cost of heat can be reparametrised to assign a score);
- socioeconomic sustainability (the socioeconomic levelised cost of heat can be reparametrised to assign a score);
- risks;
- for a phased decarbonisation approach (usually the case) where transitional, bridge solutions are needed,[33] it is important to also verify that those temporary solutions do not create a lock-in effect hampering the subsequent development of more sustainable district heating solutions. A related criterion can in this case be added to the multi-criteria analysis to reflect the potential technical, economic and legal considerations behind a possible lock-in effect. This could be referred to as flexibility or adaptability.

Introduction of criteria weights

Where the importance of the criteria (objectives) varies, criteria weights must be established. The weight of each criterion indicates its relative significance to the project compared to the other criteria.

Although in practice these weights are normally identified by experts and stakeholders (and not by the consultant performing the analysis), there are a number of different methods for establishing them. These include the normative method, which uses normative documents, estimates, recommendations, etc.; the calculation method, which applies empirical and theoretical relationships, statistical data and formulae; and the analogy method, which compares the selected analogical situation to the specified criteria.

If expert opinions are used for criteria weighting, the compatibility of these opinions have to be checked. The most popular tool for this assessment is Kendall's coefficient of correlation.[34] If opinions are compatible, they can be used further in multi-criteria analysis.

Data normalisation

If quantitative data on the criteria are to be used for the multi-criteria analysis, the type of criteria data (maximising or minimising) should first be established:

- The best values for *maximising* criteria would be the highest value.
- The best value for *minimising* criteria would be the smallest value.

In order to combine and use these values in the multi-criteria analysis evaluation, the aforementioned values have to be normalised to be set to the same dimension. The exact formulae for data normalisation depends on the multi-criteria analysis method.

If a criterion is expressed using qualitative data, the criteria values are usually established by using the expert, recommendation, sociologic, calculation or analogy methods. When using expert methods, the criteria values could be set as follows.[35]

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[33] This could be the case, for example, of coal-based district heating systems where a government decision to phase-out coal in a relatively short timeline would not leave enough time for the development of a fully decarbonised system.

[34] https://en.wikipedia.org/wiki/Kendall_rank_correlation_coefficient

[35] Zavadskas, E.K. Complex evaluation of resources and selection in construction decisions. Vilnius: Science, 209 c.

- A maximum value is set for a particular criteria (for example, on the basis of the quantified objectives defined in the previous step).
- A numerical value of ten points (100%) is assigned for the best value of the criteria.
- A ratio is established between the best value of the criteria and all the other values of the criteria.
- Relative values are assigned to all the other values of the same criteria.

Evaluation and interpretation of results

Individual calculation techniques depend on the multi-criteria analysis method applied; the highest ranked option in this analysis would be the preferred option.

Different multi-criteria analysis methods have their own strengths, weaknesses and application possibilities. A major criticism of multi-criteria analysis methods is that due to the differences between different techniques, different results are obtained when applied to the same problem. Therefore, to increase the credibility of the results, different methods could be applied for the same problem.

Simplified cost-benefit analysis: the levelised cost of heat

The heat price and the socioeconomic competitiveness and sustainability of the alternatives assessed are typically among the key criteria that the stakeholders would consider when identifying the most appropriate decarbonisation measures. The levelised cost of heat can be used as a simplified cost-benefit analysis tool to quantify the financial and socioeconomic performance of the different options.

The levelised cost of heat can be considered as a life-cycle average incremental cost, or long-run marginal cost. This is calculated as the ratio of (i) the present value of all costs (capital expenditure, operational expenses, fuel, etc.) associated with a given technology over the appropriate reference period and (ii) the present value of the heat supplied by the related plant(s) over the same time horizon.

The reference period can usually be taken to be 15 years when the measures mainly relate to heat generation, but a longer time horizon can be used when also considering investments in the district heating network, provided replacement costs for generation assets are adequately taken into account. For the discount rate used to calculate the present values, see the European Commission's Cost-Benefit Analysis Guide[36] and Economic Appraisal Vademecum.[37]

Two types of levelised cost of heat can be estimated: financial and socioeconomic. The financial type should be based on observed market prices and the related forecasts of future costs and prices to be borne by the owner(s) of the heat generation or distribution assets. The socioeconomic type should be based on the financial one and complemented with the assessment of external costs that would be borne by society at large (for example, the damage value of airborne pollutants, greenhouse gas emissions and security-of-supply considerations for certain fuels).

[36] Available at: Inforegio - Guide to Cost-Benefit Analysis of Investment Projects for Cohesion Policy 2014-2020 (europa.eu)– See Annex I and II on the financial and social discount rates, respectively.
[37] Available at: https://ec.europa.eu/regional_policy/en/information/publications/guides/2021/economic-appraisal-vademecum-2021-2027-general-principles-and-sector-applications

For combined heat and power options, the value of power generation can be netted out from the heat generation cost where appropriate. The following table summarises the costs elements typically considered in the financial and economic levelised cost of heat.

Financial levelised cost of heat	**Socioeconomic levelised cost of heat**
Capital expenditure	Capital expenditure
Operating and maintenance (O&M) costs	Operating and maintenance (O&M) costs
Fuel costs (if relevant)	Fuel costs (if relevant)
CO_2 Emissions Trading System allowance costs (if relevant)	Social cost of CO_2 emissions
	Social cost of SO_2, NO_x and PM
	(Security-of-supply cost)
(- revenue from power sales, if relevant)	(- economic value of power sales, if relevant)
Net levelised cost of heat (financial)	Net levelised cost of heat (economic)

When considering the district heating cost to the final consumers it is important to also take into account the costs associated with heat distribution and the related losses.

The externalities to be taken into account in the socioeconomic levelised cost of heat can be monetised on the basis of the unit values presented in section 4.3 above.

The net present value (NPV) of the different cost components over the project life can be divided by the net present value of the total heat generated over the same time span in order to estimate the related levelised cost sub-components.

It is important for the financial cost to be deemed competitive and affordable. The financial levelised cost of heat can be considered as a rough approximation of a heat tariff regulated on a cost-plus basis.[38] At the same time, the socioeconomic sustainability of the decarbonised district heating system with the proposed decarbonisation measures should be assessed against the next-best individual heating solutions by comparing the related socioeconomic levelised cost of heat.

The estimated financial and economic levelised cost of heat can be normalised and translated into scores for the respective criteria in the multi-criteria analysis.

[38] Differences could, for example, stem from: (i) differences between the ex-ante costs estimates and the actual costs incurred for the different alternatives; (ii) differences in average investment costs in the levelised cost of heat and the related depreciation included over the same reference period in the heat tariffs by the regulator; (iii) differences between the return on capital embedded in the discount rate used in the levelised cost of heat and the allowed profit included in the regulated tariffs; (iv) where the investment is co-financed by public grants (such as EU funds), the capital component in the related heat tariffs would likely be lower than in the financial levelised cost of heat estimated ex-ante; (v) in case of cogeneration assets, differences between the cost allocation method to transfer common heat and power costs to the heat tariff and the residual net levelised cost of heat after deduction of power sales revenue.

7. Definition of decarbonisation measures

The final stage of the methodology consists of the definition of concrete measures identified in the options analysis. Measures can mainly be split in two types: investment measures (such as in production sources, distribution infrastructure and related equipment) and non-investment measures, typically relating to changes in the organisational setup and operational design that would be required to enable district heating decarbonisation. A clear description should be provided for each measure specifying the entity responsible for implementation and the related timeline.

The investment costs (where relevant) and expected benefits of each individual measure, as well as of the whole package, should be determined.

This methodological stage should also include a final overview of the improvement achieved in the technical, financial and economic viability of the district heating system with the proposed measures, similar to the assessment made at the initial analysis stage.

The definition of measures should be complemented with an implementation plan describing the schedule and approach for implementation, as well as the parties responsible.

Furthermore, the financial and socioeconomic impact of the project on the stakeholders should be summarised, where the stakeholders will include, among others, the customers, the local authorities and the business partners (goods and services providers) of the district heating company.

8. Preparation of district heating decarbonisation projects

The European Union's ambitious 2030 and 2050 climate targets mean that there is currently substantial EU funding available from various different instruments. EU Member States are also under pressure to deliver on climate goals.

However, to access the available funding, appropriate project preparation is necessary:

- The project must be developed in compliance with the standards and requirements of the targeted funding source or instrument.
- Any project requires strategic analysis and planning at a local level before project preparation in order to identify the actual investment needs of the district heating system. JASPERS' experience indicates that outdated or incompliant local heating concepts and plans, or the reverse approach (first definition of the project, then establishment of the local heating plan) frequently present serious and time-consuming obstacles to funding.
- It should be noted that the development of low-carbon local strategies is an action eligible for European Regional Development Fund support under the current Multiannual Financial Framework. This means that if the project is supported by a cohesion policy programme, its studies can typically also be eligible for EU co-financing.

- Once a project is identified, it needs to be developed with detailed pre-feasibility and feasibility studies, business plans, environmental permitting procedures, and compliance with and sometimes coordination on state aid rules.
- The feasibility studies should identify the potential for the use of renewable energy and waste heat in the area they supply and include the indicative shares those energy sources will represent in heat generation in 2030, 2035 and 2040. In addition, district heating network transformation plans should include a pathway for the phase-out of fossil-based heat production.
- Following a standardised, proven methodology in project preparation and applying lessons learnt from other projects can avoid expensive and time consuming trial-and-error approaches.

JASPERS is an initiative co-financed by the European Commission and EIB to support the preparation of projects to be funded with EU funds, and can provide assistance in relation to the aforementioned challenges.

JASPERS has extensive experience in assisting district heating projects (particularly in central and eastern European countries) and can share this expertise with targeted support through:

- advice on the existing local district heating strategy and planning for compliance with 2030 and 2050 climate targets; where needed: assistance on strategy or planning updates;
- assistance on analysing and optimising potential funding sources from various instruments and sources, for both design and preparation of the project and for the project itself;
- support for the beneficiary in managing the project engineer or consultant using a standardised and proven project development methodology, sharing lessons learnt from other projects and advising on the issues that are typically most critical (optimised cost and funding, demand and option analysis, environmental permitting and state aid);
- assistance regarding the grant application form;
- facilitation of access to European Commission and EIB experts;
- to the extent necessary: training and capacity building (on a case-by-case basis).

The sample table of contents for the district heating decarbonisation feasibility study report can be found in Annex 1.

Any questions or requests for advice (without commitment) can be directed to jaspers@eib.org (mentioning “District Heating Decarbonisation” in the subject line of the message).

9. Useful references

Commission Recommendation (EU) 2024/2395 of 2 September 2024 setting out guidelines for the interpretation of Article 26 of Directive (EU) 2023/1791 of the European Parliament and of the Council as regards the heating and cooling supply https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AL_202402395

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https://ens.dk/sites/ens.dk/files/Analyser/technology_data_catalogue_for_el_and_dh.pdf

Annex 1 Sample table of contents of a district heating decarbonisation feasibility study report

The feasibility study report should include the following parts:

1) **Abbreviations**
2) **Definitions**
3) **Executive summary**
4) **Introduction**
   a) Objectives of the project
   b) Objectives of the study
   c) Studies and activities performed in the past, the main outcome of these studies[1]
   d) Ongoing and planned activities related to the project[2]
5) **Policy, legal and institutional framework**[3]
   a) EU policy and legal context
   b) National policy context
   c) Current national legal framework
   d) Heating tariff regulation and tariff setting principles
   e) Regional and local context:
      i) Policies and strategies
      ii) Plans and programmes
      iii) Urban/area planning
      iv) Energy and climate planning (for example, sustainable energy and climate action plan – SECAP, heating and cooling plan)
      v) Social and community aspects
6) **General description of the municipality and urban area(s)**[4]

[1] It is assumed here that some heating system decarbonisation-related activities and studies have already been conducted in the past. The results of these studies should be critically analysed.

[2] The feasibility study should reflect the current status of the decarbonisation activities.

[3] The description should focus on the energy sector, the field of renewable energy sources, and heat supply (including district heating), and should be relevant to the investment project concept.

[4] This should include size, location, geography, climate, heating and cooling degree days, morphology, demographic data (population, growth rates, trends, population projections), main economic activities in the municipality, employment data, household income, energy poverty, main industry, and economic sectors.

7) **Heating supply service provider**

   a) Ownership of the assets, and areas of activity

   b) Business concept, model and contracts[5]

   c) Organisational structure[6]

   d) Current management

   e) Financial situation[7]

   f) Tariffs

8) **Analysis of the current heating system**

   a) Heat generation

      i) Description of the current heating supply systems,[8] which shall include all the supply sources feeding heat to the heating networks and to the buildings

      ii) Operational data: Heat and power production, fuels used

      iii) Environmental aspects including air emissions

      iv) Planned decommissioning time for the existing heating assets, remaining lifetime

   b) Heating networks

      i) District heating service area[9] description, and location shown on a map of the municipality

      ii) District heating network description and map of the district heating network[10] indicating the production sources, pipe network and connected urban areas (districts)

      iii) Description of the current operating modes of the district heating system – temperature levels: flow and return, delta T, use of heat storage (if applicable),

[5] This should include an overview of main contracts (concession, public-private partnership, heat service contract, fuel supply, other essential contract), stakeholders, and a brief history of the organisation, including the ownership history.

[6] This should include an outline of the corporate structure, staffing, roles and responsibilities of the sub-structures.

[7] This could include analysis of the current financial situation, revenue breakdown, cost recovery, subsidies received and ability to finance the decarbonisation investments via grants, loans, owner's capital, etc. Financial statements could be presented as an annex. Depending on the scope, it could include full financial analysis or a brief summary of the situation.

[8] This should include at least installed and available capacity by type, plant and primary energy source (fuel, electricity), share of each heat source in the total supply mix, connected heat load, system efficiency, emissions, availability of assets, fuel handling, heat storage, etc. Could be illustrated with photos and schemes.

[9] This should include the number of populations served in the area, the number of customers heated/domestic hot water supplied, heat densities, etc.

[10] The scheme should be complete and reflect current situation. This could be described as primary and secondary network, if necessary. It should include a description of the technology, as well as all central heat transfer stations and key data (similar to the individual heat substations, see footnote 12).

pressure levels in the network, pressure and pressure difference, and temperature, pressure and flow control system

iv) Thermal and water losses in the system, loss dynamics[11]

c) Customers

i) Individual heat substations[12]

ii) Heat metering and meter reading systems

iii) Buildings and types,[13] heating, ventilation and air conditioning systems

iv) Analysis of current and historical demand data: Per customer segment, space heating and domestic hot water, typical load profiles

9) A**ssessment of the current state of the district heating system**

a) SWOT (strengths, weaknesses, opportunities and threats) analysis

b) Analysis of the key benchmarks.

i) Efficient district heating criteria: share of combined heat and power, renewable energy and waste heat used

ii) Carbon intensity

iii) Heat density

iv) Heat losses

v) Water losses

vi) Disruptions and failures

vii) Levelised cost of heat

viii) Other (financial)

c) Conclusions

10) **Heat demand analysis and forecast**

a) Main drivers of future heat demand

i) Socioeconomic factors

ii) Climate change

iii) Number of buildings connected/disconnected

iv) Expected energy efficiency improvements in the buildings

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[11] This should include a calculation of water replenishment rate and benchmark, make-up water quality data and a comparison of the required standards and best practices.

[12] Locations, types of connection (direct/indirect), capacities, design data, overall physical conditions, automation level, maintenance, and operation practices (control and regulation), ownership and boundaries (add schemes and photos to illustrate main types and components of the district heating substations).

[13] This should include a complete list of buildings with key data connected to the district heating system as an annex.

v) Competition aspects that may influence demand (individual heating solutions like natural gas boilers, heat pumps, electrical heaters and solid fuel boilers)

b) Heat demand forecast scenarios for the reference period (base case, max demand, low demand)[14]

c) Expected changes in heat consumption patterns (load curve variations), preparing hourly annual load duration curve for normal climatic year

11) **Setting decarbonisation objectives**[15]

a) Short-term objectives

b) Medium- and longer-term goals

12) **Description of potential decarbonisation measures**

a) Energy efficiency first principle

i) Reduction of heat losses

ii) Reduction of heat supply temperature

iii) Improved water management

iv) Automatic control of the network and substations, digitisation

v) Other

b) Improvements to existing generation capacity

c) Development of new generation capacity

i) Biofuel heating sources

(1) Forest biomass [16]

(2) Agricultural biomass

(3) Waste wood resource

(4) Biogas, landfill gas

(5) Other biofuel resources

(6) Location and key parameters of the new heating source

ii) Geothermal sources

(1) Locations of the resources

(2) Source temperatures, thermal potential

(3) Connection to the heating system

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[14] The heat demand forecast should be for at least 20 years and should be aligned with financial and economic projections.

[15] Goals must be quantitative and must include a time dimension.

[16] A particular emphasis should be placed on biomass sustainability requirements.

(4) Additional studies needed

iii) Heat sources for heat pumps:

(1) Aerothermal (air to water heat pumps)

(2) Hydrothermal (water to water heat pumps)

(3) Geothermal (ground source heat pump)

iv) Solar thermal sources

(1) Location-specific irradiation data

(2) Available sites

(3) Main parameters

(4) Connection to the heating system

v) Waste heat sources

(1) Local industrial excess heat

(2) Wastewater treatment plant waste heat

(3) Other waste heat

vi) Cogeneration options [17]

vii) Waste to energy

viii) Gas, fuel oil, electric peak boilers

ix) Heat storage (centralised/decentralised)

(1) Short-term/medium-term heat storage

(2) Seasonal long-term heat storage

x) Photovoltaics[18]

xi) Other sources

13) **Developing decarbonisation scenarios and options**[19]

a) Developing and describing alternative scenarios (pathways) with indicative timescales and targeted heat supply mix:

i) Heat generation options

ii) Heat storage-related options

iii) Network integration – interconnections

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[17] This should include various types of technological option: steam cycle, organic Rankine cycle (ORC), gas turbine, micro-turbines, reciprocating engines, fuel cells and various fuels such as biofuels (biomass, biogas), and natural gas.

[18] Solar photovoltaic generation could be used to cover the user's own electricity consumption.

[19] It could be that some of these resources are not available or realistic in the local municipality context.

iv) Network modifications – expansion, reduction, decentralisation

v) Network replacement and refurbishment

vi) Customer's interface modifications

vii) Other

b) Developing investment options for scenarios:

i) Main design conditions

ii) Location (siting, routing)

iii) Brief technology description

iv) Sizing (capacity selection)

v) Determination of key option parameters:

(1) Initial investment (capital expenditure)

(2) Operating and maintenance costs

(3) Revenues (for example, from power and heat sales)

(4) Heat supply curves (indication of production sources in the aggregated curve)

(5) Environmental, social and governance aspects

(6) Do-no-significant-harm aspects

(7) Other essential key parameters relevant to the option

14) **Comparison of decarbonisation scenarios and options**

a) Selecting the proper method and tools for multi-criteria analysis evaluation

b) Developing multi-criteria analysis criteria

c) Developing criteria weighting

d) Proposing multi-criteria analysis evaluation matrix

e) Selecting the best options for further analysis and development[20]

15) **Detailed development, description and evaluation of the preferred realistic options**

a) Detailed technical description of the preferred decarbonisation investment scenario and options

i) Short-term investment programme (next five to ten years)

[20] It is assumed here that after the multi-criteria analysis exercise, at least three alternative options will be chosen for further detailed analysis, but the exact number will depend on the outcome of the evaluation. The alternatives selected should be analysed by using appropriate planning, modelling and simulation software tools. Task could include organisation of the on-site seminar with the promoter and stakeholders to hold the multi-criteria analysis scoring demonstration session

ii) Medium and long-term programme (ten to 20 years)

16) **Levelised cost of heat calculation for selected options**

a) Assumptions used in levelised cost of heat calculations.

i) Energy and fuel prices

ii) Sales forecast

iii) Capital expenditure and operating expenses

iv) Other

b) Levelised cost of heat calculations (based on open Microsoft Excel spreadsheet model)

c) Risk evaluation of the options

i) Risk matrix

ii) Sensitivity

iii) Risk mitigation

17) **Description of the optimal decarbonisation action plan**

a) Short-term investment plan

i) Concept design of the proposed option: The concept design should include at least the description of main components of the proposed investment option, calculations of key parameters (such as capacity and diameters), location (site, route), layout and principal schematic diagrams. It shall also include description of main conditions and requirements for the subsequent preliminary and basic design work

ii) Project plan for the short-term investment plan implementation with milestones, which include at least:

(1) Financing plan (loan capital, grants, owner's capital)

(2) Procurement strategy and procurement plan

b) Medium- and long-term investment concept

c) Instructional and organisational setup of the implementation

18) **Recommendations and next steps**

a) Additional studies needed

b) Decisions to be made