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Transnational Strategy for Transformation of Central European DH Systems

District heating systems play a central role in the energy transition of Central Europe. In many cities, towns, and regions, they already provide an important collective heating solution, but they are still often dependent on fossil fuels, ageing infrastructure, and operating models that were designed for a different energy context. The transformation of these systems is therefore essential for achieving climate neutrality, improving energy security, reducing emissions, and ensuring affordable and reliable heat supply for citizens, public institutions, and businesses.

The strategic objective is to support the transformation of Central European district heating systems from predominantly fossil-fuel-based systems into sustainable and efficient heating and cooling systems by 2035. The target pathway is aligned with the revised Energy Efficiency Directive and requires a substantial increase in renewable energy sources and waste heat in the heat mix, with at least 50% renewable energy and/or waste heat by 2035. The strategy provides a common transnational framework for territories, public authorities, district heating operators and market stakeholders to move toward efficient, low-carbon and future-ready heat supply, while setting the direction for full decarbonisation by 2050.

By 2035, district heating systems in the EU should be transformed into efficient systems in which at least 50% of the fuel mix is supplied by renewable energy sources and waste heat. This target reflects the urgent need to reduce dependence on fossil fuels, increase the use of locally available energy sources, and improve the environmental performance of heat supply. At the same time, it recognises that district heating transformation must remain technically feasible, economically viable, socially acceptable, and adapted to local territorial conditions.

The strategy is based on a transnational perspective. Central European territories share many common challenges: fossil fuel dependence, outdated network infrastructure, limited integration of waste heat and renewable energy sources, financing constraints, regulatory barriers, and the need to engage customers and local communities more actively. However, they also share significant opportunities. These include available industrial and urban waste heat, geothermal potential, sustainable biomass, solar thermal energy, large-scale heat pumps, thermal storage, digitalisation, sector coupling, and stronger cooperation between public and private actors.

Evidence from pilot activities and local action planning is used as a practical validation layer for this strategy. The pilot evidence demonstrates how transition pathways can be prepared in real district heating systems, how barriers can be identified, how stakeholders can be engaged and how locally grounded measures can be connected to transnational learning. The strategy therefore remains practical and transferable while retaining its function as a policy-oriented transnational roadmap.

The strategy therefore combines two dimensions. At the local level, it supports territories in preparing concrete actions for modernising district heating systems and increasing the share of renewable energy sources and waste heat. At the transnational level, it creates a common framework for cooperation, mutual learning, knowledge exchange, policy recommendations, and replication across Central Europe.

The expected impact of the strategy is to accelerate the transformation of district heating systems into efficient, resilient, and sustainable heat supply systems. This includes lower greenhouse gas

emissions, reduced primary energy consumption, greater use of local resources, improved system efficiency, stronger stakeholder cooperation, and better preparedness for long-term decarbonisation. By linking local action with transnational cooperation, the strategy contributes to a more coordinated and effective district heating transition across Central Europe.

2. Introduction and Strategic Context

2.1 EU policy context

The strategy is embedded in the EU's long-term decarbonisation framework. The European Climate Law makes climate neutrality by 2050 legally binding and sets an intermediate target of reducing net greenhouse gas emissions by at least 55% by 2030 compared with 1990 levels. It also requires that EU policies and Member State action contribute to this long-term direction of travel.

The revised Energy Efficiency Directive, Directive (EU) 2023/1791, is particularly relevant for this strategy. It establishes the energy efficiency first principle as a legal principle of EU energy policy and raises the EU energy efficiency target by requiring an additional 11.7% reduction in energy consumption by 2030 compared with the 2020 reference scenario projections. For district heating and cooling, the Directive modifies the definition of efficient district heating and cooling in order to ensure a fully decarbonised district heating and cooling supply by 2050, with gradually increasing minimum requirements for renewable energy and waste heat integration.

From 1 January 2035, the Energy Efficiency Directive requires an efficient district heating and cooling system to use at least 50% renewable energy, 50% waste heat, or 50% renewable energy and waste heat; alternatively, systems may comply where the total share of renewable energy, waste heat, and high-efficiency cogenerated heat reaches at least 80%, provided that renewable energy and waste heat together account for at least 35%. From 2050, efficient district heating and cooling must be based only on renewable energy, waste heat, or a combination of both.

The Renewable Energy Directive, as revised by Directive (EU) 2023/2413, raises the EU's binding 2030 renewable energy target to at least 42.5%, with the ambition to reach 45%. This reinforces the need for heating and cooling systems, including district heating, to contribute more strongly to renewable energy deployment and fossil fuel replacement.

The Energy Performance of Buildings Directive is also relevant because the transformation of district heating systems must be coordinated with building renovation, demand reduction, and lower-temperature operation. The Commission highlights that improving building energy performance strengthens energy independence, reduces bills, reduces grid investment needs, and supports the EU energy efficiency goal of reducing energy consumption by 11.7% by 2030.

2.2 Strategic role of the transnational strategy

The transnational strategy addresses a gap between policy targets and implementation capacity. Individual platforms, tools and solutions already exist, including heat maps, waste heat maps,

geothermal and biomass assessments, and waste heat utilisation calculators. However, a comprehensive strategic approach is still needed to guide district heating operators through a tailored transformation process that connects evidence, planning, stakeholder engagement, investment preparation and long-term monitoring.

The strategy builds on previous Interreg Central Europe experience, especially the CE-HEAT project, which developed a toolbox for waste heat utilisation, and the ENTRAIN project, which developed quality standards for biomass plants. This is important because the strategy is not starting from an abstract policy position, but from tested transnational knowledge, tools and cooperation mechanisms that can be adapted to the district heating transformation challenge.

2.3 Transnational dimension

The transnational dimension is essential because Central European territories share similar structural challenges such as high heating and cooling demand, well-developed district heating models in urban areas, strong dependence on fossil fuels, and similar potential for integrating low-temperature renewable energy and waste heat sources such as geothermal heat, industrial waste heat, wastewater heat, biomass, biogas-related heat, and other local sources.

At the same time, Central European district heating systems share similar business traditions, ownership patterns, technological structures, and governance models. Many systems are organised at community level, often with public ownership of infrastructure and operation by public or private utilities. This makes the involvement of municipalities, utilities, energy agencies, heat users, owners of waste heat sources, and local communities a strategic condition for successful transformation.

The strategy therefore focuses on challenges and opportunities that are common across Central Europe, while recognising that local conditions differ. It provides a shared framework for coordinated action, mutual learning, transfer of tested methods, and replication of solutions across territories. Transnational cooperation is expected to generate better solutions by combining knowledge and experience from different partners, regions, and pilot cases, including the Austrian experience with renewable district heating as a relevant model for learning.

Through this approach, the strategy positions district heating systems as key infrastructure for community-level decarbonisation. They are not treated only as heat supply assets, but as local energy platforms capable of connecting buildings, industry, renewable heat, waste heat, storage, electricity systems, municipal planning, and consumer engagement. This is the strategic basis for transforming Central European district heating systems by 2035 and preparing them for full decarbonisation by 2050.

2.4 Literature and evidence base

The strategy is informed by four complementary bodies of literature and policy evidence. The first is the EU climate and energy acquis, especially the European Climate Law, the revised Energy Efficiency Directive, the Renewable Energy Directive and the Energy Performance of Buildings Directive. These sources establish the legal direction toward climate neutrality, the energy efficiency first principle, higher renewable energy shares and the gradual tightening of efficient district heating and cooling requirements.

The second evidence base is the academic and technical literature on fourth-generation district heating and smart energy systems. This literature emphasises low-temperature operation, integration of

renewable and recovered heat, thermal storage, sector coupling, digital control and coordinated planning between buildings, heat networks and electricity systems. It supports the strategic conclusion that district heating transformation is not only a fuel-switching task, but a system-redesign process.

The third evidence base consists of applied European guidance and project experience. JASPERS guidance on district heating decarbonisation, Heat Roadmap Europe, IEA district heating analysis and previous Interreg experience provide practical methods for baseline assessment, options analysis, investment preparation, waste heat utilisation, biomass quality management and replication. These sources are especially relevant for turning strategic objectives into bankable project pipelines.

The fourth evidence base is recent work on smart thermal networks and digitalised district heating. The Joint Research Centre and IEA DHC Annex TS4 underline that future heat networks will operate with more complex source portfolios, more active demand-side management, larger roles for heat pumps and storage, and stronger interaction with electricity systems. For Central Europe, this reinforces the need for staged transformation: accurate baselines, lower temperatures, digital monitoring, diversified local heat portfolios and structured stakeholder cooperation.

3. Specific objectives for district heating transformation by 2035

By 2035, district heating systems in Central Europe should move from fossil-dominated heat supply toward efficient, renewable, recovered-heat-based and locally integrated heat systems. The year 2035 is a strategic milestone because EU legislation significantly tightens the criteria for “efficient district heating and cooling” from 1 January 2035. Under Article 26 of the revised Energy Efficiency Directive, a system can qualify as efficient from 2035 if it uses at least 50% renewable energy, 50% waste heat, or 50% renewable energy and waste heat; alternatively, it may qualify where renewable energy, waste heat and high-efficiency cogeneration together reach at least 80%, provided that renewable energy and waste heat together account for at least 35% (Directive (EU) 2023/1791; Commission Recommendation (EU) 2024/2395).

The first strategic objective is therefore to ensure that district heating systems reach at least 50% renewable energy and/or waste heat in the heat supplied by 2035. This should be treated not as a maximum ambition, but as a minimum transformation threshold. The preferred local mix will differ by territory, but eligible sources should include geothermal energy, solar thermal energy, ambient heat, sustainable biomass, biogas, sewage and wastewater heat, industrial waste heat, data-centre heat, waste heat from service-sector facilities, and heat upgraded through large-scale heat pumps. The Renewable Energy Directive defines renewable energy broadly, including solar thermal, geothermal, ambient energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases (Directive (EU) 2018/2001 as amended by Directive (EU) 2023/2413).

The second objective is to reduce fossil-fuel dependence and avoid new fossil lock-in. By 2035, coal, oil and unabated natural gas should no longer provide the structural baseload of district heating systems. Fossil fuels, where still present, should be limited to transitional, peak, back-up or emergency roles, with clear phase-out pathways. This objective is consistent with the European Climate Law,

which makes EU climate neutrality by 2050 legally binding and sets the EU's net greenhouse gas reduction target of at least 55% by 2030 compared with 1990 levels (Regulation (EU) 2021/1119).

The third objective is to increase system efficiency across the full heat chain: generation, transmission, distribution, substations and end-use. District heating transformation should reduce network losses, improve plant efficiency, optimise hydraulic operation, modernise substations, introduce advanced metering, and use digital monitoring to support lower return temperatures and better demand forecasting. This follows the "energy efficiency first" principle and the EU's 2030 energy efficiency framework, which requires an 11.7% reduction in energy consumption by 2030 compared with the 2020 reference scenario projections (Directive (EU) 2023/1791).

The fourth objective is to lower network temperatures wherever technically and economically feasible. Lower supply and return temperatures are essential for reducing losses and enabling the integration of low-temperature renewable and recovered heat sources. This is especially important for geothermal heat, wastewater heat, ambient heat, industrial low-grade waste heat and large-scale heat pumps. The 4th Generation District Heating literature identifies low-temperature operation, smart thermal grids, renewable energy integration and system flexibility as core features of future sustainable heat networks (Lund et al., 2014).

The fifth objective is to integrate district heating into local energy, climate, spatial and building-renovation planning. District heating transformation cannot be planned only by heat operators; it depends on urban density, building renovation rates, future heat demand, land availability, industrial heat sources, customer connection potential and local infrastructure planning. EU policy increasingly connects efficient district heating with buildings policy: the revised Energy Performance of Buildings Directive recognises efficient district heating and cooling as one of the compliant energy supply options for zero-emission buildings, while also requiring Member States to plan the transformation of the building stock toward zero-emission buildings by 2050 (Directive (EU) 2024/1275).

The sixth objective is to mobilise investment and create bankable transformation pathways. By 2035, each district heating system should have a phased investment plan covering source diversification, network modernisation, storage, digitalisation, customer-side upgrades, permitting, financing and risk allocation. Investment planning should compare options using life-cycle cost, levelised cost of heat, emissions reduction, tariff impact, resilience and replicability. The JASPERS guide to district heating decarbonisation highlights that heat pumps, metering, customer information, renewable and waste heat integration, and avoidance of new fossil heat sources are central elements of EU-aligned district heating investment planning (JASPERS/EIB, 2024).

The seventh objective is to strengthen flexibility and sector coupling. By 2035, district heating systems should increasingly operate as flexible local energy platforms, not only as heat delivery networks. This requires thermal storage, power-to-heat, large heat pumps, smart controls, demand-side management and coordination with renewable electricity production. Modern district heating can integrate solar

thermal, geothermal heat, waste heat and large-scale heat pumps most effectively when operating temperatures are reduced and system flexibility is increased (IEA, 2023).

The eighth objective is to protect affordability, reliability and consumer confidence during the transition. Decarbonisation must not weaken the social function of district heating. Transformation pathways should therefore assess tariff impacts, connection costs, customer protection, service reliability, communication needs and options for supporting vulnerable consumers. Customer trust is especially important where new investments require temporary construction disruption, tariff restructuring, new connection rules or changes in heat-supply contracts.

The ninth objective is to establish transparent monitoring and governance. By 2035, district heating systems should regularly monitor and report at least: RES and waste heat share, fossil fuel share, greenhouse gas intensity, delivered heat, network losses, supply and return temperatures, outage frequency, investment progress, customer satisfaction and affordability indicators. Article 26 of the Energy Efficiency Directive also provides an alternative emissions-based pathway for efficient district heating, with greenhouse gas intensity thresholds falling to 100 g/kWh from 2035, 50 g/kWh from 2045 and 0 g/kWh from 2050 (Directive (EU) 2023/1791; Commission Recommendation (EU) 2024/2395).

3.1 Long-term outlook to 2050

The 2035 objective should be understood as an intermediate milestone on the pathway to fully decarbonised district heating by 2050. By 2050, district heating systems should operate without fossil fuels and should be supplied only by renewable energy, waste heat, or a combination of renewable energy and waste heat. This is directly aligned with the 2050 endpoint in the revised Energy Efficiency Directive definition of efficient district heating and cooling (Directive (EU) 2023/1791).

The long-term role of district heating will be to function as a local energy integration platform. Instead of relying on one or two central fossil heat sources, future systems should combine multiple low-carbon sources: deep and shallow geothermal energy, large-scale solar thermal fields, sustainable biomass residues where appropriate, biogas, ambient heat, mine-water heat, wastewater heat, industrial excess heat, data-centre heat, large heat pumps, renewable electricity, and short- and long-duration thermal storage. This direction is consistent with 4th Generation District Heating and smart energy-system research, which positions district heating as a key infrastructure for integrating renewable heat, recovered heat, storage and flexible electricity systems (Lund et al., 2014; Heat Roadmap Europe, 2019).

By 2050, the transformation should also be coordinated with a substantially more efficient building stock. As buildings are renovated and heat demand decreases, district heating systems will be able to operate at lower temperatures, reduce losses, and use lower-temperature renewable and recovered heat sources more effectively. The Energy Performance of Buildings Directive requires national building renovation plans to describe how existing private and public buildings will be transformed into zero-

emission buildings by 2050, while also linking building performance with efficient district heating and renewable energy supply (Directive (EU) 2024/1275).

The 2050 outlook therefore implies a staged transformation. Up to 2035, the priority is to cross the structural threshold from fossil-dominated systems to systems based substantially on renewable and recovered heat. Between 2035 and 2045, the priority is to scale up renewable and waste heat shares, complete major network modernisation, reduce temperatures, and expand storage and flexibility. By 2050, all remaining fossil heat should be phased out, and district heating should meet the zero-emission requirements of climate-neutral local energy systems (European Climate Law; Directive (EU) 2023/1791).

4. Current DHS situation in Central Europe

Heating and cooling remain central to Europe's energy transition. Space and water heating represented 77.1% of the final energy consumed by EU households in 2024, making heat demand the dominant component of residential energy use (European Commission, 2026; Eurostat, 2026a). At EU level, renewable energy in heating and cooling reached 26.7% in 2024, showing progress but also confirming that most heat demand is still supplied by fossil or non-renewable sources (Eurostat, 2026b).

District heating systems in Central Europe are diverse, but they share several common features. Many networks were developed during periods when energy systems were based on centralised heat production, high heat densities, large residential blocks, industrial heat demand, and relatively stable fossil fuel supply. In many territories, district heating still plays a strategic role in urban heat supply, particularly in larger cities, industrial towns, and dense residential areas.

The current baseline is therefore mixed. Some systems are large metropolitan networks with hundreds of kilometres of pipes and multiple heat sources. Others are medium-sized municipal networks based on gas-fired or coal-fired combined heat and power. Some smaller towns operate compact systems serving public buildings, housing estates, hospitals, or local industry. In other territories, district heating is not yet present or has declined, but municipal heat planning is reopening the question of whether new low-carbon heat networks should be developed.

This diversity means that Central Europe cannot rely on a single transformation model. However, the direction of change is common. District heating systems need to move from fossil-dominated heat supply toward efficient, renewable, recovered-heat-based and flexible local energy systems. This aligns with the revised Energy Efficiency Directive, which progressively tightens the definition of efficient district heating and cooling and points toward fully decarbonised district heating and cooling by 2050 (Directive (EU) 2023/1791; European Commission, 2023).

District heating is especially relevant in Central Europe because many cities and towns already have collective heat supply infrastructure, often linked to municipal utilities, combined heat and power plants, industrial areas, dense housing estates, and public buildings. This creates an important opportunity: existing networks can become platforms for integrating renewable heat, recovered waste heat, large-scale heat pumps, storage, and smart energy management. At the same time, it creates a

challenge, because many systems were designed for fossil-based, centralised, high-temperature operation and now require deep technical and organisational transformation.

4.1 Baseline situation in Central Europe

4.1.1 Fuel mix and decarbonisation gap

The main baseline challenge in Central Europe is the gap between the current fuel mix and the level of renewable and recovered heat required for future efficient district heating systems. Across much of the region, district heating systems remain dependent on coal, lignite, natural gas, oil, or fossil-based cogeneration. This creates exposure to carbon costs, fuel-price volatility, energy-security risks, air-quality concerns, and tightening EU climate and energy rules.

The decarbonisation gap differs by system type. Coal- and lignite-based systems face the need for structural replacement of baseload heat. Gas-based systems must avoid becoming long-term transition traps. CHP-based systems must adapt to a future in which cogeneration alone will no longer be sufficient to qualify as efficient unless combined with substantial renewable and waste heat shares. Smaller systems often face higher unit investment costs and limited internal technical capacity, while large urban systems face complex phasing, source diversification, permitting, and financing challenges.

At EU level, the Renewable Energy Directive sets a binding target of at least 42.5% renewable energy in the EU energy mix by 2030, with an ambition to reach 45% (European Commission, 2023). For Central European district heating, this means that renewable and waste heat integration must accelerate substantially before 2035. The baseline situation shows that many systems are still far from this trajectory and require planned, staged transformation.

4.1.2 Infrastructure condition and operational efficiency

A second baseline issue is infrastructure condition. Many Central European district heating systems operate with high supply and return temperatures, older pipe sections, limited digital monitoring, and substations that were not designed for low-temperature operation. These conditions increase heat losses and make it harder to integrate low-temperature renewable and recovered heat sources.

High-temperature networks are particularly challenging because many promising local heat sources are low- or medium-temperature. Industrial waste heat, wastewater heat, shallow geothermal energy, ambient heat, mine-water heat, river or lake heat, and data-centre heat often require heat pumps, storage, or lower network temperatures to become technically and economically feasible. The transition toward smart thermal networks therefore requires not only new heat sources, but also network modernisation, customer-side improvements, digitalisation, hydraulic optimisation, and demand-side management.

Recent EU research on smart thermal networks highlights the importance of lower flow temperatures, intelligent control, large-scale heat pumps, waste heat recovery, thermal storage and stronger system

integration as key features of modern district heating (European Commission, Joint Research Centre, 2025). The Central European baseline shows that many systems still need to move from conventional heat distribution toward this smarter and more flexible operating model.

4.1.3 Renewable and waste heat potential

Central Europe has significant potential for renewable and recovered heat, but this potential is unevenly distributed and often insufficiently mapped at project level. Relevant sources include geothermal energy, sustainable biomass, solar thermal energy, ambient heat, wastewater and sewage heat, industrial waste heat, waste heat from service-sector facilities, large heat pumps, biogas-related heat, and thermal storage.

Industrial and urban waste heat represent an important opportunity, especially in territories with manufacturing, food processing, metallurgy, cement, chemicals, wastewater treatment plants, data centres, hospitals, supermarkets, cold storage, or other heat-intensive activities. However, waste heat projects depend on more than theoretical energy potential. They require suitable temperature levels, sufficient operating hours, reasonable distance to the network, reliable heat availability, contractual certainty, compatible investment cycles, and a clear business model between the heat source owner and the district heating operator.

Geothermal energy can provide stable renewable baseload heat where geological conditions are favourable, but it often requires high upfront investment, geological risk management, permitting, drilling capacity, and long project preparation. Biomass can support the transition in some areas, especially where local sustainable residues are available, but it must be used carefully because of sustainability, air-quality, land-use, biodiversity, and competing-use constraints. Solar thermal energy can contribute to seasonal heat supply where land is available, particularly when combined with storage. Large-scale heat pumps can connect low-temperature sources to existing networks, but their feasibility depends strongly on electricity prices, grid capacity, operating temperatures, and system flexibility.

The strategic baseline conclusion is therefore that Central Europe does not lack potential heat sources. The main challenge is turning dispersed local potential into bankable projects that can be connected to real heat demand under acceptable technical, financial, environmental, and social conditions.

4.1.4 Governance, planning and market conditions

District heating transformation in Central Europe is strongly influenced by governance and planning conditions. Heat networks are local infrastructure, but they are affected by EU legislation, national regulation, tariff systems, municipal planning, building policy, industrial development, environmental permitting, and customer decisions. This creates a complex implementation environment.

Many municipalities are now expected to play a stronger role in heat planning. The transformation of district heating must be connected with spatial planning, local climate plans, building renovation

strategies, industrial development, energy poverty measures, and infrastructure investment. This is particularly important because future heat demand will change as buildings are renovated, demographics shift, industrial activity changes, and climate conditions evolve.

Market conditions also shape the baseline. District heating operators often face high upfront capital needs, regulated tariffs, uncertain fuel and electricity prices, limited access to affordable finance, and customer sensitivity to heat prices. In some systems, operators lack sufficient internal capacity for complex project development, including feasibility studies, lifecycle cost comparison, procurement, risk allocation, and financing structuring. This creates a need for standardised tools, technical assistance, public-private cooperation, and stronger knowledge exchange across Central Europe.

4.1.5 Social and consumer baseline

District heating transformation will only succeed if it maintains affordability, reliability, and public trust. In many Central European countries, district heating is connected to social expectations of secure and reasonably priced heat supply. Customers may support decarbonisation in principle but oppose tariff increases, construction disruption, mandatory connection rules, or poorly explained technology choices.

The social baseline therefore includes more than customer numbers. It includes household affordability, trust in operators and municipalities, quality of communication, transparency of tariffs, customer-side control, metering, complaint mechanisms, and the involvement of housing associations, building owners, public institutions, and large heat users. Where district heating systems seek expansion or new connections, acceptance will depend on whether customers perceive district heating as reliable, competitive, transparent, and future-proof.

4.2 Strategic baseline conclusions

The baseline situation in Central Europe can be summarised in five strategic conclusions.

First, district heating is already a major local energy infrastructure in many Central European territories and can become a key decarbonisation platform.

Second, many systems remain structurally dependent on fossil fuels, especially coal, lignite, and natural gas, creating a significant gap to 2035 and 2050 requirements.

Third, infrastructure modernisation is as important as fuel switching. Without lower losses, lower operating temperatures, better substations, digital monitoring, and storage, many renewable and waste heat sources will remain difficult to integrate.

Fourth, renewable and waste heat potential exists across the region, but it must be converted into practical, bankable, locally accepted projects.

Fifth, the transformation challenge is territorial and institutional as much as technical. Successful district heating transition requires municipalities, operators, regulators, industrial heat suppliers, building owners, customers, financial institutions, and technology providers to work within a shared long-term pathway.

5. Common Challenges and Opportunities

The transformation of district heating systems in Central Europe is shaped by a set of common structural challenges and a parallel set of common opportunities. The challenges are substantial because many systems were developed for a fossil-fuel-based, centralised and high-temperature energy system. However, the same systems also represent strategic assets for the energy transition: they already aggregate heat demand, connect public and private consumers, provide a platform for integrating local resources, and can reduce the cost and complexity of decarbonising dense urban and industrial areas. This strategy therefore treats district heating not only as a sector requiring transformation, but also as enabling infrastructure for climate-neutral, resilient and locally anchored energy systems.

5.1 Dependence on fossil fuels and exposure to external risks

A central challenge across the region is the continuing dependence of many district heating systems on coal, lignite, natural gas, oil and fossil-based cogeneration. This dependence creates several interrelated risks. It exposes operators and consumers to volatile fuel prices and, in some countries, to import-dependency and energy-security concerns. It also increases exposure to the EU Emissions Trading System and to national decarbonisation obligations. Systems relying on coal or lignite face the most urgent structural replacement challenge, while gas-based systems face the risk of becoming long-term transition assets unless they are embedded in a credible phase-out pathway. Fossil cogeneration can continue to provide transitional flexibility in some systems, but it is no longer a sufficient long-term decarbonisation strategy on its own, particularly after the tightening of the efficient district heating and cooling definition in the revised Energy Efficiency Directive.

The common strategic implication is that district heating operators should avoid one-for-one replacement of fossil units with a single new fuel. A resilient transformation requires a portfolio approach in which renewable energy, recovered heat, thermal storage, demand reduction, network optimisation and flexible operation are combined. This reduces technology risk and enables each territory to use its own resource base rather than importing a standardised solution.

5.2 Ageing infrastructure, high temperatures and operational inefficiencies

Many Central European systems operate with infrastructure that was designed for high-temperature supply, large central heat sources and relatively predictable demand. Ageing pipe sections, insufficient insulation, high return temperatures, hydraulic imbalances, outdated substations and limited metering increase network losses and reduce the ability to integrate low-temperature sources. These operational characteristics are particularly problematic for geothermal heat, wastewater heat, river or lake heat, data-centre heat, industrial low-grade waste heat and ambient heat upgraded by large heat pumps.

Infrastructure modernisation is therefore not a secondary issue; it is a precondition for source diversification. Lower network temperatures reduce distribution losses and improve the performance of renewable and recovered heat integration. Digital monitoring, advanced metering, automated substations, pressure and flow optimisation, and better demand forecasting make it possible to operate more complex systems with multiple heat sources. The shift from conventional networks to smart thermal networks is also consistent with the principles of fourth-generation district heating, in which lower temperatures, renewable energy, waste heat, system flexibility and integrated planning are

treated as mutually reinforcing elements (Lund et al., 2014; European Commission, Joint Research Centre, 2024).

5.3 Market, regulatory and planning barriers

The transformation of district heating is influenced by EU legislation, national energy regulation, municipal responsibilities, tariff-setting rules, permitting procedures, competition between heating options, and the availability of long-term heat-planning instruments. In many systems, operators are expected to decarbonise while maintaining affordability and reliability, but investment incentives and tariff methodologies may not always reward lifecycle efficiency, avoided carbon costs or recovered local heat. In addition, permitting procedures for geothermal wells, large heat pumps, solar thermal fields, biomass facilities, pipelines, storage and industrial waste heat connections can be complex and time-consuming.

A further common barrier is the insufficient integration of district heating into spatial planning, building renovation strategies and local energy planning. Heat demand will change as buildings are renovated, industrial activity evolves and electricity systems become more renewable. If heat-source planning, network planning and building renovation are not coordinated, there is a risk of over-dimensioned assets, stranded investments or missed opportunities for low-temperature operation. Municipalities and local authorities therefore need a stronger planning role, while operators need stable regulatory conditions that allow phased investment and transparent cost recovery.

5.4 Financing constraints and bankability gap

The capital requirements for district heating transformation are high. Investment is needed not only in new renewable and recovered heat sources, but also in feasibility studies, permitting, geological risk assessment, network rehabilitation, substations, metering, digital systems, storage, customer connections and project development capacity. Smaller operators may lack internal resources to prepare bankable investment packages, while larger systems often face complex sequencing and risk allocation across multiple sources and stakeholders.

The financing challenge is therefore partly a cost issue and partly a project-preparation issue. District heating projects must demonstrate technical feasibility, lifecycle cost-effectiveness, emissions reduction, tariff impacts, investment phasing and risk management. This requires a stronger pipeline approach: identification of local resources, screening of options, pre-feasibility analysis, stakeholder commitments, business model definition, funding and financing packaging, procurement preparation and implementation monitoring. The JASPERS Guide to Decarbonisation of District Heating Systems underlines the importance of objective setting, options analysis, definition of measures and optimisation of investment packages for EU-aligned district heating decarbonisation (JASPERS/EIB, 2024).

5.5 Public acceptance, affordability and consumer engagement

District heating transformation will succeed only if it retains the confidence of heat users. In many Central European territories, district heating has a strong social function because it serves apartments, public buildings, schools, hospitals and municipal facilities. Consumers are likely to support decarbonisation in principle, but they may resist tariff increases, connection obligations, temporary construction disruption or technology choices that are not clearly explained. Affordability and transparency are therefore strategic conditions, not communication add-ons.

Consumer acceptance depends on the ability of operators and municipalities to explain why transformation is needed, what benefits it will bring, how investment costs will be managed, and how vulnerable consumers will be protected. Customer-side measures such as metering, individual consumption information, building-level controls, substation optimisation and renovation coordination can improve both efficiency and perceived fairness. The strategy should therefore promote structured engagement with housing associations, building managers, public institutions, large heat users and citizen groups, using existing communication channels as well as local media, events and consultations.

5.6 Availability of local renewable and waste heat sources

Central Europe has significant renewable and recovered heat potential. Industrial waste heat may be available from manufacturing, metal processing, food and beverage production, chemicals, cement, waste-to-energy plants and other industrial processes. Urban waste heat can come from wastewater treatment plants, sewage systems, data centres, refrigeration, supermarkets, service-sector facilities and transport infrastructure. Renewable heat sources include geothermal energy, solar thermal energy, ambient heat, river and lake heat, sustainable biomass, biogas and heat upgraded through large-scale heat pumps. The availability, temperature level, continuity and ownership of these sources differ by territory, which means that local mapping is essential.

The opportunity is not simply to identify individual heat sources, but to create an integrated local heat portfolio. A system may combine a stable baseload source such as geothermal energy or sustainable biomass with industrial waste heat, seasonal solar thermal energy, large heat pumps, thermal storage and peak/back-up units. In other cases, a new low-temperature or cold district heating network may be more suitable than the conversion of an existing high-temperature system. The common opportunity is that local resources can reduce fossil imports, keep energy value in the territory and strengthen resilience if they are developed through technically sound and financially viable projects.

5.7 Digitalisation, flexibility and sector coupling

The integration of multiple heat sources increases operational complexity. District heating systems that previously relied on a limited number of dispatchable fossil units will increasingly need to coordinate variable renewable heat, intermittent waste heat, electricity-market signals, storage, demand response and building-side flexibility. Digitalisation enables this transformation by improving forecasting, hydraulic control, source dispatch, fault detection, return-temperature management and customer information.

Sector coupling is a particularly important opportunity. Large heat pumps and electric boilers can convert renewable electricity into useful heat, especially when electricity prices are low or renewable generation is abundant. Thermal storage can shift heat production over hours, days or seasons, increasing the value of both renewable electricity and renewable heat. In this way, district heating can become a flexibility resource for the wider energy system while also reducing fossil heat production.

5.8 Strategic synthesis

The common challenge for Central Europe is therefore not only to replace fossil fuels, but to redesign district heating systems as efficient, flexible, consumer-oriented and locally integrated energy platforms. The common opportunity is that existing networks, municipal engagement, industrial structures and regional knowledge can be used to accelerate this transition. A structured transformation process should combine transnational cooperation, pilot evidence, practical

knowledge tools, capacity building, local action planning and stakeholder engagement in a way that can be replicated across different territorial contexts.

6. Vision for 2035 and Outlook to 2050

6.1 Shared transnational vision

The shared transnational vision is that, by 2035, Central European district heating systems will be transformed from predominantly fossil-fuel-based heat supply systems into efficient, resilient and sustainable local energy platforms. They should supply reliable and affordable heat while using at least 50% renewable energy and/or waste heat in accordance with the 2035 milestone in the revised Energy Efficiency Directive. They should also be technically prepared for a complete transition to renewable energy and waste heat by 2050.

This vision combines compliance with EU requirements and a broader territorial development objective. Transformed district heating systems should reduce greenhouse gas emissions, improve energy security, use local resources, support building renovation, enable industrial symbiosis, strengthen municipal climate action and protect consumers from avoidable exposure to fossil-fuel volatility. They should be designed around local conditions but connected through a common transnational learning framework.

6.2 What district heating systems should look like by 2035

By 2035, transformed district heating systems in Central Europe should have several defining characteristics. First, they should meet or exceed the efficient district heating and cooling criteria applicable from 2035, with at least 50% renewable energy, 50% waste heat, or a combined 50% share of renewable energy and waste heat in the heat supplied. Where high-efficiency cogeneration remains part of the system, it should be combined with a substantial and increasing share of renewable and recovered heat, in line with Article 26 of Directive (EU) 2023/1791 and Commission Recommendation (EU) 2024/2395.

Second, the heat supply should be diversified. No district heating system should be structurally dependent on a single fossil source. Local portfolios should combine the most suitable sources available in each territory, such as geothermal energy, sustainable biomass, solar thermal energy, wastewater heat, industrial waste heat, data-centre heat, large heat pumps, renewable electricity and thermal storage. Fossil fuels, where still present, should be restricted to transitional, peak, back-up or emergency functions with defined phase-out milestones.

Third, networks should operate more efficiently and, where feasible, at lower temperatures. Lower supply and return temperatures will reduce losses and increase the feasibility of low-temperature renewable and recovered heat. Modern substations, metering, digital monitoring, hydraulic balancing, improved insulation and demand-side coordination should become standard features of transformed systems.

Fourth, district heating should be integrated into local energy and climate governance. Operators, municipalities, energy agencies, building owners, industrial heat suppliers, regulators, financial institutions and consumers should work within a shared long-term pathway. District heating should be

visible in local climate plans, spatial plans, renovation strategies, industrial development strategies and energy-poverty policies.

Fifth, transformed systems should be socially credible. The transition must not weaken the public-service role of district heating. Affordability, reliability, transparent tariff communication, customer protection and consumer participation should be treated as core performance requirements. Decarbonisation should therefore be communicated as a pathway to cleaner, more secure and locally beneficial heat supply, not only as a technical compliance exercise.

6.3 Guiding principles for the strategy

The guiding principles define the quality criteria for district heating transformation. They are intended to support consistent decision-making across territories while leaving room for local adaptation. In practice, they should be used when comparing heat-source portfolios, assessing investment plans, designing governance arrangements and monitoring progress toward 2035 and 2050.

Resilience, security of supply and affordability must remain the first guiding principle. District heating systems provide an essential service and therefore have to remain reliable during and after the transition. Transformation pathways should reduce exposure to imported fossil fuels, carbon-price volatility and single-source dependency, while maintaining socially acceptable heat prices and protecting vulnerable consumers. Resilience should be assessed not only through fuel diversification, but also through back-up capacity, storage, operational flexibility, supplier reliability and clear emergency arrangements.

The energy efficiency first principle should guide all investment decisions. Before new generation capacity is selected, local pathways should assess demand reduction, network-loss reduction, lower return temperatures, hydraulic optimisation, substation modernisation, metering, digital control and building-side improvements. This principle reduces the scale and cost of supply-side investments, improves affordability and increases the feasibility of low-temperature renewable and recovered heat sources.

Sustainability and climate neutrality should be treated as long-term compatibility requirements. Measures selected for the 2035 milestone should also be consistent with the 2050 endpoint, when efficient district heating and cooling must be based only on renewable energy, waste heat or a combination of both. This requires avoidance of long-lived fossil lock-in, careful assessment of biomass sustainability, respect for environmental safeguards, protection of air quality and consideration of lifecycle impacts.

Local resource use should be prioritised where technically feasible, environmentally sound and economically proportionate. Renewable heat and recovered heat strengthen territorial resilience because they reduce imported fuel dependence and keep energy value within the region. Local portfolios may combine geothermal energy, solar thermal energy, sustainable biomass residues, industrial waste heat, urban waste heat, wastewater heat, ambient heat upgraded by large heat pumps and thermal storage. The appropriate mix should be determined through evidence-based heat planning rather than through a uniform technology hierarchy.

Consumer orientation and social acceptance are essential conditions for implementation. Heat users should receive clear information on the reasons for transformation, expected benefits, investment costs, tariff implications, construction impacts and reliability safeguards. Customer-side measures such as metering, building-level controls, lower return-temperature incentives and renovation

coordination should be presented as part of the transformation pathway, because they improve both technical performance and perceived fairness.

Replicability and transnational learning should be built into the strategy from the beginning. Measures should be documented in comparable formats, including baseline conditions, selected options, barriers, costs, enabling factors and lessons learned. This makes it possible for municipalities, operators and sector organisations in other Central European territories to adapt the approach to their own conditions and avoid repeating avoidable mistakes.

The principles are mutually reinforcing. Efficiency improves affordability; local resources strengthen resilience; stakeholder engagement improves social acceptance; and transparent monitoring strengthens replicability. A balanced transformation pathway should therefore assess options against all principles together, rather than maximising a single criterion at the expense of long-term system quality.

6.4 Outlook to 2050

The 2035 milestone is not the end point of the transformation. By 2050, district heating and cooling systems that qualify as efficient under the revised Energy Efficiency Directive must be based only on renewable energy, waste heat or a combination of both. The strategic direction is therefore clear: all remaining fossil heat must be phased out, and high-efficiency cogeneration based on fossil fuels cannot remain a structural decarbonisation solution beyond the transition period.

The 2050 district heating system should function as a climate-neutral energy integration platform. It should connect highly efficient buildings with renewable heat, recovered heat, thermal storage and renewable electricity. It should also support sector coupling by using power-to-heat technologies when they provide system value and by integrating local sources of unavoidable excess heat. As building renovation reduces heat demand, networks should be progressively adapted to lower temperatures, improved control and more flexible operation.

The pathway from 2035 to 2050 will require continued investment, but the most important strategic decisions must be taken before 2035. New assets installed in the 2020s and early 2030s will shape heat supply for decades. For this reason, the strategy emphasises no-regret measures, fossil lock-in avoidance, careful lifecycle assessment and staged investment planning. The objective is to ensure that investments made to reach the 2035 threshold also remain consistent with the 2050 endpoint.

7. Strategic Pathways for DH Transformation

The transformation of district heating systems requires a structured pathway rather than a single intervention. The following pathways form the core of this transnational strategy. They should be adapted to local circumstances, but they are relevant across the Central European context and can guide the preparation of local action plans, investment plans and policy recommendations.

7.1 Establishing a robust baseline and integrated heat-planning process

The first pathway is the creation of a reliable evidence base. Each district heating system should establish a baseline covering heat demand, customer structure, generation assets, fuel mix, carbon intensity, network losses, supply and return temperatures, condition of substations, future demand scenarios, tariff structure, regulatory constraints and available local heat sources. This baseline should

be spatially explicit where possible, linking demand areas, network routes, industrial zones, public buildings, renewable heat potential and possible storage locations.

The baseline should not be a static diagnostic document. It should become part of an integrated heat-planning process coordinated with municipalities and relevant stakeholders. Heat planning should assess how building renovation, demographic trends, industrial development, customer connections, energy prices, permitting and climate targets affect future district heating demand and investment needs. This is particularly important because oversized systems can become inefficient if demand falls, while under-planned systems may miss opportunities to connect local resources or new customers.

7.2 Fuel switching towards renewable energy and waste heat

The second pathway is the systematic replacement of fossil heat with renewable and recovered heat. The preferred source mix should be determined locally, but the assessment should consider both technical parameters and broader system value. Relevant criteria include temperature level, availability profile, seasonal variability, distance to the network, ownership, permitting requirements, connection costs, environmental impacts, contribution to baseload or peak supply, compatibility with network temperatures and long-term security of supply.

Waste heat should be treated as a strategic local resource where it is technically recoverable, economically viable and compatible with the long-term decarbonisation pathway. Industrial waste heat can provide substantial volumes in some territories, but projects require contractual arrangements that define heat quality, delivery profile, investment responsibilities, back-up solutions, data sharing, price-setting and risk allocation if industrial operations change. Urban waste heat sources such as wastewater treatment plants, data centres and refrigeration facilities may provide lower-temperature heat that can be upgraded through heat pumps and integrated into lower-temperature networks.

Renewable heat integration should be diversified. Geothermal energy can provide stable baseload heat where geological conditions are favourable, but it requires careful exploration, permitting and risk management. Sustainable biomass can play an important role, especially in smaller systems and regions with local residues, but it should be used efficiently and in accordance with sustainability and air-quality safeguards. Solar thermal energy can provide seasonal heat, particularly when combined with storage. Large heat pumps can use ambient heat, water sources, wastewater, industrial low-grade heat or renewable electricity to provide flexible low-carbon supply. No single option will fit all territories; the strategic requirement is that each local portfolio should be credible, diversified and aligned with the 2035 and 2050 milestones.

7.3 Energy efficiency improvements in generation and networks

The third pathway is efficiency improvement across the full heat chain. On the generation side, this includes improved plant efficiency, better dispatch, reduction of auxiliary energy use, flue-gas condensation where suitable, integration of storage and optimal operation of multi-source systems. On the distribution side, it includes replacement or rehabilitation of old pipe sections, improved insulation, leakage reduction, hydraulic balancing and pressure optimisation. At the customer interface, it includes substation modernisation, building-level controls, metering and reduction of excessive return temperatures.

Efficiency measures are often among the most cost-effective decarbonisation actions because they reduce the volume of heat that must be produced by new renewable or recovered sources. They also improve affordability by reducing losses and fuel use. The energy efficiency first principle should

therefore be applied in all investment planning: before new generation capacity is selected, operators should assess whether demand-side measures, network improvements and operational optimisation can reduce the required capacity and improve lifecycle economics.

7.4 System modernisation and smart operation

The fourth pathway is the modernisation of district heating into a smart thermal network. This involves digital monitoring of heat flows, temperatures, pressures, substations and customer consumption; automated control of generation units; predictive maintenance; better demand forecasting; and optimisation of source dispatch. Digitalisation should be practical and proportional, especially for smaller operators, but it should create the information needed to operate more complex, multi-source systems.

Smart operation also enables progressive temperature reduction. Operators should identify the parts of the network where lower supply temperatures can be implemented first, assess customer-side constraints and define stepwise return-temperature reduction measures. Low-temperature zones, network sections or new developments can be used as demonstration areas before broader system conversion. This approach reduces technical risk and helps build confidence among consumers and building owners.

7.5 Thermal storage and flexibility

The fifth pathway is the integration of thermal storage and flexibility. Storage allows operators to separate heat production from heat consumption over time. Short-term storage can improve daily dispatch, reduce peak fuel use and increase the utilisation of waste heat or heat pumps. Larger or seasonal storage can support solar thermal integration, geothermal optimisation and broader system flexibility. Storage also strengthens resilience by providing operational buffers during source outages or market-price spikes.

Flexibility becomes increasingly important as electricity systems incorporate more variable renewable generation. District heating can provide flexibility through large heat pumps, electric boilers, thermal storage and demand-side management. These assets can use renewable electricity when it is abundant and reduce electricity demand when the power system is constrained. The value of this flexibility should be reflected in business models, tariff design and system planning.

7.6 Integration with local energy systems and building renovation

The sixth pathway is local energy-system integration. District heating transformation should be coordinated with building renovation, urban development, industrial policy, electricity-grid planning, renewable electricity deployment and municipal climate strategies. As buildings become more efficient, heat demand will decline and lower operating temperatures will become more feasible. At the same time, electrification of heating through heat pumps will create new electricity demand, making coordination between heat and power systems more important.

Municipalities should therefore use district heating as part of a broader heat-planning portfolio. In dense urban areas, district heating may be the most efficient decarbonisation option. In lower-density areas, individual or collective heat pumps, local low-temperature networks or hybrid solutions may be more appropriate. The strategic objective is not expansion for its own sake, but the selection of the most efficient, affordable and climate-compatible heat solution for each area.

7.7 Business model innovation

The seventh pathway is business model innovation. Traditional district heating business models are often based on heat production and sales from assets owned or operated by the utility. Future systems will increasingly depend on heat purchase agreements with industrial or urban heat suppliers, joint investments with municipalities, third-party ownership of renewable assets, energy service contracts, public-private partnerships, flexibility services and customer-side efficiency services. These models require transparent contracts, stable revenue streams and fair sharing of risks and benefits.

Waste heat projects are a clear example. The heat supplier, district heating operator and consumers all need confidence that the arrangement is technically reliable and economically fair. Contracts should address heat availability, temperature, back-up, duration, pricing, metering, liability, data sharing and termination conditions. For renewable heat projects, similar attention is needed to resource risk, permitting risk, construction risk, operational performance and tariff impacts.

7.8 Governance and stakeholder cooperation

The eighth pathway is cooperation. District heating transformation cannot be delivered by operators alone. It requires municipalities, regulators, energy agencies, heat-source owners, housing associations, building managers, customers, technology providers, financial institutions and civil society to act within a shared process. Governance arrangements should define responsibilities, decision points, information flows and conflict-resolution mechanisms. They should also connect local decisions with national policy and transnational learning.

A relevant cooperation model for district heating transformation combines expert coordination, structured capacity building, pilot activities, local action plans and replication activities. Such cooperation should be maintained beyond individual project cycles wherever possible, because district heating transformation is a long-term process that requires repeated investment cycles and continuous adaptation.

7.9 Customer communication and demand-side participation

The ninth pathway is the active involvement of heat users. Consumers influence heat demand, return temperatures, connection decisions, acceptance of construction works and support for tariff changes. Customer communication should therefore begin early, before investment decisions are perceived as final. Operators and municipalities should explain the baseline challenge, compare options transparently, show expected benefits and costs, and provide clear information about implementation timelines.

Demand-side participation can include building-level optimisation, metering and feedback, renovation coordination, heat-saving campaigns, voluntary demand response for large users, and agreements with public institutions to act as early adopters. These measures reduce technical risks and reinforce the idea that district heating transformation is a community-level climate action, not only a utility investment.

8. Joint Objectives and Transnational Measures

This transnational strategy defines joint objectives and measures that can support district heating transformation across Central Europe while leaving room for local adaptation. The objectives below

should be understood as a common framework for local action plans, pilot implementation, knowledge transfer and policy recommendations.

8.1 Joint Objective 1: Reach at least 50% renewable energy and/or waste heat by 2035

The primary joint objective is that participating and replicating district heating systems should be on a credible trajectory to reach at least 50% renewable energy and/or waste heat by 2035. This threshold should be embedded in local heat strategies, local action plans, operator investment plans and municipal climate governance. It should be measured on the basis of delivered heat, with transparent accounting rules that are consistent with EU legislation and with national implementation frameworks.

The recommended approach is to prepare a local heat-source inventory for each system. The inventory should cover renewable heat and recovered heat potential, including geothermal energy, solar thermal energy, sustainable biomass, biogas-related heat, ambient and hydrothermal heat, wastewater and sewage heat, industrial waste heat, service-sector waste heat, data-centre heat, large-scale heat pumps and thermal storage. The inventory should not only describe theoretical potential; it should also assess temperature level, seasonal availability, operating hours, distance to the network, ownership, environmental constraints, permitting requirements, connection costs and reliability.

Source options should then be compared through a common screening approach. The most relevant criteria are lifecycle cost, levelised cost of heat, emissions reduction, security of supply, temperature compatibility, permitting feasibility, grid impacts, land requirements, tariff effects and contribution to the 2050 decarbonisation pathway. Portfolios that replace fossil baseload and avoid long-lived fossil lock-in should receive strategic priority, while remaining fossil assets should be limited to transitional, peak, back-up or emergency roles with defined phase-out milestones.

The objective should be implemented as a portfolio strategy. Few territories will be able to rely on a single renewable or recovered heat source. More robust pathways will combine stable baseload sources, flexible heat-pump operation, short- or long-duration storage, network temperature reduction and demand-side optimisation. The transnational value of this objective lies in using comparable methods while allowing each territory to select the source mix that fits its resource base, heat density, infrastructure condition and affordability constraints.

8.2 Joint Objective 2: Improve energy efficiency and reduce network losses

The second joint objective is to reduce energy losses and improve operational efficiency across generation, distribution, substations and end-use interfaces. Efficiency measures should be treated as no-regret actions because every unit of heat saved reduces the scale, cost and risk of new low-carbon generation. This objective should therefore be implemented before, and in parallel with, major heat-source investments.

Each system should assess network losses, temperature profiles, hydraulic performance, pipe condition, substation condition, metering coverage and return-temperature behaviour. This assessment should be translated into a phased modernisation plan covering pipe rehabilitation, improved insulation, leakage reduction, pressure optimisation, substation upgrades, advanced metering, digital monitoring and targeted customer-side interventions. Where data availability is weak, the first step should be to improve measurement and operational visibility.

Return-temperature reduction deserves particular attention because it directly improves heat-source integration. Lower return temperatures improve the efficiency of heat pumps, enable more effective use of geothermal and waste heat, reduce losses and increase the value of storage. Return-

temperature programmes should combine technical measures, building-side dialogue, contractual incentives, operator support and monitoring.

8.3 Joint Objective 3: Develop bankable transformation investment plans

The third joint objective is to translate strategic ambition into investment-ready project pipelines. Local action plans should identify priority investments, responsible actors, estimated costs, financing sources, implementation sequence, permitting requirements, procurement needs, risk allocation and monitoring arrangements. Investment planning should be transparent enough to support municipal decisions, utility board approval, funding applications, public communication and financial appraisal.

A common project-development pathway should be applied. It should move from baseline validation and heat-source mapping to pre-feasibility screening, options analysis, feasibility studies, stakeholder commitments, business model definition, financing structure, procurement, implementation and operational monitoring. This staged approach helps avoid premature technology decisions and allows projects to mature progressively from concept to bankability.

Investment options should be compared through multi-criteria assessment. In addition to capital cost, the assessment should consider emissions reduction, levelised cost of heat, tariff impact, system resilience, environmental safeguards, supply-chain risks, permitting complexity, compatibility with lower-temperature operation and replicability. Public grants, municipal resources, utility finance, private investment, concessional loans and EU funding instruments should be combined where this improves affordability and risk sharing.

8.4 Joint Objective 4: Strengthen local governance and stakeholder engagement

The fourth joint objective is to place district heating transformation within local climate, spatial, building-renovation and economic-development governance. Heat networks are local infrastructure, but they are affected by national regulation, EU targets, municipal planning, building ownership, industrial development and customer decisions. Strong local governance is therefore required to align decisions and maintain legitimacy.

Each local pathway should be supported by a stakeholder group or coordination platform involving municipalities, district heating operators, energy agencies, building representatives, industrial and urban heat-source owners, public institutions, regulators, financing actors and consumer representatives where appropriate. The platform should not function as a symbolic consultation body only; it should support data exchange, option screening, barrier identification, communication planning and monitoring.

Stakeholder engagement should be structured and continuous. The process should start with mapping stakeholders by their influence, interest, data contribution and potential concerns. Engagement should then move through baseline explanation, option comparison, preferred-pathway discussion, implementation communication and progress reporting. Local media, public events, municipal channels, operator websites, customer newsletters and existing customer-service channels should be used in a coordinated way.

8.5 Joint Objective 5: Build capacity for operating more complex district heating systems

The fifth joint objective is to build the institutional and technical capacity needed for future district heating systems. Future systems will combine multiple renewable and recovered heat sources, lower operating temperatures, heat pumps, storage, digital controls, new contractual arrangements,

customer-side efficiency measures and more demanding monitoring requirements. Operators, municipalities and expert organisations therefore need stronger competences across technical, financial, legal and communication fields.

Capacity building should address heat-source mapping, waste heat contracting, geothermal risk, sustainable biomass management, heat-pump integration, solar thermal and storage, digital operation, network-temperature reduction, lifecycle costing, tariff-impact assessment, EU funding preparation, procurement, stakeholder engagement and regulatory compliance. Training should be practical and should use real cases, pilot learning, peer review and study visits rather than abstract instruction only.

The transnational knowledge base should make capacity building reusable. Methodologies, templates, case studies, business model examples, indicator sets and lessons learned should be maintained in a format that can be used by both advanced systems and territories that are still at an early stage of transformation planning.

8.6 Joint Objective 6: Improve policy, regulatory and strategic conditions

The sixth joint objective is to identify and address the policy and regulatory barriers that delay district heating transformation. Barriers may relate to permitting, tariff regulation, heat planning, waste heat access, land use, public procurement, state-aid interpretation, grid connection, environmental procedures, building renovation coordination or the recognition of district heating in local energy strategies.

Policy recommendations should be prepared at local, regional and national levels. At local level, recommendations should strengthen integrated heat planning, municipal coordination, public communication and alignment with building renovation. At regional and national levels, recommendations should focus on enabling regulation, predictable tariff frameworks, faster permitting, support for early-stage project preparation, transparent waste heat rules and funding mechanisms that reward lifecycle emissions reduction and efficiency.

Policy improvement should be evidence-based. Recommendations should draw on repeated barriers observed across pilot cases, investment preparation and stakeholder dialogue. This will make the recommendations more credible for public authorities and more useful for other Central European territories facing similar implementation constraints.

8.7 Joint Objective 7: Support replication across Central Europe

The seventh joint objective is to ensure that the strategy produces transferable value beyond the participating systems. Replication requires more than dissemination. It requires comparable documentation, practical guidance, credible examples, peer-to-peer communication and adaptation to different system types, ownership structures and regulatory contexts.

Pilot cases and local action plans should therefore be documented in a common format. Each case should describe the baseline, heat-source potential, selected pathway, rejected alternatives, barriers, enabling conditions, investment needs, stakeholder process, monitoring indicators and lessons learned. This will allow other operators and municipalities to recognise whether a given solution is relevant for their own typology and what adaptations would be required.

National district heating associations, municipal networks and professional organisations should be used as replication channels. Technical webinars, workshops, study visits and policy dialogues should

be designed for specific audiences: operators need technical and business guidance, municipalities need governance and communication tools, policy makers need evidence on regulatory barriers, and consumers need clear information on benefits, costs and reliability.

8.8 Joint Objective 8: Monitor progress and maintain accountability

The eighth joint objective is to establish a transparent monitoring framework that connects strategy with implementation. Progress should not be measured only by the existence of strategies or plans. It should be measured through concrete indicators such as renewable and waste heat shares, fossil fuel reduction, emissions intensity, network losses, temperature reduction, investment maturity, financing progress, stakeholder engagement and customer affordability.

Monitoring should support learning and corrective action. If renewable and recovered heat integration is delayed, the monitoring process should identify whether the barrier is technical, financial, regulatory, permitting-related or social. If efficiency indicators do not improve, the monitoring process should identify whether the limitation is network condition, substation performance, customer-side equipment or insufficient operational control.

At transnational level, monitoring should make results comparable. A shared indicator set will help identify recurring barriers, successful measures and policy gaps across Central Europe. The results should feed back into the knowledge base, capacity-building formats, replication activities and future updates of the strategy.

9. Mutual Learning, Knowledge Base and Cooperation Mechanisms

Mutual learning is a core requirement of this strategy because district heating transformation is technically complex, locally specific and institutionally demanding. Central European systems share many structural features, but they are at different stages of transformation. As some systems are still at the beginning of source mapping and stakeholder engagement, others already have identified resources and need support for feasibility, business model design or investment preparation. A structured learning mechanism allows these differences to become a resource for the whole transnational community of practice.

9.1 Transnational expert task force model

A transnational expert task force model is recommended as the central technical and methodological cooperation mechanism. Its role is to support district heating systems in the technological, economic, legal, business and organisational aspects of transformation. It provides a structured way to coordinate common methods and templates, review emerging solutions, support pilot-based learning, and ensure that local action plans remain aligned with the transnational strategy. This type of expert mechanism also creates continuity between strategic work, practical tools and pilot implementation.

The expert cooperation mechanism should operate through regular expert meetings, thematic reviews, methodological guidance and targeted support to pilot territories. Its work should be documented in a way that allows non-partner systems to understand not only the final recommendations, but also the reasoning behind them. This is important because replication depends on transferable decision-making logic, not only on final investment concepts.

9.2 Learning Lab and capacity-building model

A learning lab and capacity-building model should build the competences needed to manage new-generation district heating systems. Training activities should address both technical and non-technical topics: renewable and waste heat integration, heat pumps, biomass quality management, geothermal risk, solar thermal and storage, digital operation, network-temperature reduction, business models, financing, stakeholder engagement and policy frameworks. Training should be designed for operators, municipalities, energy agencies and other stakeholders involved in implementation.

The learning model should combine expert input with peer learning. Study visits, case clinics, pilot presentations and problem-solving sessions can be used to compare practical barriers and solutions. The Austrian experience with renewable district heating and quality management for biomass systems can provide valuable learning, but the objective is not to copy one model mechanically. Instead, the learning process should help stakeholders identify which elements are transferable under different territorial and regulatory conditions.

9.3 Knowledge kit and evidence base

A practical knowledge kit should serve as the main operational knowledge base supporting implementation and replication. It should bring together guidelines, templates, tools and evidence in a user-oriented format. The knowledge base should include at least the following components:

- methodology and templates for heat-source mapping, including renewable heat and waste heat sources;
- methodology and templates for stakeholder mapping and engagement;
- calculation tools for the preliminary evaluation of source viability, technical integration and economic performance;
- guidance on options analysis, lifecycle cost comparison and emissions assessment;
- case studies and best practices from pilots and other relevant European examples;
- model business arrangements for waste heat, renewable heat, storage and heat-pump projects;
- policy and regulatory recommendations addressing local, regional and national barriers;
- monitoring indicators and reporting templates aligned with the 2035 objective.

The knowledge base should be maintained as a living resource. As pilot results become available, templates should be improved, assumptions should be clarified and lessons learned should be added. The final knowledge kit should therefore reflect both expert knowledge and real pilot experience, making it a practical resource for other district heating operators in Central Europe.

9.4 Peer review and pilot learning

Pilot cases should be used as structured learning laboratories. Peer review should assess the quality of baseline data, the credibility of selected source portfolios, the robustness of business models, the feasibility of stakeholder engagement and the alignment of investment concepts with the 2035 and 2050 targets. The objective is not to rank pilots, but to identify transferable lessons and improve the quality of solutions.

Peer reviews should be organised at key decision points: after baseline and source mapping, after preliminary option screening, after business model definition, and before finalisation of local action

plans or investment concepts. Each review should generate practical recommendations and record unresolved issues. This creates an evidence trail that can support replication and policy learning.

9.5 Cooperation with associated partners and wider sector networks

National district heating associations, chambers, sectoral networks and associated partners are essential for scaling the strategic approach. They can provide professional feedback, disseminate tools, identify additional operators for replication and communicate policy barriers to national authorities. Cooperation should therefore go beyond one-way dissemination and be organised as a two-way exchange between pilot partners, expert organisations and the wider district heating community.

The replication mechanism should include national workshops, technical webinars, thematic study visits, presentations at regular meetings of district heating associations, and direct engagement with municipalities and public authorities. The communication of results should be adapted to target groups: operators need technical and business guidance, policy makers need regulatory and planning recommendations, municipalities need governance and communication tools, and consumers need clear explanations of benefits, costs and reliability.

9.6 Data governance and evidence quality

A credible knowledge base requires reliable data. Partners should use common definitions, document assumptions and distinguish between measured data, estimated data and scenario assumptions. This is particularly important for heat-source availability, network losses, emissions factors, costs and tariff impacts. Where data are uncertain, sensitivity analysis should be used rather than presenting a single result as definitive.

The transnational strategy should therefore promote a minimum evidence standard for local action plans and investment concepts. This standard should include transparent baseline data, documented source-screening criteria, clear cost assumptions, emissions methodology, stakeholder commitments and monitoring arrangements. Such evidence discipline improves bankability and strengthens trust among decision makers and consumers.

10. Territorial Typologies and Transferability

Central European district heating systems differ in size, ownership, fuel mix, heat density, resource availability, regulatory context and stage of transformation. A transnational strategy must therefore avoid prescribing a single technological pathway. Territorial typologies can help identify which measures are likely to be transferable under which conditions. The typologies below are not rigid categories; many systems will combine elements of several types. They provide a practical framework for interpreting pilot results and supporting replication.

10.1 Coal and lignite-dependent systems in transition regions

This typology includes systems historically linked to coal mining, coal-fired power generation or lignite-based heat production. Their main challenge is the replacement of fossil baseload heat while managing social, economic and employment impacts in transition regions. The relevant measures include comprehensive source mapping, early stakeholder engagement, geothermal and biomass

assessment, industrial waste heat screening, large heat pumps, storage, network temperature reduction and use of just-transition financing where available.

Transferability depends on the ability to coordinate heat transformation with broader regional transition strategies. Former coal regions may have infrastructure, industrial land, electricity-grid connections and skilled workers that can support new heat solutions. However, they may also face affordability concerns and limited municipal fiscal capacity. Pilot experience in coal-dependent or coal-transition territories can therefore provide important lessons for combining technical planning with social acceptance and regional development objectives.

10.2 Gas-based municipal systems

Gas-based district heating systems, especially in small and medium-sized cities, often have more compact infrastructure but face a strategic risk of gas lock-in. Their near-term emissions may be lower than coal-based systems, but long-term compliance with 2035 and 2050 requirements requires a clear shift toward renewable and recovered heat. Relevant measures include large heat pumps, solar thermal energy, wastewater heat, industrial waste heat, biomass where sustainable, electric boilers for flexibility, and gradual conversion of gas units to peak or back-up use.

This typology is highly relevant for many Central European municipalities because gas systems are widespread and often embedded in municipal service provision. Replication potential is strong if practical templates are available for heat-source screening, tariff-impact analysis, customer communication and phased investment planning.

10.3 Large urban systems with multiple heat sources

Large urban district heating systems can have high heat density, multiple generation assets and strong potential for source diversification. They may be able to integrate industrial waste heat, waste-to-energy heat, large-scale heat pumps, geothermal energy, wastewater heat, data-centre heat, thermal storage and network zoning. Their main challenge is not usually the absence of options, but the complexity of sequencing, financing, permitting, network constraints and stakeholder coordination.

For this typology, transferability is strongest in governance, optimisation and investment planning methods. Large systems need sophisticated dispatch models, long-term asset plans, clear connection strategies, industrial heat contracts and mechanisms for managing tariff impacts over several investment cycles. The strategic approach can support these systems by providing common tools, peer review and policy recommendations.

10.4 Industrial waste heat opportunity areas

Some territories have significant industrial or service-sector waste heat potential located close enough to existing or planned networks. The strategic opportunity is to turn unavoidable excess heat into a resource for local consumers. The main barriers are technical matching, temperature upgrading, contractual risk, industrial continuity, ownership of connection infrastructure and agreement on heat pricing.

Measures that transfer well across this typology include waste heat mapping, early engagement with heat-source owners, feasibility screening, heat purchase agreement templates, risk-sharing models, and back-up arrangements. Such projects require trust between operators and industrial partners. Municipalities can play an important facilitation role by integrating waste heat into spatial planning and by signalling long-term policy support.

10.5 Geothermal and hydrothermal potential areas

Geothermal, mine-water, river, lake and groundwater sources can provide stable or scalable renewable heat where local conditions are favourable. The main challenges are geological uncertainty, environmental permitting, upfront costs, seasonal operation, temperature levels and the need for heat pumps or storage. These sources are particularly valuable where they can supply baseload or semi-baseload heat with low emissions.

Transferability depends on the quality of resource assessment and risk-management frameworks. Common guidance should support staged exploration, preliminary risk screening, public communication, environmental safeguards and integration with network-temperature strategies. Where deep geothermal risk is high, shallow geothermal or hydrothermal heat pumps may offer more scalable options.

10.6 Biomass-based and rural/small-town systems

Sustainable biomass can be a practical option for smaller networks, rural towns and regions with local forestry, agricultural or industrial residues. Its value lies in dispatchability and compatibility with existing high-temperature systems. However, biomass should not be treated as unlimited or automatically sustainable. It must be sourced responsibly, used efficiently, and assessed against air-quality, land-use and competing-use considerations.

Transferable measures include quality management systems for biomass district heating plants, fuel-supply chain assessment, emissions control, storage integration, flue-gas condensation, and combination with solar thermal or heat pumps to reduce biomass consumption. The experience of quality management approaches developed in previous Interreg projects and applied in Austria is particularly relevant for this typology.

10.7 New low-temperature and cold district heating systems

In new development areas or territories without suitable existing high-temperature networks, low-temperature or cold district heating may provide a future-proof alternative. Such systems can use ambient heat, water bodies, shallow geothermal energy or waste heat, with decentralised or building-level heat pumps. They can be particularly relevant for new districts, renovated areas, mixed-use developments and locations where conventional high-temperature district heating would be inefficient.

Transferability requires careful assessment of building demand, temperature levels, ownership models, customer-side responsibilities, electricity demand and control strategies. These systems can provide important lessons for the long-term evolution of district heating, especially as building renovation reduces heat demand and enables lower-temperature operation.

10.8 Transferability conditions

Transferability should be assessed through enabling conditions rather than through superficial similarity between territories. A measure that works in one place is transferable only when the relevant technical, institutional, financial and social conditions can be reproduced or adapted. The purpose of the typologies is therefore to support practical judgement: which lessons can be copied directly, which require adaptation and which are not appropriate for a given system.

A reliable baseline is the first transferability condition. Replication requires comparable information on heat demand, demand density, customer structure, network condition, supply and return

temperatures, existing assets, local resources, emissions intensity, tariffs and future demand scenarios. Without this evidence, technology choices may be based on general assumptions rather than on real system needs.

A responsible local coordination actor is the second condition. District heating transformation needs an organisation capable of convening stakeholders, coordinating data, maintaining the roadmap, linking the pathway to municipal decision-making and following up after feasibility studies are completed. In many territories this role will be taken by a municipality, utility or energy agency, but the responsibility should be explicit.

Stakeholder willingness to share data and participate in solution design is the third condition. Waste heat owners, building managers, public institutions, housing associations, electricity-grid operators and financing actors often hold information that is decisive for feasibility. Replication is more likely when data-sharing rules, confidentiality arrangements and engagement formats are clarified early.

Financial plausibility is the fourth condition. A transferable measure should have a credible financing route, realistic cost assumptions and an acceptable tariff pathway. This does not mean that every measure must be commercially viable without public support. It means that the public value, risk allocation, funding need, tariff impact and long-term affordability should be transparent enough for decision makers and financing institutions.

Regulatory and permitting feasibility is the fifth condition. Measures involving geothermal drilling, biomass plants, solar thermal fields, waste heat pipelines, river or wastewater heat, large heat pumps or storage may face different procedures across countries and municipalities. Replication therefore requires early screening of legal constraints, land-use issues, environmental safeguards, procurement rules and tariff regulation.

Technical compatibility is the sixth condition. A solution must fit the network temperature level, hydraulic structure, customer-side equipment, available space, grid capacity and operational requirements. Where compatibility is not immediate, replication may still be possible through staged measures such as return-temperature reduction, substation upgrades, low-temperature zones, storage or source-side heat pumps.

Social acceptance and transparent communication are the seventh condition. Measures that affect tariffs, construction works, land use, biomass supply, customer obligations or industrial partnerships require early explanation and visible public-interest safeguards. Replication is stronger when communication materials, engagement sequences and affordability measures are transferred together with the technical concept.

Monitoring and documentation are the final condition. Transferable measures should be accompanied by indicators that allow results to be compared across territories, including cost, emissions, efficiency, renewable and waste heat share, implementation barriers, stakeholder feedback and operational performance. This makes replication evidence-based and allows the strategy to evolve through real implementation experience.

11. Governance and Stakeholder Engagement Framework

District heating transformation is a governance challenge as much as a technical challenge. It requires coordination across sectors, administrative levels and stakeholder groups. The governance framework should define roles, decision-making processes, engagement methods and communication principles that can support implementation at both transnational and local levels.

11.1 Roles of key actors

Municipalities and local authorities should provide strategic direction, integrate district heating into local energy and climate plans, facilitate access to public land and infrastructure, engage citizens, coordinate with building renovation programmes and ensure that affordability and public-interest objectives are considered. Where municipalities own district heating assets or utilities, they also have a direct role in investment approval and long-term asset stewardship.

District heating operators are responsible for technical planning, operation, data provision, investment preparation, customer service, reliability and implementation. They should lead system diagnostics, source integration studies, network modernisation plans, tariff-impact analysis and operational monitoring. Operators should also communicate clearly with customers and provide practical information about service changes, construction works and benefits.

Energy agencies, research institutes and expert partners provide technical assistance, methodology, training, modelling, policy analysis and facilitation. Expert cooperation mechanisms are particularly important for supporting operators that lack internal capacity for complex transformation planning.

Owners of waste heat and renewable heat sources, including industrial facilities, wastewater utilities, data centres, public facilities and landowners, are potential partners in the future heat supply chain. Their early involvement is necessary to assess data availability, heat quality, investment responsibilities and contractual conditions.

Building owners, housing associations and public institutions influence demand, return temperatures, renovation sequencing and customer acceptance. They should be involved in substation upgrades, metering, energy-efficiency measures and communication with end users. Public buildings can act as anchor customers or demonstration sites for demand-side measures.

Regulators and national or regional authorities shape the framework for tariffs, permitting, public procurement, funding, energy planning, environmental protection and consumer rights. Their involvement is important for identifying barriers that cannot be solved at local level.

Financial institutions, managing authorities and private investors influence the availability and structure of capital. They require credible project pipelines, risk allocation, cash-flow visibility and evidence of policy support. Their early feedback can improve the bankability of local action plans.

Consumers and local communities are the ultimate beneficiaries and, in many cases, contributors to transformation. They should receive transparent information and opportunities to participate in decisions that affect affordability, service quality and local environmental outcomes.

11.2 Governance arrangements for implementation

Each local action plan should be supported by a clear governance arrangement. At minimum, this should include a responsible lead organisation, a steering group or coordination body, a technical working group, a stakeholder engagement plan and a monitoring process. The governance arrangement should specify decision points, responsibilities, data-sharing rules and links to municipal or utility decision-making.

For complex projects, a staged governance process is recommended. The first stage should focus on baseline validation and heat-source mapping. The second stage should assess technology options and select a preferred portfolio. The third stage should prepare business models, financing and permitting. The fourth stage should support implementation, communication and monitoring. This staged

approach improves transparency and allows stakeholders to provide input before decisions become irreversible.

11.3 Stakeholder engagement process

Stakeholder engagement should be systematic, not occasional. It should begin with mapping stakeholders according to their role, influence, interests, potential contribution and likely concerns. Engagement methods should then be adapted to each group. Industrial heat suppliers may need confidential technical discussions and contractual negotiations. Building owners may need practical workshops on substations and renovation. Consumers may need accessible information on tariffs, reliability and environmental benefits. Policy makers may need concise evidence on regulatory barriers and investment needs.

Engagement should be organised around the following sequence: identify stakeholders, explain the transformation challenge, collect data and concerns, compare options transparently, discuss the preferred pathway, communicate implementation steps, and report progress. This sequence supports trust and reduces the risk of opposition caused by late or unclear communication.

11.4 Communication principles

Communication should be accurate, transparent and tailored to the audience. It should avoid presenting decarbonisation as a purely technical issue and instead explain the local relevance: cleaner air, lower emissions, reduced fossil-fuel dependence, improved reliability, potential use of local resources, and long-term cost stability. At the same time, it should be honest about investment needs, construction impacts, tariff risks and uncertainties.

Communication through local media, public events, municipal channels, operator websites, customer newsletters, social media and existing customer-service channels should be coordinated. Local action plans should be communicated to pilot communities and heat users in line with the communication principles of this strategy. For public trust, communication should not stop at publication; it should continue during implementation and monitoring.

11.5 Conflict management and social safeguards

District heating transformation can create conflicts about costs, land use, technology choices, construction disruption, biomass sustainability, industrial heat contracts or connection policies. A governance framework should therefore include mechanisms for responding to concerns and resolving disputes. This can include public Q&A sessions, dedicated contact points, transparent tariff explanations, independent technical review, and clear procedures for complaints.

Social safeguards should address affordability and vulnerable consumers. Local action plans should assess tariff impacts and identify mitigating measures where needed. Municipalities and operators should coordinate with existing social policy instruments to ensure that decarbonisation does not increase energy poverty. Affordability should be monitored throughout implementation.

11.6 Transnational governance

At transnational level, governance should focus on coordination, quality assurance, learning and replication. The Task Force, Learning Lab and pilot replication framework should connect local implementation with wider Central European knowledge exchange. Transnational governance should

ensure that local results are documented in comparable formats, that lessons are shared across partner countries, and that policy recommendations reflect evidence from multiple territories.

12. Financing and Resource Mobilisation

The transformation of district heating systems will require significant financial, institutional and human resources. Financing must therefore be considered from the beginning of the strategy process, not only after technical concepts have been selected. A credible financing approach should connect investment needs, project preparation, risk allocation, tariff impacts, funding sources and long-term affordability.

12.1 Investment needs

Investment needs can be grouped into several categories. The first category is project preparation: data collection, heat-source mapping, feasibility studies, environmental assessment, permitting, legal advice, financial modelling and stakeholder engagement. These costs are often modest compared with infrastructure investment, but they are decisive for bankability.

The second category is heat-source investment. This may include geothermal wells and plants, biomass boilers and fuel logistics, solar thermal fields, large heat pumps, electric boilers, waste heat recovery equipment, heat exchangers, pipelines connecting external heat sources, waste heat upgrading, and back-up or peak-load units compatible with the long-term decarbonisation pathway.

The third category is network and customer-side investment. This includes pipe rehabilitation, insulation, pressure optimisation, network extensions, low-temperature zones, substations, metering, building-level controls and measures to reduce return temperatures. The fourth category is flexibility and digitalisation: thermal storage, control systems, sensors, data platforms, forecasting tools and cybersecurity measures. The fifth category is organisational capacity: training, staff time, procurement capacity, contract management and communication resources.

12.2 Funding and financing sources

A combination of sources will usually be required. Public grants can reduce the cost of socially desirable investments and support early-stage project preparation. EU and national funds may be relevant for energy efficiency, renewable energy, just transition, cohesion, innovation and infrastructure modernisation. Municipal budgets can support planning, stakeholder engagement, public-building connections and strategic infrastructure. Utility finance can support commercially viable assets where tariffs allow cost recovery. Private investors may participate through project finance, energy service contracts, public-private partnerships or third-party ownership of specific assets such as heat pumps, solar thermal plants or waste heat recovery systems.

The appropriate financing model depends on ownership, tariff regulation, project size, risk profile and revenue certainty. Smaller operators may need stronger public support and technical assistance, while larger systems may be able to structure multi-source investment programmes. In all cases, financing should be linked to a credible implementation roadmap and monitoring framework.

12.3 Bankability requirements

To become bankable, district heating projects should demonstrate a clear baseline, realistic demand forecast, technically feasible source integration, robust cost estimates, emissions benefits, permitting

pathway, stakeholder commitments, procurement approach, tariff impact and risk allocation. Projects should also show how they contribute to 2035 efficient district heating criteria and 2050 decarbonisation.

Risk allocation should be explicit. Geothermal projects need geological risk management. Waste heat projects need contractual arrangements for industrial continuity and heat availability. Biomass projects need sustainable fuel-supply contracts and emissions safeguards. Heat pump projects need electricity price and grid-connection analysis. Network modernisation projects need demand assumptions and construction planning. The earlier these risks are identified, the easier it is to structure financing and public support.

12.4 Public and private roles

Public actors should create enabling conditions: heat planning, permitting coordination, funding support, social safeguards, public communication and alignment with climate strategies. Municipalities can also provide land, guarantee anchor loads, coordinate renovation and support customer engagement. Public funding should be targeted where it unlocks high public value that is not fully reflected in market revenues, such as emissions reduction, resilience, energy poverty mitigation or local environmental benefits.

Private actors can bring capital, technology, project development expertise and operational know-how. Their involvement should be structured through transparent procurement, fair risk sharing and long-term public-interest safeguards. Public-private partnerships can be useful where risks and responsibilities are clearly allocated, but they should not weaken transparency or consumer protection.

12.5 Resource mobilisation beyond finance

Financing alone will not deliver transformation. Operators and municipalities also need human resources, technical skills, data, legal expertise, procurement capacity, communication capacity and political commitment. Capacity building should therefore be treated as a resource-mobilisation measure within the transformation roadmap. Training, templates, peer learning and technical assistance can reduce transaction costs and improve the quality of investment decisions.

Resource mobilisation should also include data-sharing agreements with industrial heat suppliers, cooperation with housing associations, access to municipal GIS and planning data, coordination with electricity-grid operators, and engagement with research institutions. These non-financial resources are often decisive for moving from strategic ambition to implementable projects.

12.6 Affordability and tariff management

Investment planning must assess tariff impacts transparently. Decarbonisation may require substantial capital expenditure, but it can also reduce exposure to fossil fuel and carbon-price volatility. Local action plans should compare scenarios on lifecycle cost rather than only upfront cost. They should identify measures to protect vulnerable consumers and avoid abrupt tariff shocks, such as phased implementation, grant support, concessional finance, efficiency measures that reduce losses, and careful sequencing of investments.

13. Monitoring Framework and Success Indicators

Monitoring is necessary to ensure that the strategy remains implementation-oriented and accountable. The monitoring framework should operate at two levels. At local level, each district heating system should track progress against its own baseline and local action plan. At transnational level, comparable indicators should be aggregated to identify common barriers, document lessons and support replication.

13.1 Core indicators

The core indicator set should track whether the transformation pathway is moving toward the 2035 milestone and remains compatible with the 2050 endpoint. Indicators should be simple enough to be reported consistently, but sufficiently complete to cover decarbonisation, efficiency, investment progress, reliability, affordability and stakeholder engagement. The minimum set should be used by all local action plans, while advanced indicators can be added where data quality allows.

Renewable energy and waste heat share in delivered district heat should be the central outcome indicator. It should be calculated annually as a percentage of delivered heat and should distinguish between renewable energy, recovered waste heat and other qualifying sources according to EU and national accounting rules. This indicator directly measures progress toward the 2035 threshold.

Fossil fuel share should be reported alongside the renewable and waste heat share. It should be disaggregated by coal, lignite, natural gas, oil and other fossil sources. This allows monitoring of both the remaining fossil dependency and the role of fossil units as baseload, peak, back-up or emergency capacity. It also helps identify whether gas or other transitional fuels are becoming long-term lock-in risks.

Greenhouse gas intensity of delivered heat should be reported in g CO2-equivalent per kWh where data allow. The calculation method, emission factors and treatment of electricity used by heat pumps should be documented transparently. This indicator is important because EU efficient district heating rules also include an emissions-based compliance pathway and because consumers and municipalities increasingly expect clear climate-performance information.

Heat delivered, peak heat demand and annual heat demand by main customer category should be monitored to understand how demand is changing. This includes residential buildings, public buildings, commercial users, industrial users and new connections where relevant. Demand indicators are essential for investment sizing, network planning, tariff assessment and coordination with building renovation.

Network losses should be reported as absolute losses and as a percentage of heat input to the network. Loss indicators should be interpreted together with supply and return temperatures, pipe condition, network density and operating hours. They show whether efficiency measures are reducing avoidable heat production and whether the system is becoming more suitable for low-temperature renewable and recovered heat.

Supply and return temperatures should be monitored as annual averages, seasonal values and peak values where possible. Return-temperature performance is especially important because it affects heat-pump efficiency, geothermal integration, waste heat recovery, storage performance and network losses. Temperature indicators should therefore be connected with substation modernisation, building-side measures and customer engagement.

Source diversification should be monitored by reporting the share of heat supplied by individual renewable and recovered sources, such as geothermal energy, sustainable biomass, solar thermal energy, industrial waste heat, wastewater heat, ambient heat and large-scale heat pumps. This indicator shows whether the transformation is creating a resilient local heat portfolio rather than replacing one dependency with another.

Thermal storage and flexibility should be tracked through installed storage capacity, operational use of storage, power-to-heat capacity, heat-pump operating patterns and, where relevant, demand-side flexibility agreements. These indicators help assess whether the district heating system is becoming an active part of the wider local energy system.

Investment-pipeline progress should be reported for priority projects. Each project should be classified by stage: concept, pre-feasibility, feasibility, financing, permitting, procurement, construction, commissioning or operation. This indicator is necessary because the 2035 target cannot be reached only through planning documents; it requires a visible pipeline of mature investments.

Affordability and customer-protection indicators should include tariff development, connection costs where relevant, communication on tariff changes and, where data allow, indicators related to vulnerable consumers. These indicators should be interpreted carefully because affordability is influenced by national social policy, fuel prices, building condition and household income, but they remain essential for maintaining the social legitimacy of district heating.

Reliability indicators should include outage frequency, outage duration, service interruptions, complaint numbers and response times where available. Decarbonisation should not weaken security of supply, and reliability performance should be communicated clearly to customers during periods of construction and system change.

Stakeholder engagement indicators should record meetings, consultations, participating organisations, communication actions, feedback received and evidence of how stakeholder input influenced the pathway. These indicators show whether transformation governance is inclusive, transparent and capable of managing social and institutional barriers.

13.2 Strategic milestones

Monitoring should be linked to milestones. By 2030, systems should have implemented no-regret efficiency measures, secured financing for priority investments and begun integrating renewable or recovered heat sources at meaningful scale. By 2035, systems should meet the minimum 50% renewable energy and/or waste heat threshold or an equivalent compliant pathway under EU rules. After 2035, monitoring should track progress toward the 2050 requirement of fully renewable and/or waste heat-based district heating.

13.3 Data quality and reporting responsibilities

Each local action plan should assign responsibility for data collection and reporting. Operators are usually best placed to provide technical and operational data, while municipalities may provide information on planning, engagement and affordability. Industrial heat suppliers and other third parties should provide data defined in cooperation agreements. Where data are commercially sensitive, aggregated or anonymised reporting can be used, but the assumptions should remain transparent.

Data quality should be classified. Measured operational data should be distinguished from estimates, modelled values and scenario assumptions. This is particularly important for early-stage source

mapping, where technical potential may be much higher than economically viable potential. Monitoring should therefore track not only potential, but also the maturity of each project option.

13.4 Use of monitoring for learning and correction

Monitoring should support management decisions. If renewable and waste heat integration is delayed, the monitoring process should identify whether the cause is permitting, financing, technical feasibility, stakeholder resistance, supply-chain constraints or regulatory uncertainty. If network temperatures remain too high, the process should identify whether the barrier is customer-side equipment, hydraulic operation, building condition or lack of incentives. This diagnostic use of monitoring turns reporting into a learning tool.

At transnational level, comparable monitoring will help identify which measures are progressing fastest, which barriers recur across countries and which policy recommendations are most important. The monitoring framework should therefore feed into replication activities and future updates of the knowledge base.

13.5 Indicator governance

To avoid excessive administrative burden, indicators should be prioritised according to relevance and data availability. A minimum indicator set should be mandatory for all local action plans, while advanced indicators can be added by systems with better data. The minimum set should include RES/waste heat share, fossil fuel share, delivered heat, emissions intensity, network losses, supply and return temperatures, investment progress and stakeholder engagement. Annual reporting is recommended, with a more detailed review at key milestones such as 2030 and 2035.

14. Implementation Roadmap

The implementation roadmap translates the strategy into a staged pathway to 2035 and beyond. It recognises that district heating transformation requires time for planning, permitting, financing, construction, customer engagement and operational learning. The roadmap should be adapted to each local action plans, but the following stages provide a common transnational structure.

14.1 Stage 1: Strategy adoption and baseline validation

The first stage should focus on consolidating the strategic framework and translating it into local actions. DH transformation territories should validate their baselines, refine source mapping, complete stakeholder mapping and identify priority transformation measures. The results should be used to test and improve the knowledge kit, refine templates, assess the quality of proposed solutions and document lessons learned. Local action plans should be communicated to local communities through media, events and existing customer channels, while operators should begin preparing investment concepts for priority measures.

Key outputs of this stage should include final local action plans, validated pilot lessons, a refined knowledge kit, initial investment pipelines, stakeholder engagement records and policy recommendations. The focus should be on moving from strategic ambition to implementable projects.

14.2 Stage 2: Project preparation and no-regret implementation, 2028-2030

The second stage should focus on preparing and implementing no-regret measures. These include network-loss reduction, substation modernisation, metering, digital monitoring, return-temperature reduction, energy-efficiency measures, small-scale renewable or waste heat integration where feasible, and completion of feasibility studies for larger investments. Operators should secure financing for priority projects, begin permitting processes and integrate district heating transformation into municipal and regional planning instruments.

By 2030, each system should be able to demonstrate measurable progress: improved data quality, reduced losses where measures have been implemented, concrete investment decisions, financing applications or approvals, signed cooperation agreements with heat-source owners where relevant, and active communication with customers. This stage should also contribute to EU 2030 energy and climate objectives, including increased energy efficiency and renewable energy deployment.

14.3 Stage 3: Scale-up of renewable and recovered heat, 2031-2035

The third stage should deliver the major structural shift required by the 2035 milestone. Larger renewable and waste heat projects should be implemented, network modernisation should be scaled up, storage and flexibility assets should be integrated, and fossil baseload should be replaced. Gas, coal, oil and fossil cogeneration should be progressively limited to peak, back-up or transitional roles where still necessary.

By 2035, district heating systems should meet the minimum 50% renewable energy and/or waste heat threshold, or another compliant pathway under EU efficient district heating and cooling rules. Systems that cannot reach this threshold by 2035 should have a documented explanation, corrective plan and accelerated investment pathway. The transnational cooperation framework set out in this strategy should support systems facing implementation barriers and facilitate the transfer of successful solutions from more advanced territories.

14.4 Stage 4: Full decarbonisation pathway, 2036-2050

The fourth stage should build on the 2035 transformation and complete the phase-out of fossil heat by 2050. Priorities should include further temperature reduction, expansion or optimisation of renewable and waste heat sources, deeper integration with building renovation, additional storage, flexible operation with renewable electricity, and retirement of remaining fossil peak and back-up assets where alternatives become available. The 2050 objective should be incorporated into all major investment decisions before 2035 to avoid stranded assets.

14.5 Link with local energy transition strategies

The transnational strategy supports local energy transition strategies by providing a common framework, but implementation must be local. Each municipality or district heating operator should translate the strategy into measures that reflect its heat demand, resource base, infrastructure condition, governance capacity and financing possibilities. Local action plans should be integrated into municipal climate plans, spatial planning, renovation strategies and infrastructure investment programmes. This ensures that district heating transformation is not treated as an isolated utility project, but as part of the wider community transition to climate neutrality.

15. Conclusions and Recommendations

15.1 Main strategic direction

District heating systems in Central Europe are at a decisive point in their development. Many systems remain dependent on fossil fuels and operate with infrastructure designed for a previous energy era. At the same time, they offer one of the most practical platforms for decarbonising heat in dense urban areas, industrial towns and public-service networks. The strategic direction is therefore clear: district heating should be transformed into efficient, diversified, renewable, recovered-heat-based and flexible local energy systems by 2035, with full decarbonisation by 2050.

This strategy confirms that the transformation is not only a technological task. It requires integrated heat planning, local resource mobilisation, network modernisation, business model innovation, financing, governance, communication and continuous learning. The target of at least 50% renewable energy and/or waste heat by 2035 should be treated as a minimum threshold and as a catalyst for deeper system redesign.

15.2 Priority recommendations

The following recommendations should guide implementation after the adoption of the strategy:

- Embed the 2035 target in local action plans, municipal strategies and district heating operator investment plans.
- Start with a reliable baseline and local heat-source mapping, including renewable heat, industrial waste heat and urban waste heat.
- Prioritise energy efficiency first: reduce losses, lower return temperatures, modernise substations and improve operational control before oversizing new generation.
- Avoid new long-term fossil lock-in and restrict remaining fossil assets to clearly defined transitional, peak, back-up or emergency roles.
- Develop diversified local heat portfolios combining the most suitable renewable and recovered sources for each territory.
- Prepare bankable investment pipelines with lifecycle cost analysis, emissions assessment, tariff-impact analysis, permitting pathways and risk allocation.
- Use structured tools, learning formats and expert support to build capacity and reduce project-preparation barriers.
- Strengthen municipal heat planning and connect district heating with building renovation, spatial planning, industrial development and energy-poverty policies.
- Engage customers and local communities early, transparently and continuously, using both local media and existing operator communication channels.
- Monitor progress annually using comparable indicators and use the results for learning, corrective action and replication.

15.3 Expected impact for Central Europe

If implemented effectively, the strategy will contribute to lower greenhouse gas emissions, reduced fossil-fuel dependence, improved energy efficiency, greater use of local renewable and recovered heat, enhanced security of supply and stronger consumer confidence. It will also support local economic development by mobilising endogenous resources, creating investment pipelines and strengthening cooperation between municipalities, utilities, industry, technology providers and financial institutions.

At transnational level, the expected impact is a stronger common capacity to transform district heating systems across Central Europe. The combination of pilot evidence, methodological tools, local action plans, policy recommendations and replication activities can reduce the gap between EU policy targets and implementation on the ground. It can also help other district heating operators avoid fragmented decision-making and move more quickly toward bankable, socially accepted and climate-compatible solutions.

The principles guiding the strategy should remain constant throughout implementation: resilience and affordability, energy efficiency, sustainability, local resource use, consumer orientation, social acceptance and replicability. These principles provide a balanced basis for decision-making when technical, financial and social trade-offs arise. They also ensure that district heating transformation contributes to climate neutrality while continuing to fulfil its essential public-service role in Central European communities.

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