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CLIMATE AND ENERGY INVESTMENTS IN THE HEATING INDUSTRY

2014–2030

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Project in brief

The report contributes to the output of the O.IV project " **Climate investment capacity: climate finance dynamics & structure for financing the 2030 targets (CIC 2030**)". The main objective of the CIC 2030 project is to build capacity in the area of assessment of investment needs and plans for achieving the 2030 climate targets, together with identifying ways to meet these investment needs. The main outputs of the project are knowledge and procedures for (i) climate-energy investment maps to monitor public and private finance flows, (ii) analyses of investment needs and investment gaps to achieve climate and energy targets by 2030, (iii) capital raising plans to cover the gap between identified investment needs and current investment flows, and (iv) investment policy plans for meeting the 2030 heating targets. This report presents outputs focused on climate-energy investment and investment plans for the heating sector for 2030.

Report abstract

This report responds to the challenge of a low-carbon transformation of the heating sector in the area of realised climate-energy investments and their link to the expected investment needs for the low-carbon sector transformation by 2030. The report aims to map and evaluate the flows of climate and energy investment in the heating sector in 2014-2019 and highlight the investment need for the transition of heating from coal to low-carbon, sustainable sources. At the same time, we point to the possible trends and diversification of this sector's activities, using the example of two case studies.

Disclaimer

This project is part of the European Climate Initiative (EUKI – www.euki.de) of the German Federal Ministry of Environment, Nature Protection and Nuclear Safety (BMU). The main objective of the EUKI is to promote climate cooperation within the European Union (EU) to mitigate greenhouse gas emissions. The opinions presented in this report are the authors' sole responsibility, and they do not necessarily reflect the views of the Federal Ministry of Environment, Nature Conservation and Nuclear Safety (BMU).

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Acronyms

AEL	Associated Emission Levels
BAT	Best Available Technology
BMU	Nature Protection and Nuclear Safety
BREF	Best Available Techniques Reference Document
BSAE	Battery electricity storage system
DHS	District heat supply system
CR	Czech Republic
EEX	European Energy Exchange
EU	European Union
EUKI	European Climate Initiative
ERO	Energy Regulatory Office
EU ETS	European Emission Trading Scheme
PV	Photovoltaic power plant
CHP	Combined heat and power
NIP	National Investment Plan
OPEI	Operational Programme Enterprise and Innovation
OPEIC	Operational Programme Enterprise and Innovation for Competitiveness
OPE	Operational Programme Environment
RES	Renewable energy sources
SAF	Solid alternative fuels
TG	Turbine generator
TS CR	Teplarenské sdružení ČR (Association for the District Heating of the Czech Republic)
HHO	Heavy heating oil
PM	Particulate matter
WER	Energy recovery from waste

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Executive summary

The report ***aims to assist the low carbon transformation of the heating sector of the Czech Republic,*** *providing evidence-based information and advice*. In 2015, ca. 40% of heat demand in the residential sector was addressed by the sector and thus, it plays a big role in the economic structure and the energy system of the country. The sector relies on domestic coal, which currently accounts for nearly 60% of its fuel mix and the transformation is a big challenge.

The report ***presents the contribution of the sector to meeting 2030 country climate, energy, and renewable energy targets***. The Czech Republic has not set clear sector climate targets and it does not have yet a dedicated strategy for the sector's low carbon transformation. One of the main anchoring commitments is a recommendation of the Coal Commission on the phase out of coal mining and combustion in the Czech Republic. In December 2020, the Commission recommended to phase out coal by 2038, but this deadline has not been yet approved by the Czech Government. It is expected that the actual phase out of coal firing in the heating sector will occur earlier than this date due to the number of reasons. These include the overall economic and policy climate related to the EU long-term decarbonization targets, such as availability and cost of capital with a growing favour on low carbon technologies, as well as a decrease in the amount of free emission allocation for the heating sector, and a growing price of emission allowances due to the revision of legislation under the emission cap-and-trade regime of the European Union (Emission Trading Scheme – EU ETS).

The report discusses investment need, recent investment, and solutions to close the investment gap of the heating sector's energy transition. More specifically, it calculates the investment need of the sector over 2021-2030 to realize its greenhouse gas (GHG) emission reduction potential in line with the country's 2030 energy and climate targets and long-term decarbonization plans. It further tracks such investment occurred over the period 2014–2019, taking into account the recently adopted EU Taxonomy of Sustainable Activities. Finally, it offers two case studies representing typical Czech heating plants, for which it discusses decarbonization strategies. The experiences of these case studies offer useful food for thought and recommendations for the rest of the sector. The report represents the fourth study in a series prepared within the Climate Investment Capacity 2030 project supported by the European Climate Initiative, with the first report focusing on the assessment of investment need to meet the country's 2030 energy and climate targets in selected sectors, the second report tracking the recent investment in this process, and the third report articulating on the capital raising plan to close the investment gap between the investment need and the recent investment flows[1].

Investment needs for the low-carbon transformation of the heating sector

The transformation investment in the heating sector must be aligned with the EU Taxonomy of Sustainable Activities. The taxonomy is a scientific-based classification system that allows identifying whether an investment is in line with long-term sustainable and climate plans and commitments of the European Union. It is a part of the European Commission's Action Plan on Financing Sustainable

[1] Please see the reports at the website of the Climate Investment Capacity (CIC2030) project at URL https://www.ikem.de/en/portfolio/cic2030/

Growth. It aims to support the trend of sustainable investment and to reduce the risk of greenwashing[2]. Non-compliance of investment with the taxonomy will likely cause a number of challenges for the operation of installations already in the near-term future. For instance, it may lead to a lower access or higher cost of capital from financial intermediaries, such as the EU funds, and thus also undermine these installations' competitiveness.

The low carbon transformation is not always straightforward, and the application of the EU Taxonomy of Sustainable Activities creates some uncertainty. Economic activities that are incompatible with net zero emissions and where technological alternatives exist do not comply with the taxonomy, such as coal firing for heat production. Where full low-carbon transition is not technologically and economically feasible in the short-term, the taxonomy temporarily allows some transition activities, which do not yet comply with climate neutrality. For the heating sector, this concerns above all the firing of natural gas. For these sectors, the taxonomy sets technical performance thresholds that determine whether such an activity can be regarded as sustainable. The thresholds for individual sectors are still being prepared at the time of writing of this report that creates some uncertainty in the investment decisions of heating companies.

In case of the Czech Republic, the re/construction of heating plants to allow natural gas firing is identified as a transition solution. As illustrated with the argumentation below for different categories of installations, the sector does not have many immediate alternatives, i.e., on the supply side of heat. It is important to emphasize that changes on the supply side (heat production) must be linked to changes in the heat demand, i.e., at final consumers. The transformation of the production base for heat supply must reflect the priority, which is to increase energy efficiency on the part of consumers (and thus the expected decline in heat consumption and a change in the profile of heat consumption during the year). At the same time, plans for the transformation of heat production must take into account the expected development in the use of RES (solar collectors, PV, heat pumps) together with heat accumulation, and design the entire development of heat supply systems to allow gradual integration of decentralized heat sources based on RES. These aspects were assessed and discussed in our previous reports in the series.

Scaling up of some of these solutions is not possible in the immediate timeframe and it is a long-term task. It is therefore the heating sector that shall search for immediate solutions giving the time for scaling up the right mix of low-carbon technologies at the demand and supply side.

Although natural gas firing brings an immediate reduction of GHG emissions as compared to coal, it cannot stay as a permanent solution in the current technological setting hindering the achievement of long-term EU decarbonization targets (in accordance with the meaning of the EU "taxonomy", EU Regulation 2020/852 and general transition to climate neutrality), ***therefore such installations will have to be supplemented in the coming decades by either "greening of gas" or replaced by other technologies.*** While *"greening of gas" may be an* important element of the future decarbonization trajectory, it is not currently clearly anchored technologically, economically, and politically.

In the category of heating plants above 300 MWt, it is practically possible to consider only their reconstruction to allow firing natural gas. At present, the experts do not see an alternative to

[2] Misuse of being referred to sustainable without being sustainable

reconstructing these plants so that they would emit less GHG emissions. While it is also theoretically possible to re/construct these installations for large-scale biomass firing and cofiring, practically it is hard due to the need to collect, transport, and store a large amount of sustainable biomass that will offset emission reductions gained. For these reasons, heating companies do not plan to build new installations in this size category. The same applies for using other fuels (such as energy recovery of municipal waste).

In the category of heating plants between 50 MWt and 300 MWt, it is technologically and economically feasible at present only to consider the re/construction of installations based on firing natural gas or hybrid solutions with (smaller) different boilers firing natural gas and biomass. To reconstruct or construct installations fully on biomass is not possible due the same reasons as discussed above. We also analysed a possibility to introduce installations in this size category based on energy recovery from municipal waste and alternative solid fuels. These installations will unlikely achieve higher output than 50 MWt due to the nature of the fuel, its limited availability, and its large collection distances and therefore, they cannot be an alternative in this category.

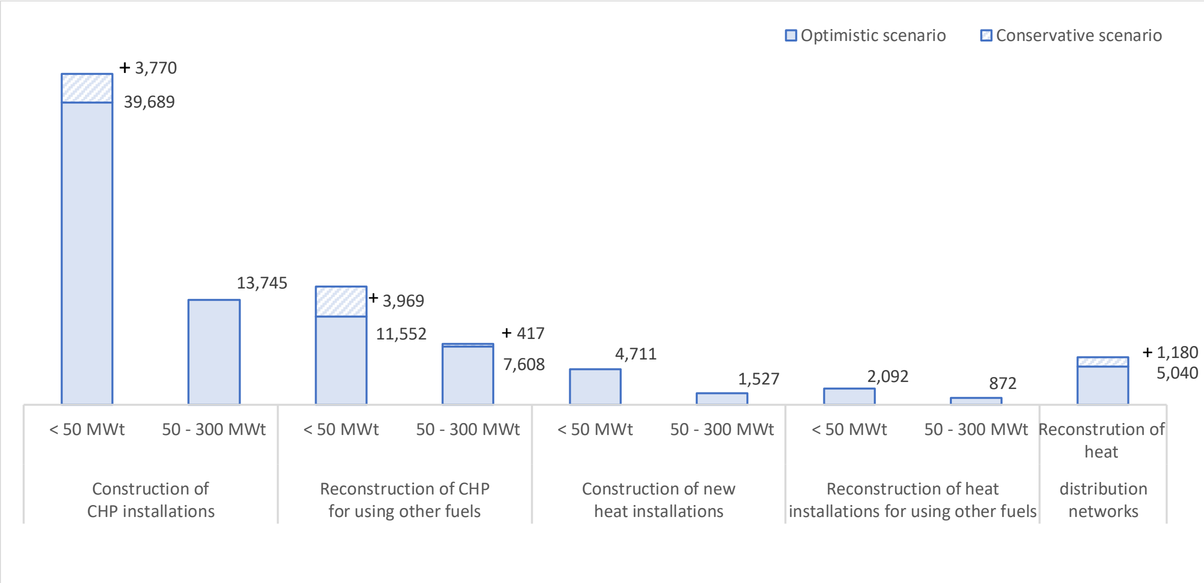
For the installations below 50 MWt, the choice of fuels is more flexible, but still somewhat constrained. The category includes at present mostly the installations under 20 MWt because many such existing units have downscaled to below 20 MWt, so not covered by the EU ETS, and thus they are out of our definition of the heating sector for investment needs purposes. They often had to undergo some reconstruction or modernization, realizing to some extent the decarbonization potential. For new installations in this category, next to natural gas and/or biomass, it is possible to consider those based on energy recovery from municipal waste and alternative solid fuels. The latter two installations are however not always possible, because they need a respective reliable supply of waste or alternative fuels that is site-specific. It is also not possible to reconstruct existing facilities to allow them utilizing these fuels, therefore these installations could only be new.

In summary, based on these limitations, ***the sector transformation is likely to see a replacement of coal in the short- to medium- term mainly by natural gas and partly also by biomass and waste*** *(with the expected development of renewable energy sources)*. Relying on these conclusions, we developed two scenarios, optimistic and conservative, to estimate the investment costs by 2030 required to follow this trajectory. Only installations above 20 MWt were covered in this analysis. The optimistic scenario identifies the lowest cost estimate, whereas the conservative scenario calculates its highest range.

According to the optimistic scenario the total investment required over 2021-2030 is CZK 98.3 billion, and it totals to CZK 107.2 billion in the conservative scenario (in nominal prices of the given year). Figure presents the breakdown of investment need according to capacity and type of the installations. It illustrates that most of these needs are installations up to 50 MWt. The largest investment is required for the construction of new combined heat and power (CHP) units, followed by the reconstruction of existing CHP units. Altogether, about two thirds of the current production of coal supply heat is expected to be secured by the reconstructions or new sources for natural gas, about a fifth of coal will be replaced by biomass, about 13% production of supply heat from coal will be replaced by new sources based on energy recovery from municipal waste and alternative solid fuels.

The investment identified will have to be implemented stage-wise. Until 2025, only projects that had been already prepared before 2020 are to be implemented. Between 2025 and 2030, a major part of required reconstruction covering ca. 70-80% of production and distribution capacity will take place. From 2030 to 2035, the last portion of ca. 10-15% capacity will be reconstructed, and the last coal-firing installations will be phased out.

Figure: Investment needs for the transition of the Czech heating sector in 2021-2030, million CZK



Recent investment in low-carbon transformation of the heating sector

In order to understand, how well Czechia is on track in meeting its investment needs in energy transition and specifically in the district heating sector, we tracked such recent investment. We found that ***CZK 33.1 billion was invested over 2014–2019 in the measures, which led to a reduction of GHG emissions in the sector***. The highest volume was invested in 2014 as illustrated in Figure, being triggered by the National Investment Plan (NIP). In 2016–2018, the investment was ca. CZK 3 billion/yr.

Figure 2 breaks down the investment according to three groups: investment complying with the taxonomy, transition investment, and investment not complying with the taxonomy. The first category includes investment in heat production from renewable energy sources and investment in energy efficiency of heat distribution networks. The second category includes investment in natural gas firing. The third category includes investment reducing emissions of coal-firing installations.

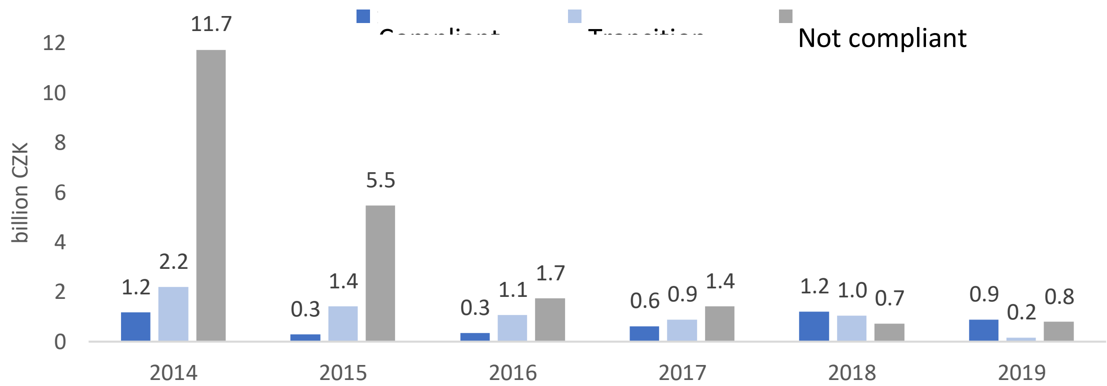
The analysis of Figure illustrates that ***CZK 21.9 billion or two thirds of the investment occurred over 2014-2019 are those, which enable the reduction of emissions at coal firing installations without fuel switch and this is therefore the investment which cannot be counted as taxonomy-aligned***.

As this investment occurred relatively recently, it will have to be amortized before the end of its typical 20-year lifetime. This will require the adoption of measures on the part of the state in terms of accounting rules and enabling, for example, an accelerated write-off of the investment so that this problem does not prevent the transformation of such constructed resources.

The structure of the investment flows with a higher share of those not complying with the taxonomy is explained by the fact that subsidy programmes supporting them were set to reduce emissions but not eliminate them.

The figure however also illustrates that over time, this category of investment had declined. ***In 2018 and 2019, investment aligned with the taxonomy including the transition investment was 75% and 66% of the total volume respectively.*** Out of the taxonomy-compliant volume over 2014-2019, 40% or CZK 4.48 billion was directed to the reduction of losses in heat distribution. The next flow of CZK 4.38 billion or 39% of the compliant volume represented the transition investment in new natural gas-based CHP installations. Finally, CZK 2.37 billion or 21% of the volume also was transition investment in the modernization and reconstruction of existing coal installations to allow them firing natural gas and/or biomass.

Figure: Investment in energy transition and decarbonization of the Czech heat sector broken down according to the compliance with the EU taxonomy of sustainable activities, in billion CZK



Note: The estimates present only primary investment flows, i.e., those that create new or additional physical assets. Therefore, they do not reflect expenditure, which was linked to intangible (soft) measures, such as energy audits, project preparation, documentation, and similar. The main sources of data were the reporting under the EU ETS, the project inventory of the NIP, the Operational Programme Enterprise and Innovation for Competitiveness (OPEIC), including its predecessor the Operational Programme Enterprise and Innovation (OPEI), and the Operational Programme Environment (OPE); as well as activities and data of COGEN Czech, an association for CHP generation bringing together small CHP producers, who are not covered by the EU ETS and are not eligible to the above subsidy programmes.

Private investment, consisting of own resources of companies and commercial loans, was the key flow covering over 80% of the total capital expenditure over the period analysed. This private investment was supported and/or triggered by policies and public finance. These were the NIP, as a part of the EU ETS, and then specific grant schemes offered by the Operational Programmes (OPs) of the European Regional Development Fund and the Cohesion Fund, including OP "Enterprise and

Innovation for Competitiveness" (OPEIC) formerly OP "Enterprise and Innovation" (OPEI), and OP "Environment" (OPE) implementing the EU funds.

The role of public finance is proved by the dynamics of the investment over 2014-2019. Grants covered 17% of the compliant and transition investment volume, with a growing share over time, up to 35% of the investment volume supported recently by the OPs. Lower volumes of investment in 2016-2017 are due to the late start of the OPEIC financed from the EU funds within the EU budget period of 2014-2020. The NIP and the EU ETS are not explicitly reflected in investment flows: whenever heating plants implemented investment from their own resources, these were on the basis and in the value of freely provided emission allowances.

Over the next decade, it is expected that the largest role in supporting the investment will be played by the Modernization Fund, the Recovery and Resilience Facility, and operational support. The Modernization Fund will likely play the key role, setting aside ca. CZK 40 billion to support the Czech heating sector. The other source of funding is the Recovery and Resilience Facility, which is expected to support the modernization of heat distribution networks. Finally, the operational support for the combined heat and power production is expected. The level of support for the investment will be very important so that the transformation of the district heating industry is reflected as low as possible up to the price of heat for final customer.

Investment plans for representative case studies

Many heating plants in the Czech Republic face a need to modernize or reconstruct their installations to decrease the CO_2 emissions. For our case studies, we have selected two of such, which have already started restructuring and/or modernization: the ***heating plant in Písek and the heating plant C- Energy in Planá nad Lužnicí***. They represent different types of heating organizations, the first is a municipal heating plant and the second is a heating plant supplying heat to a portfolio of industrial customers next to buildings, commerce, and trade. Experiences of these heating plants ***suggest useful recommendations for decarbonization strategies for similar organisations in the heating sector.***

Heating plant in Písek

The plant supplying heat to the town of Písek was built in 1987. The plant was initially equipped with two lignite boilers backed up with a fuel oil boiler used in case of failures and additionally on frosty days. ***During the last 5 years, heat sales ranged from 350,000 to 380,000 GJ***, and the annual fuel consumption was respectively 40,000-50,000 tons of low-sulfur coal. The plant also produces 10 - 12 GWh/yr of electricity, which was dependent on heat supply, and which was used for own consumption or delivered to the distribution system. The heat is sold to 8,000 flats and over 400 other customers, including trade, services, and industry. Heat consumption is, therefore, affected by seasonality and average yearly temperatures. Heat was delivered to consumers via a steam distribution system.

The heating plant has been implementing a decarbonization strategy over 2016 – 2022. Implementing it scales to CZK 500 million over these years. About 30 % of the amount is being financed from grant programmes, mostly from the OP EIC, followed by long-term commercial loans, and own funds.

The largest share of investment need is for the reconstruction of heat distribution system from steam to hot water pipelines. The hot water system acts as heat accumulator and storage, which helps balancing peak loads. This will also allow reducing heat losses and thus downscaling heat production. This goes hand-in hand with the assessment of future heat needs of the town. Elimination of subsidies for heat consumption and gradual thermal efficiency improvement of buildings since the early 1990s resulted in the reduction of heat consumption of ca 1%/yr and some routes, therefore, are not cost-effective to operate. Simultaneously with the reconstruction of the pipelines and retrofitting the pipes, the reconstruction is underway for several dozen heat exchanger stations.

The next investment need is associated with a replacement of existing installations with those relying on low carbon fuels. The backup installation based on fuel oil was replaced by a natural gas boiler with installed capacity of 19 MW. The plant also introduced one additional natural gas boiler with installed capacity of 5 MW for the use in case of failures, accidents. One of two coal boilers was replaced with a boiler firing local biomass. One of the original coal boilers will remain for a few years more.

The plant has been developing further opportunities. The next stage is commissioning of a biogas installation in 2022. The opportunities considered include installing a smaller CHP unit in a place that would be optimized with respect to the topology of the heating system. The other investment in consideration is heat storage, which would allow balancing the load with faster adjustments to outdoor temperature fluctuations. Furthermore, the plant considers construction of an installation allowing energy recovery from municipal waste. This will also address town priorities at a time when landfilling will be banned or at least significantly reduced. The preparation of this investment requires not only cooperation within nearby towns, but also with municipalities in the vicinity, to gather their waste for incineration. One of key challenges is to determine the annual amount of waste fired, that is expected to be ca 25 - 40 thousand tons.

C-Energy Planá s.r.o.

The plant producing heat for plastic and fiber factory, Silon Planá was constructed around 1960. At present, this is an ***independent power and heat provider generating 350,000 GJ/yr of steam and producing 250,000 GJ/yr of hot water***. ***Steam is mostly used for processes at industrial installations, whereas hot water is supplied for space heating*** to the City of Sezimovo Ústí, the town of Planá nad Lužnicí, and to some localities in the town of Tábor. Space heating is mostly needed during cold periods, the demand for steam is more evenly distributed.

In 2012, the C-Energy started implementing a greening concept. The total investment required to realize it since then has been ca. CZK 1.5 billion. The investment was financed from own resources and commercial loans. Subsidies of approximately CZK 300 million were obtained from the OP E financed from the Cohesion Fund, Priority Axis 2 on emission reduction. The verification conducted in 2019 concluded on a reduction of SO_2 emissions by factor of 50, NO_2 emissions by factor of 3.65, and particle pollutants by factor of 83.3.

The largest share of investment was associated with a replacement of existing installations. *The company replaced three old coal boilers* with two 40 t/h coal fluid boilers equipped with exhaust gas cleaning system based on desulphurization, it also *reconstructed the turbogenerator to increase its capacity*. Later, these new installations started with *30% cofiring of wood chips* was. The company further *installed four CHP units with 10MW natural gas engines and exhaust-gas boilers generating steam and hot water*. It also installed one backup natural gas steam boiler with installed capacity of 15

MWt. *The company also launched a trial operation of a steam unit for energy recovery from non-recyclable plastics*. The company further constructed additional pipelines to provide heat to residential sector, instead of locally used less efficient and more polluting heating sources.

Increasing its capacity and diversification allowed the company providing a wider range of power balance services and flexibility. To further improve the latter, it installed a battery storage with an output of 4 MW/2.5 MWh and photovoltaic power plant of 0.520 MWp (currently, the largest battery storage facility in Czechia).

Until 2025, the company plans to optimize available capacities and resources reducing less ecological operations in Tábor and replacing them with more ecological heat from Planá nad Lužnicí. The plans also include the reconstruction of steam into hot water pipelines to reduce heat losses and gain other benefits. In February 2021, CE Energy Planá adopted the Planá 2025 strategy. Its goal, while maintaining competitiveness and affordability of heat, is to completely abandon coal combustion and reduce CO_2 emissions from the current 120,000 to 11,000 tons per year by 2025.

In 2025-2030, the vision of the company is to phase out coal and operate in a CHP mode aiming towards carbon neutrality. This goal will be met by replacing coal with wood chip boilers. The company also considers energy recovery from municipal waste with an annual utilization capacity of waste of ca. 40 thousand tons/yr. This will allow utilizing all municipal waste produced in the Tábor region. The company also plans to increase the capacity of the battery storage to allow for even larger flexibility.

Recommendations for other heating plants

The case studies suggest the following lessons learned for similar heat producing installations:

Fuel diversification and flexibility is a key to optimize heating plant operations and reduce its costs. The diversification also makes it possible to reduce the sensitivity of heating plants to external shocks such as fuel price fluctuations, prices of emission allowances, and changes in the regulatory environment. For these reasons, financial intermediaries also prefer financing low carbon technologies instead of fossil fuels, and especially coal.

Fuel switch to natural gas is a short-term technological alternative, which may allow reducing emissions in a relatively cost-efficient and time-wise affordable way. However, the emission reduction is only 40-50% and in the future the installations may either be further upgraded to allow „greening gas“ or other energy carriers with lower carbon content. *In the short term,* it may help achieve greater flexibility and ability to provide power balancing.

Biomass can only fully replace coal in small installations, for large installations long-term supply of sustainable biomass must be secured, which is highly challenging. Addressing heat demand in large urban areas would require a large amount of biomass that is rarely possible to produce in a sustainable manner nearby or that is rarely possible to deliver in a low carbon manner. Other renewable sources, such as heat from biogas, have also limited potential.

Energy recovery from waste is a win-win small-scale installation which may deliver sustainable and reliable energy supply and simultaneously address the needs of sustainable waste management. The realization of this approach could only be, however, realized in an agreement and cooperation with the nearby municipalities, for whom this concept shall be an element of their waste management strategy. The latter is not always possible due to other, conflicting interests.

Gas turbines and battery energy storage systems can significantly improve the flexibility of energy systems. Technologies which allow regulating electric power supply in a short time significantly contribute to the reliability of production and supply of electricity and heat.

The other way to make the system flexible is to provide energy services to customers. Whenever a retrofit of a heating plant takes place, it is useful to consider the future development of heat demand and supply. It is further useful to work on the reduction of peak demands and thus energy management of customers to avoid the need to address it through additional supply and/or storage.

The reconstruction of heat distribution is an important measure requiring significant investment, especially for the repair and reconstruction of steam distribution systems. Switching to heat distribution at lower temperatures may significantly reduce heat losses, as well as switching to hot water supply instead of steam. Sometimes, it is also beneficial to install a steam generator next to a customer instead of transporting steam for long distances.

The case studies illustrate that investment to extensively reconstruct both heat production and heat networks is high while required within a too short timeframe. Our case studies articulated that ***addressing it is hardly possible without one-off investment support from subsidy programmes***.

Obsah

1 Introduction

Member states of the European Union have set the objective to achieve climate neutrality by 2050. It is also aided by the updated target of a 55% greenhouse gas emission reduction by 2030 (from the original 40%) in comparison with 1990[3]. Although this target is not binding yet, the Czech Republic has simultaneously taken a major step towards a low-carbon economy by establishing the Coal Commission in the autumn of 2019. Even though the final date for the phase-out of brown coal mining and use in Czechia was not known at the time of writing[4], the transformation of the heating sector from a major share of coal to other, low-carbon sources is quite clear and inevitable at the moment.

This Report thus responds to the challenge to transform the heating sector most importantly in terms of climate and energy investments made in recent years and their conjunction with the expected investment need necessary for a low-carbon transformation of the sector by 2030. The objective of the Report is therefore to assess the flows of climate and energy investments in the heating sector in the period 2014-2019, including in terms of the current view of classification of sustainable investment, and to point out the investment need for a transition of the heating sector from coal to low-carbon, sustainable sources for heat supply. At the same time, we demonstrate on two case studies potential directions for development and diversification of activity in the sector.

1.1 Report structure

The following chapter puts the heating sector and its analysis in a broader context, including definition of the sector, its legislative ties and new requirements related to classification of sustainable investment. The third chapter summarizes the present state of the heating sector, including the historical context and current regulatory challenges and a broader context of coal phase-out. The fourth chapter analyses the present state of climate and energy investments in the heating sector, that is investments in the period 2014-2019 that contributed to reducing greenhouse gas emissions in the heating sector. The overview deals with sources of funding for the investments, mediating entities and support tools up to the final use. The fifth chapter models the investment need in the heating sector to meet the targets for 2030, with a view to the critical factor of the coal phase-out. The following chapter then uses two case studies to demonstrate potential directions of development and diversification of activity in the heating systems as well as an overview and analysis of expected support tools for the diversification and transformation. The seventh chapter sums up the main findings of the study and recommendations.

[3] https://ec.europa.eu/clima/policies/eu-climate-action/law_en

[4] The Coal Commission has recommended 2038, but the Czech Government has postponed the final decision for the time being. For more information, see Chapter 3.3.

2 Research framework

The study makes an analysis of structural changes in the heating sector as one of Czechia's energy sectors. In connection to that, the study maps the amount of necessary investments for transforming the heating sector in the context of meeting Czechia's climate targets.

Although the study is based on targets in the area of energy and climate for 2030, which are defined by the National Energy and Climate Plan, it puts the targets in the broader context of the EU 2050 Climate Neutrality Strategy. The study therefore does not consider 2030 to be the target state, but only an intermediate step for achieving the EU strategic objectives for 2050.

For this reason, the changes in the heating sector are seen from the perspective of long-term ("climate") sustainability of investment, and one of the methodological approaches employed is the use of the EU Taxonomy – system for classification of investment in light of its sustainability.

The investment classification system is introduced in conjunction to Regulation (EU) 2020/852 (Taxonomy) on the establishment of a framework to facilitate sustainable investment. The study authors regard the classification system as one of the fundamental factors defining the direction of transformation of each of the energy industries, including the heating sector.

The Czech Republic's heating sector is currently facing a fundamental change of both its fuel base and methods of further functioning. The heating sector is facing a phase-out of use of domestic coal, which currently still makes up an essential share of heat supply generation. The share of brown coal on the total heat supply (being 87.5 PJ) was approx. 46% in 2019; black coal constituted another approx. 11%[5].

This radical change is induced not only by performance of Czechia's commitments in the area of greenhouse gas emission reduction, but also the economic pressure caused by constantly rising prices of emission permits.

The coal phase-out will required massive investment in the source base, as coal is expected to be replaced, by 2025-2035, most importantly with natural gas, and partly with biomass and energy recovery from waste. Along with that, use of other types of RES in the heating sector will develop (besides biomass), most importantly large heat pumps as well as solar installations.

The substitution of natural gas for coal has to be seen as a transition solution, which will bring a significant greenhouse gas emission reduction compared to coal, but cannot be considered the target state from the carbon neutrality perspective. That is why it is necessary to plan and evaluate the energy sector transformation in light of the long-term objectives for 2050 without considering such methods of transformation that would prevent achieving those objectives (in accordance with the Taxonomy and Regulation (EU) 2020/852).

[5] See the 2019 Annual Report on Heating System Operation. http://www.eru.cz/documents/10540/5391332/Rocni_zprava_provoz_TS_2019.pdf/a4d8e72d-4f7b-4d02-b464-201bf1648479. Note: The heat supply amount only includes losses in the distribution system for independent licensed entities, not losses at producers who are also heat suppliers. These losses can be estimated at approx. 10 PJ. The reason for the difference is the reporting method from entities to ERU.

However, the heating sector not only has to respond to the above factors, but its transformation has to respect trends of increasing energy efficiency (particularly in buildings), which will result in decreasing need for heat supply. Undoubtedly, the heating sector transformation will be reflected in the price of heat, but to succeed, the transformation needs to find such paths that will lead to a price of heat acceptable for end customers[6].

Another factor to which the heating sector will have to respond is the promotion of the sector coupling[7] concept as the fundamental unifying concept of transformation of the whole energy system. Last but not least, it will have to respect the fact that large heating sources make significant contributions to the electricity generation balance and SVR provision.

2.1 Heating sector definition

The heating and cooling sector is significant in light of meeting climate and energy objectives. The sector can be split into two basic parts: (1) heat/cool supply systems with central heat sources (the term heating sector is used in the Czech Republic); (2) decentralized (individual) satisfaction of the heat/cool need.

The definition of the term heating sector, or delineation of the heating sector as a specific sector of the energy industry, is not quite stabilized. EU strategic documents, EU statistics and definitions of EU targets typically follow the heating and cooling sector. However, countries such as the CR have a much higher share of heat supply systems in the total final energy consumption for heating and cooling than the EU as a whole, which is why it is advisable to consider the heating sector separately. The energy industry transformation process towards decarbonization in countries with a high share of heat/cool supply from centralized systems will be significantly different from countries with prevalent decentralized methods of heat/cool provision.

Act no. 458/2000 Coll. (as amended) does not contain an explicit definition of the heating sector either. Nevertheless, it regards the heating sector as one of the energy sectors. Act no. 458/1997 Coll. explicitly defines the thermal energy supply system as a *"system comprising interconnected sources of thermal energy and heat distribution equipment used for thermal energy supply for heating, cooling, domestic hot water and technology processes, if operated based on a licence for thermal energy generation and a licence for thermal energy distribution; the thermal energy supply system is established and operated in the public interest".*

Moreover, Act no. 458/1997 Coll. lays down that a licence is not required for thermal energy production for a single customer's single building.

EU Directive 2018/2001 on the promotion of the use of energy from renewable sources uses the term "district heating/cooling" as "distribution of thermal energy in the form of steam, hot water or chilled

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[6] The price of heat after the transformation has to remain acceptable for customers, because in the long run, heat supply systems have competition in other technologies with which customers may satisfy their heating needs, including individual sources.

[7] https://irena.org/energytransition/Power-Sector-Transformation/Sector-Coupling

liquids, from central or decentralised sources of production through a network to multiple buildings or sites, for the use of space or process heating or cooling".

However, to define the framework of this study, we need to make an arbitrary decision on the limits of the term "heating sector". Several options are at hand:

1. include in the heating sector all entities that have a licence for production or supply of thermal energy;
2. include in the heating sector only heat/cool supply systems where the total thermal output of sources in the system exceeds a defined limit.

The first option in fact includes a large number of fundamental decentralized sources, such as smaller decentralized heat sources based on gas cogeneration, supplying heat only to a limited number of customers/buildings.

A significant part of the heat produced is consumed directly at industrial facilities for their own processes. Approximately 32% of the 161.7 PJ of heat produced (gross, 2019) was consumed in own businesses or facilities – these are predominantly "factory heating plants", which are not not included in category 35 of the classification of economic activity (CZ NACE) – Production and distribution of electricity, gas, heat and conditioned air.

The heating and cooling sector can thus be divided into the following categories:

1. local and decentralized heat/cool sources (without a licence for heat production and supply),
2. small systems with aggregate thermal output lower than 20 MWt,
3. heat/cool supply systems with thermal output above 20 MWt.

For the purposes of this study, the heating sector includes all licensed entities; see also the next chapter.

In terms of types of investment, the analysis follows investment in:

- own sources (typically replacement of fuel and process equipment), as well as other induced investment in the source (e.g., due to emission limits on conventional gaseous pollutants),
- systems for heat supply to end users (e.g., renovation of heat distribution lines in order to reduce heat loss),
- metering and control (e.g., due to integration of decentralized heat sources based on RES, such as solar collectors),
- heat accumulation equipment.

2.2 Legislation regarding licences

Doing business in the Czech Republic's energy sectors is only possible pursuant to law[8] based on a licence, issued by the Energy Regulatory Office for a defined territory. In terms of its legal

[8] Act no. 458/2000 Coll. on Business Conditions and Public Administration in the Energy Sectors and on Amendment to Other Laws (Energy Act)

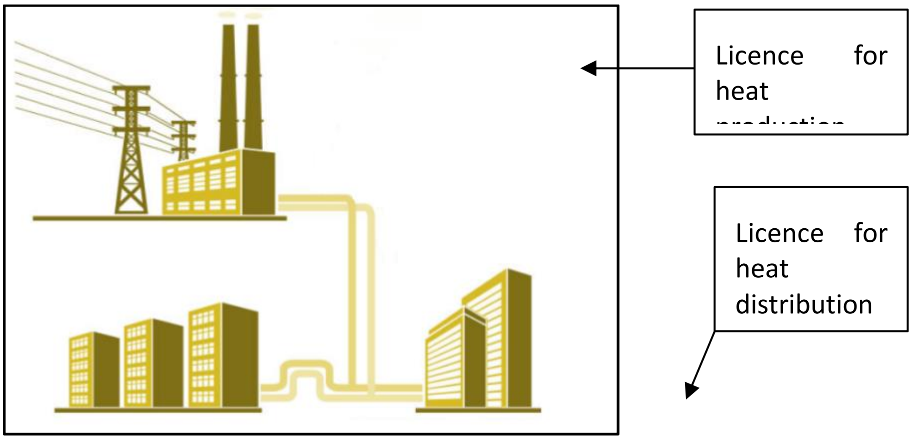
characteristics, the licence can be described as a public subjective right awarded by a state authority, authorizing the licensee for certain activity, specifically performance of defined business activities in the energy sector. In terms of its legal nature, the licence can be equalled to other public subjective rights authorizing one for a specific activity, such as the trade licence. However, entities that are not required to have a licence are also active on the energy market, including the heating sector. With some simplification, it can be said that the licence is only required if the activity in the energy industry shows substantial signs of business, i.e., if it is a consistent profit-making activity in order to make profit. The definition of doing business in the Czech legal system can be derived from the Civil Code[9]. A licence for thermal energy production is awarded for no more than 25 years, and a licence for thermal energy distribution can be issued for an indefinite period of time.

In the heating sector, the law requires a licence for thermal energy production and thermal energy distribution, but no licence is required under the law for thermal energy production for a single customer's single building. In practice, this concerns cases of operation of domestic or block boiler rooms for thermal energy production for households or various industrial compounds or, e.g., hospitals, where the consumers (e.g., the hospital) will not provide their own production of thermal energy in the compound. For this reason, they typically agree heat supply with another entity that provides the heat generation. Very often, this is even done using production equipment owned by the consumer. In other words, the hospital, for example, owns a heat generation facility in its compound (a gas boiler room, cogeneration plant, etc.) but entrusts the operation of the facility to another business entity. By nature, these thermal energy production plants are separated from the central heat supply system. No licence is required in such cases. There are cases in practice, however, where one building block comprises several buildings with separate administration, owned by different owners, with one of the buildings housing a thermal energy production facility producing thermal energy for these several owners. In this case, the law says the thermal energy is not produced for a single customer's single building, and thus requires a licence.

Unfortunately, the above legislative status of heat producers and operators of heating facilities in the Czech Republic, where in some cases they are subject to the obligation to run their activity based on a licence and not in others, determines the availability of data on the quantity of heat produced in the Czech Republic for this study. Although the Energy Regulatory Office publishes its reports on operation of heating systems in the Czech Republic periodically, it admits that all the data contained in the reports are obtained only from licensed entities to whom it has issued licences for thermal energy production.

[9] Act no. 89/2012 Coll., the Civil Code, Section 420, pursuant to which "whoever performs, independently and at his own account and responsibility, profit-making activity in the method of trade or similar with the intention to do so consistently for the purpose of making profit, is regarded with a view to such activity as an entrepreneur".

Figure 1 Block diagram of a heating plant with a licence for thermal energy production and distribution



Just like the Energy Regulatory Office statistics and operation report focus only on large heating plants with licences for thermal energy production and distribution, our study too will focus only on future investment in the heating sector for which the investors will need a licence necessarily.

2.3 EU taxonomy and the heating sector[10]

The so-called sustainable investment taxonomy constitutes a significant step in the transition to a low-carbon economy. The taxonomy will continue to define which activities can be regarded as sustainable, and is a key component for determining "sustainability" of investment. The present Report therefore assesses investment in the heating sector from the point of view of requirements and criteria of the Taxonomy. The following section thus presents the main principles of the Taxonomy and then focuses on the Taxonomy criteria connected to the heating sector.

2.3.1 Basic approach

Achievement of EU sustainable development targets and, most importantly, of strategic goals in the area of climate neutrality (goals for 2050) requires directing finance to sustainable investment. Harmonization of economic activity and supporting financial tools with environmentally sustainable goals plays an important role here. That is why a classification system has been developed at the EU

[10] The following text is made based on: (1) Regulation (EU) 2020/852 of 18 June 2020 on the establishment of a framework to facilitate sustainable investment (hereinafter, the Regulation), (2) Technical Report – Taxonomy: Final report of the Technical Expert Group on Sustainable Finance (3/2020), hereinafter, the TR, and (3) Taxonomy Report – Technical Annex (3/2020), hereinafter, the TA.

level that enables identification whether any given economic activity is environmentally sustainable. Along with that, an obligation is instituted for financial market participants to publish for investors in a harmonized manner their method of assessment of their investments in terms of meeting of environmental objectives. A similar obligation rests on large companies, which shall classify their activities and investments in light of meeting of the environmental goals specified below. The investment classification also applies to strategic policies at the member state level and that of the whole EU, e.g., 40% of investment from the European Fund for Strategic Investments should go to climatically sustainable infrastructure and innovation projects.

Regulation 2020/852/EU[11] establishes a framework for sustainable funding, and defines the term sustainable investment as such, and further develops publication obligations under Regulation 2019/2088 on sustainability-related disclosures in the financial services.

The main classification (Taxonomy) principles were approved at the policy level in December 2019.

Details on investment classification, individual environmental objectives and (proposed) classification criteria can be found in the Technical Report (TR) and the Technical Annex (TA) to the Report. The TR summarizes recommendations of the Sustainable Finance Technical Group, set up by the European Commission[12].

The TR sets a framework and defines environmental objectives and procedures for implementation of the sustainable investment classification. It also discusses new legal requirements for financial market participants, large companies and EU member states.

The Regulation in turn establishes a system where financial market participants on the one hand are obliged to publish how they assess sustainability of their financed projects and assets. On the other hand, (large) companies are obliged to assess their activities and new projects in light of meeting of environmental objectives defined by the Regulation. The system is generally focused on promoting investors' decision-making towards a low-carbon, resilient and efficient economy. The investment classification (Taxonomy) is a fundamental instrument for promoting the "sustainable financing" concept.

The investment assessment/classification is based on six criteria (measuring environmental objectives):

1. Climate change mitigation measures
2. Climate change adaptation measures
3. Sustainable use and protection of water and marine resources
4. Transition to a circular economy
5. Pollution prevention and control measures
6. Protection and restoration of biodiversity and ecosystems

[11] https://eur-lex.europa.eu/legal-content/CS/TXT/PDF/?uri=CELEX:32020R0852&from=EN

[12] https://ec.europa.eu/info/publications/sustainable-finance-technical-expert-group_en

The purpose of the criteria is to make a plan (investment) achieve a significant improvement in at least one of the criteria, without posing a significant risk of worsening of the 5 remaining criteria, and while meeting the minimum requirements[13].

The key principles implemented by the Regulation include:

- Financial market participants offering financial products in Europe now have to include publication with a reference to the Taxonomy. The publication requirements differ depending on financial product category – see the definitions in Regulation 2019/2088[14] sustainability-related disclosures in the financial services
- Companies that are subject to the information publishing requirements pursuant to the Non-financial Report Directive (NFRD) have to publish information with a reference to the Taxonomy.
- The technical verification criteria will be developed in two phases: The first technical criteria for activities that significantly contribute to climate change mitigation or adaptation will be adopted by the end of 2020 and enter into force from 2022.
- The second set of technical screening criteria, covering economic activities materially contributing to the other four environmental objectives, will be adopted by the end of 2021 and come into use at the end of 2022.

The definition of sustainable investment pursuant to Regulation 2019/2088 is:

an investment in an economic activity that **contributes to an environmental objective**, as measured, for example, by key resource efficiency indicators on the use of energy, renewable energy, raw materials, water and land, on the production of waste, and greenhouse gas emissions, or on its impact on biodiversity and the circular economy, **or** an investment in an economic activity that **contributes to a social objective**, in particular an investment that contributes to tackling inequality or that fosters social cohesion, social integration and labour relations, or an investment in human capital or economically or socially disadvantaged communities, **provided** that **such investments do not significantly harm any of those objectives** and that the **investee companies follow good governance practices**, in particular with respect to sound management structures, employee relations, remuneration of staff and tax compliance;

Regulation 2020/852 refines this definition further and says that a sustainable investment is only such investment that qualifies pursuant to the Regulation as sustainable, thus brings a major effect in light of one of the above environmental objectives, without significantly harming any of the remaining environmental objectives. The Regulation and the associated legislation then define for different types of economic activities what is a significant contribution and what is the limit for not harming.

[13] So-called safeguards – e.g., OECD Guidelines on Multinational Enterprises and the UN Guiding Principles on Business and Human Rights, http://mneguidelines.oecd.org/mneguidelines/ and https://www.ohchr.org/documents/publications/guidingprinciplesbusinesshr_en.pdf

[14] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R2088&from=EN

The European Commission shall adopt (by 1 June 2021) a legislative deed in devolved power specifying how the obligations in the area of publishing information about companies should be applied in practice. The document shall reflect differences between non-financial and financial companies.

The classification system (Taxonomy) distinguishes between two basic types of activities:

- **Enabling activities** – Economic activities where the provision of products or services enables a significant contribution in other activities (create preconditions for them).
- **Economic activities**, resulting in products significantly directly contributing to meeting of environmental objectives.

Examples of "enabling activities" include: manufacturing of components and equipment, communication technologies, research, etc. An example of economic activities directly contributing to meeting of environmental objectives is low-carbon energy production. The activities/investments must not cause "lock-in", i.e., conservation of assets (freezing the situation) endangering the long-term meeting of environmental objectives[15]. Significant environmental benefit has to be based on a life cycle assessment.

2.3.2 Transition activities

If there are no technologically and economically feasible low-carbon alternatives to an activity, such an activity is regarded as having a significant benefit for climate change mitigation if:

- its GHG emissions are at the level of best indicators in the sector,
- it does not prevent development and implementation of low-carbon alternatives, and
- does not cause a lock-in of carbon-intensive assets (technologies, investments) with a view to their lifetime.

For assessing whether an economic activity meets the environmental criteria, the Commission shall adopt a respective set of technical screening criteria. Those criteria should be based on the technical neutrality principle and include both short-term and long-term impacts of the technology. The criteria shall define minimum requirements for each activity.

Specific requirements for these criteria include, among other things, that the **use of fossil fuels for electricity generation will not be regarded as a sustainable activity**, and the criteria will be subject to periodic revisions by the Commission.

[15] Erickson et al. (2015) (https://iopscience.iop.org/article/10.1088/1748-9326/10/8/084023/meta) define the carbon lock – in: The term "carbon lock-in" refers to the tendency for certain carbon-intensive technological systems to persist over time, 'locking out' lower-carbon alternatives, and owing to a combination of linked technical, economic, and institutional factors. These technologies may be costly to build, but relatively inexpensive to operate and, over time, they reinforce political, market, and social factors that make it difficult to move away from, or "unlock" them. As a result, by investing in assets prone to lock-in, planners and investors restrict future flexibility and increase the costs of achieving agreed climate protection goals.

2.3.3 Exclusion of fossil fuels

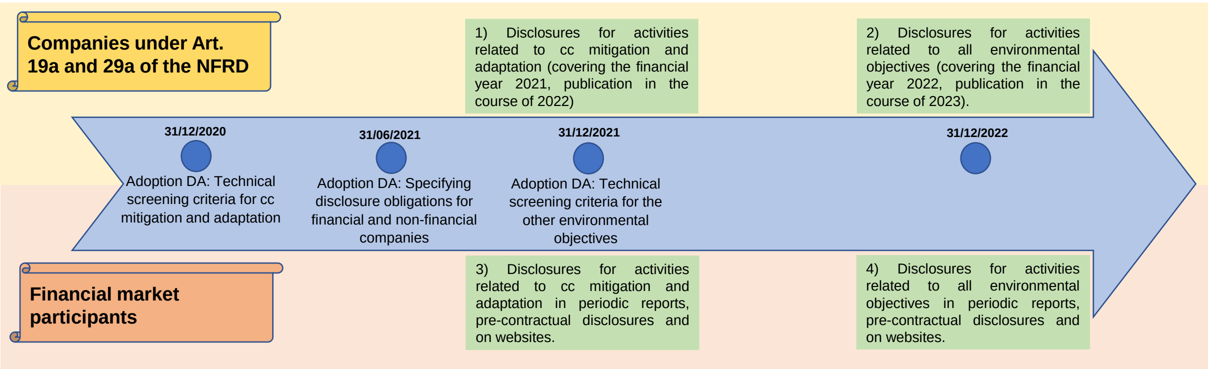
The transition to a low-carbon economy will involve a gradual phase-out of some economic activities, such as energy generation based on fossil fuels. Even though there may be certain short-term advantages for reducing environmental damage caused by such activities, they cannot be regarded as "significant" contribution to climate change mitigation. The classification (taxonomy) should therefore exclude activities that would ultimately undermine the climate change mitigation objectives if their operation is conserved in the long run.

The excluded activities include, in particular activities associated with storage and/or transport of fossil fuels (including liquid and gaseous). Energy generation from gaseous or liquid fossil fuels should significantly contribute to climate change mitigation only if it meets the technical screening criteria, which are recommended at <100 g CO_2e/kWh, decreasing in five-year steps to 0 g CO_2e/kWh by 2050[16].

2.3.4 Time frame

Financial market participants have the first reporting obligation pursuant to the Taxonomy as of the end of 2021. Large companies have the obligation in the course of 2022 in connection with the financial year 2021. The technical criteria will be published by the Commission by the end of 2020. Additional publication requirements relate to the end of 2022. The Commission will also publish technical criteria for assessment of environmental objectives three to six by the end of 2021. The following diagram (Figure 1) describes the whole process timing.

Figure 2 Diagram of obligation to publish information about investment sustainability



Source: Taxonomy: Final report of the Technical Expert Group on Sustainable Finance, EU 2020

[16] The current transformation from coal to natural gas at larger sources above 50 MW is effectively the dominant path under Czechia's specific conditions. The point is that investments in system transformation must not be made in a way that they preclude further development towards decarbonization. Essentially, the transformation from coal to NG need not be the case if it will be possible in future to replace fossil NG with a low-carbon/zero-carbon alternative, thus meeting the specific CO_2 emission criteria.

2.3.5 Specific requirements for companies in the heating sector

Specific requirements for companies (investor) include publication of **which environmental objective** the investment contributes to, and to **what percentage** the investment is in accordance with the classification, including breakdown into investments meeting the requirements and so-called transient investments. Furthermore, the companies shall publish their **turnover of assets** that are **in accordance with the classification** and costs (investment, operating if relevant) of achieving compliance of the activity with the Taxonomy requirements.

The Technical Report (TR) further specifies categories of economic activities – sectors – to which environmental criteria 1 to 6 apply. The heating sector being analysed is subject primarily to technical criteria for environmental objectives 1 and 2 – mitigation and adaptation (Table 1).

Table 1 Technical criteria associated with heating sector[17]

	Climate change mitigation (Substantial Contribution)			Climate change adaptation (DNSH)	Water (DNSH)	Circular economy (DNSH)	Pollution (DNSH)	Ecosystems (DNSH)
	Own performance	Enabling activities	Transitional activities					
NACE Activity								
Production of Electricity from Gas	✔		✔	✔	✔		✔	✔
Production of Electricity from Bioenergy (Biomass, Biogas and Biofuels)	✔		✔	✔	✔	✔	✔	✔

[17] Adapted from Taxonomy: Final report of the Technical Expert Group on Sustainable Finance (TR), Chapter 5

District Heating/ Cooling Distribution	✓		✓	✓		✓	✓
Cogeneration of Heat/Cool and Power from Gas	✓	✓	✓	✓		✓	✓
Cogeneration of Heat/Cool and Power from Bioenergy (Biomass, Biogas, Biofuels)	✓	✓	✓	✓	✓	✓	✓
Production of Heat/Cool from Gas (not exclusive to natural gas)	✓	✓	✓	✓		✓	✓
Production of Heat/Cool from Bioenergy (Biomass, Biogas, Biofuels)	✓	✓	✓	✓	✓	✓	✓

Note: Technical criteria for objective 2 (adaptation) include “enabling activities” unlike those for objective 1.

The TA contains details on the proposed criteria. The activities are classified using NACE codes[18]. A selection of criteria for the heating sector – combined heat and power generation, heat generation and heat supply – follows, with proposed thresholds for identification of investment as sustainable. Specified criteria for assessment of compliance with the six environmental objectives are shown for each activity. Criteria relating to objectives 1 and 2 (mitigation and adaptation) are crucial for the heating sector. Furthermore, there is a list of the most important criteria for the two objectives and activities of relevance for the heating sector (the selection excludes activities relating to use of RES except biomass in the heating sector).

Table 2 Criteria relating to objective 1 – mitigation

Electricity generation from gas	Specific emissions for the whole life cycle below 100 g CO2e/kWh, with a decrease to 0 g CO2e/kWh by 2050 (reducing the 100 g limit every 5 years) Emissions – compliance with BAT (best available technology) or limits under BREF[19]
Electricity generation from biomass, biogas and biofuels	Reduction in emissions of more than 80% compared to fossil fuels (relative fossil fuel comparator under RED II), with a 100% reduction by 2050. 80% reduction means achieving specific emissions below 100 g CO2e/kWh Digestate is used as fertiliser or soil quality improver Methane releases are monitored according to a monitoring plan Emissions – compliance with BAT or limits under BREF
Heat/cool distribution (supply system and related infrastructure)	Construction and operation of supply systems is compliant to the Taxonomy if it meets the definition of an efficient heat supply system[20].
Cogeneration and heat generation from gas	Combined specific heat/cool and electricity emissions below 100 g CO_2e/kWh, with a decrease to 0 g CO_2e/kWh by 2050 (reducing the 100 g limit every 5 years)

[18] Classification of economic activities (Nomenclature statistique des activités économiques dans la Communauté européenne)

[19] https://www.mpo.cz/cz/prumysl/ippc-integrovana-prevence-a-omezovani-znecisteni/aktuality/zavery-o-bat-pro-velka-spalovaci-zarizeni---231318/

[20] 50% from RES or waste, 75% from cogeneration or 50% from a combination

	Emissions – compliance with BAT or limits under BREF
Cogeneration and heat generation from biomass, biogas and biofuels	Same as electricity generation

Criteria relating to objective 2 – adaptation

The assessment differs according to the primary purpose of the activity: whether it is an activity directly aimed at adaptation or one enabling adaptation. The former case are activities

- Reducing risks of climate change as much as possible
- At the same time, the activity must not endanger adaptation options in other sectors
- Simultaneously, the reduction in the climate change risk has to be measurable.

The criteria for the latter case are:

- The activity enables reduction to a climate change risk in other activities

If the purpose of the investment is objective 2 (adaptation), criterion thresholds are defined so that meeting of objective 1 is not significantly endangered. The following are mentioned explicitly:

Cogeneration from gas and biomass (same as electricity generation)	Limit of 262 g CO_2e/kWh (electricity) as the regional average (applies to cogeneration from both gas and biomass) BAT: the lowest limit is BAT-AEL[21]
Heat/cool distribution (supply system and related infrastructure)	The direct greenhouse gas emissions from this activity are equal to or lower than 262 g CO2e/kWh in the EU or the regional average intensity of electricity generation life cycle emissions in other regions of the world.
Heat/cool generation from gas	No increase to emission intensity from an activity as a consequence of adaptation; the activity must not have an emission intensity above the average for all electricity generation facilities

[21] BAT AEL: Best available technology associated emission levels, BREF: Best available techniques Reference Document (https://ec.europa.eu/environment/legal/law/12/pdf/2_Grimeaud_BAT.pdf)

3 State of the heating sector in the CR

The following text briefly describes the development of the heating sector in the Czech Republic up to this day, where its fuel base is changing significantly above all. The regulatory environment and differing approach to heating sector entities significantly affects larger entities, and disadvantages then in some cases with stricter legislation. An important cost item for large systems is the emission permits, which force a transition to other fuels in accordance with the original intention. This is associated with high investment in new equipment and savings in heating sector systems.

3.1 Overview of the heating sector in the CR

The heating sector (district heat supply) has a long history in Czechia, dating back before World War II. The chief reason for developing these systems was industrial development in the interwar period and the need to provide process heat besides electricity supply. Heating systems began to supply heat to residential development as well, and were mostly based on combined heat and power generation. In the mid 20th century, there were typically systems with a source based on domestic coal, with steam distribution lines, which is a design unacceptable for new development at present[22]. Housing development in the latter half of the 20th century assumed generally heating of apartment buildings (largely prefabricated) based on larger heating systems generally reliant on combined heat and power generation. Since the 1980s, many areas have been supplied from new natural gas sources, but they are mostly only heating-oriented, without cogeneration.

Thus, the largest systems were built in Prague, Plzeň, České Budějovice and Brno, Olomouc and the Ostrava conurbation. There are systems supplied via long-distance heat supply lines from more remote sources (Mělník-Praha, Opatovice-Pardubice and Hradec Králové). A more recent project has just been implemented for tapping (waste) heat from Temelín Nuclear Power Plant, which will displace coal and some of the natural gas from in České Budějovice. There are thus dozens of large systems, supplied from a centralized source with heat distribution lines. Companies in the Association for District Heating alone supply about 60 areas with over 10 thousand inhabitants.

The energy industry underwent fundamental structural changes in the 1990s. A large part of the heating plants became independent heat and electricity producers and suppliers. Massive investment has been made approximately since then, first in desulphurisation and compliance with emission limits for other pollutants. The fuel base changed significantly, with some medium-sized and larger sources replacing a part of the fossil fuels with combusting heat together with biomass. Separate biomass combustion was implemented mostly by building new sources with a capacity up to 10 MW due to their availability. Smaller heat sources of single MW and, most importantly, new individual heating sources, have been implemented largely as natural gas heating plants[23]. The expected future

[22] Where not forced by process equipment need, the steam distribution lines are being replaced with hot-water lines.

[23] The share of “small” CHP heat sources is approx. 5% (up to 1 MWt) and 6% (sources between 1 and 5 MWt) of the installed thermal capacity of CHP.

replacement of coal in the larger sources will be with natural gas; however, it will be used for heat generation partly even in the base load given the widespread nature of large heat supply systems in the CR. Several areas expect installation of waste energy recovery facilities, but these projects lack greater public support so far. Smaller areas are assumed to develop decentralized sources with gas cogeneration.

The changes in heating plant ownership have led to the sector being largely decentralized at present, not only for technical reasons of supplying separate areas with denser development, but also in terms of ownership. The ERO has issued 656 licences for heat production and 646 licences for heat distribution to entities supplying heat to third parties. There are 102 companies licensed for total thermal output above 20 MW and 524 with above 1 MW.

At present, the country has approx. 1800 heat sources with an installed capacity above 5 MWt and approx. 17 000 smaller ones with an installed capacity between 0.2 and 5 MWt. The share of district heat supply in the total supply was approximately 40% of the households at the end of 2015[24]. The number of households connected to district heating systems has grown slightly in recent years, since half of the new flats are connected to DHS; another frequent form of heating is a building heat source. Less than 10% of flats have a heat source directly in the flat.

The ERO statistics[25] show the shares of fuels. The distribution of supply and fuels used is very uneven across different regions of the CR. Households consumed 33,657 TJ in 2019, which is 42% of the total consumption; industry consumed 22,279 TJ (28% of the total) and the trade and service sector used 18,575 TH (23% of the total). The total installed thermal capacity of heat generation facilities was 41,348.3 MW at the end of 2019. The total length of the distribution lines was 7,479 km in 2020, including 1,360 km of steam lines, 3,462 km of warm-water lines and 2,657 km of hot-water lines.

District heat generation in the CR is implemented both using heating plant sources (heat only) and combined heat and power generation (CHP) sources. About 65% of the heat generation in 2019 was from CHP.

The total gross heat generation in 2019 was 161 PJ, and the net generation was 152 PJ (excluding own process consumption of heat). Heat supplies to third parties were 87.5 PJ, excluding supply to cover losses in DH pipelines in cases where the licensed producer is also the distributor. After subtracting heat loss in DH pipelines, amounting to 6.7 PJ, for licensed suppliers who are not producers, the heat sales to end customers were 80.8 PJ. The remaining heat was heat supplies to own companies (at the place of generation) and heat loss.

For more information, see http://www.eru.cz/documents/10540/5381883/Rocni_zprava_provoz_ES_2019.pdf/debe8a88-e780-4c44-8336-a0b7bbd189bc

[24] Energo 2015 Survey, Czech Statistical Office, available from www.csu.cz

[25] 2019 Annual Report on Heating System Operation. http://www.eru.cz/documents/10540/5391332/Rocni_zprava_provoz_TS_2019.pdf/a4d8e72d-4f7b-4d02-b464-201bf1648479. Note: The statistics for sectors exclude a part of unidentified heat distribution. This amount should be insignificant in light of the reported data.

The heat supply amount has been decreasing for several years, mostly caused by decreasing numbers of day-degrees (growing average temperatures in key months of the heating season in the CR) and implementation of efficiency measures by heat consumers[26].

Heat generation from CHP has been decreasing from larger sources, inter alia, due to the low power electricity prices on the market. Electricity generation from CHP has been growing in the segment of small cogeneration plants for hundreds of kW to single MW based on natural gas.

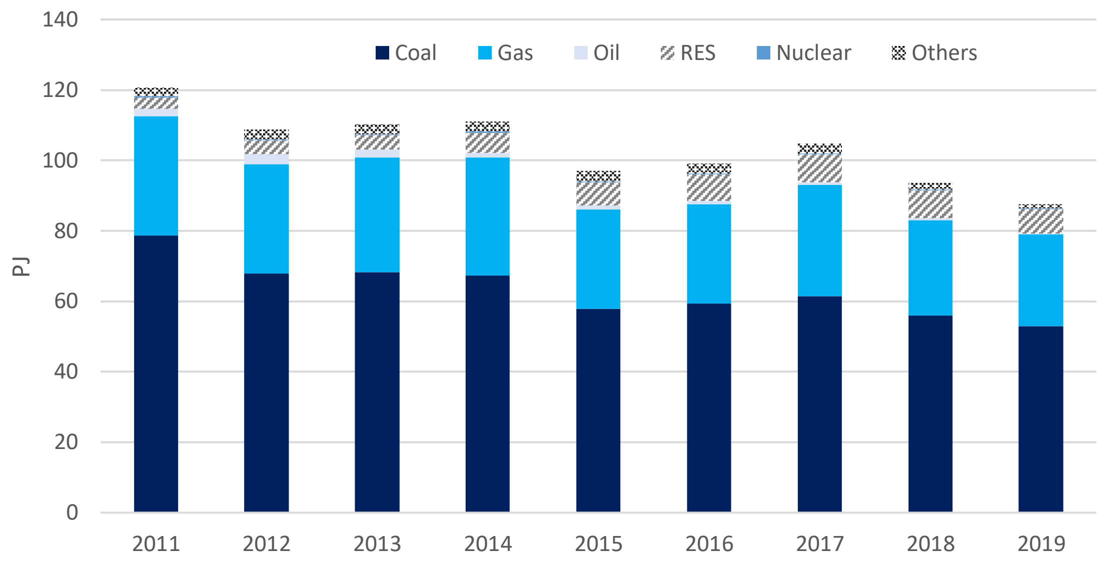
Table 3 Heat supply by fuel [PJ][8]

Fuel	2011	2012	2013	2014	2015	2016	2017	2018	2019
Coal fuels	78.6	67.9	68.2	67.3	57.9	59.4	61.4	56.0	52.9
Natural and mine gas	34.0	31.0	32.7	33.5	28.1	28.1	31.6	27.0	26.1
Petroleum fuels	2.0	2.8	2.1	1.3	1.2	1.0	0.9	0.5	0.2
RES (OZE)	3.3	4.1	4.2	5.8	6.6	7.5	7.8	8.1	7.0
Nuclear fuel	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Other fuels	2.4	2.7	2.9	2.9	3.0	3.0	2.9	1.9	1.1
Total supplies	120.6	108.8	110.5	111.0	97.1	99.2	104.9	93.7	87.5

The table above is also illustrated by Figure 1 below.

[26] See, e.g., https://knoema.com/nrg_chdd_a/cooling-and-heating-degree-days-by-country-annual-data

Figure 3 Shares of fuels in heat supplies (PJ)



The primary fuel, used the most in Czechia's heating sector is still coal and coal fuels, making up approximately 60% of the fuel mix; approx. 80% of the coal is used in combined heat and power generation. However, this share has decreased some 20 percentage points compared to the fuel mix in 2011. The share of natural gas in heat supply remains more or less constant around 30% of the fuel mix. The consumption of petroleum fuels (primarily heating oils) has registered a relatively major decrease in the last period; their share in the fuel mix was only 0.2% in 2019. Conversely, the RES category of fuels has been on the rise, making up approx. 8% of the fuel mix in 2019, with biomass being the greater part.

In absolute figures and in more detail, the share of biomass in heat supply is evident (6.5 PJ in 2019 compared to approximately 2 PJ in 2010), and the share of biogas has doubled compared to 2010 (0.54 PJ in 2019 compared to 0.25 PJ in 2010).

3.2 Challenges in the heating sector

3.2.1 From a monopoly to a competitive environment

Operation of extensive DH systems built in the mid 20th century was originally regarded as a sector falling into the category of so-called natural monopolies, because DH was usually the only available source of thermal energy in the respective area. DH systems required state regulation. However, the situation changed radically as a consequence of the overall national gas system installation in the 1990s, because smaller gas boilers and other local heat sources began to compete with conventional heating plants. At present, natural gas is available in most of the cities, towns and larger villages in the Czech Republic. At the same time, the gas boiler technology improved massively, leading to automation. Heat pumps have undergone a revolution; thanks to major technical improvements coupled with price decreases, they are another major competitor to district heating today. Practically every customer connected to district heating thus currently has the option to switch to an alternative heating methods, and the option is used. A change in the heating method admittedly requires a building permit, through which an air protection authority issues its binding position statement, and the investor has to prove with an energy review that using heat from a district heating system is not economically acceptable to him.

Given the almost universal availability of substitute to district heating and its factually non-existent legislative protection in the Building Act and other related regulations, one has to assume that district heating is essentially in a competition with other heating methods. Thus, the heating sector has changed from its original monopoly to a competitive economic environment.

3.2.2 Regulatory

Although most experts do not perceive the heating sector as a purely monopoly environment, the price of heat from all licensed sources is still regulated. The regulation is provided by the Energy Regulatory Office in the form of so-called factual price regulation pursuant to Section 6 of Act no. 526/1990 Coll. on Prices, as amended, consisting in setting of certain conditions for calculation and negotiation of thermal energy prices. These conditions are specified in the Energy Regulatory Office Price Decisions, and are binding for all licensed suppliers of thermal energy. Currently in force is Energy Regulatory Office Price Decision 6/2020 of 29 September 2020 on Thermal Energy Prices.

As part of the factual regulation, the price of heat may only reflect economically justified costs, adequate profit and value added tax in accordance with the Price Decision. The thermal energy price for the calendar year is calculated for one price area in the same way for points of consumption at the same level of transmission; each calculation may only contain relevant economically justified costs, adequate profit and a corresponding quantity of thermal energy.

The thermal energy price is calculated as preliminary in the course the calendar year and as final after its end. The preliminary price is based on a preliminary calculation, which may only include expected economically justified costs, adequate profit and the expected quantity of thermal energy in the calendar year. The final price is based on the final calculation, which includes the actually expended economically justified costs and corresponds to revenues from the thermal energy and the actual quantity of thermal energy for the completed calendar year.

In terms of inspection of justified costs and adequate profit by the Energy Regulatory Office, the price of heat regulation differs from price regulation for natural monopolies, such as electricity and gas distribution. Holders of licences for heat generation distribution may do business in other sectors as well, which complicates inspection of justified costs. In the next period, the ERO will apply a different approach, strengthening regulation towards protected customers, i.e., households and small consumers, while strengthening market principles between equally powerful large entities.

3.2.3 Legislative

Reform of the emission trading scheme (EU ETS) for the period after 2020

The EU ETS (European emission trading scheme) was launched in 2005 and requires facilities meeting certain parameters (combustion sources above 20 MW of installed thermal capacity) to monitor, report and verify greenhouse gas emissions. A so-called emission permit, or EUA (European allowance), has to be turned in for each verified tonne of emissions. The emission allowances have been primarily auctioned since 2013 (facilities have to buy them in auctions, or on a secondary market), as well as partially allocated free of charge under predefined and verified conditions, to endangered sectors and for electricity generation modernisation.

Basic parameters of the EU ETS:

- works in 30 countries (all 27 EU member states plus Iceland, Liechtenstein and Norway)
- restricts emissions from approx. 11,000 stationary facilities (power plants, heating plants and other industrial facilities) and airlines working among these countries
- covers approximately 45% of greenhouse gas emissions in the EU.

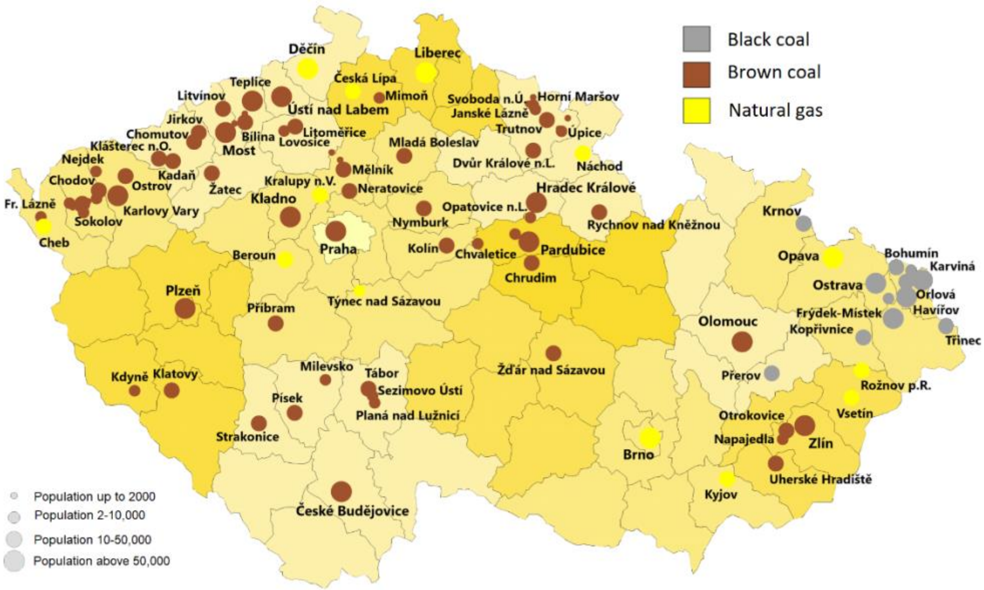
Purchases of emission allowances encumbered 98.9% of heat generation from coal and 59.4% of heat generation from natural gas in 2018.

Fig. 4 and 5 show all the fossil fuel heating plants included in the EU ETS in 2018 and 2020. A comparison of the two maps shows that some of the sources[27] "fell out" of the system between 2018 and 2020 due to the increase in the emission allowance price along with decreasing allocation for heat and electricity[28], thus costs of their purchase. This trend is going to accelerate further with increasing allowance prices, and is a threat to "larger" district heating sources. Moreover, leaving the EU ETS also means a risk to meeting of the CR's objectives for sectors outside the EU ETS under the Effort Sharing Regulation (ESR).

[27] These sources include, e.g., Kdyně, Klatovy, Písek, Ostrov, Litoměřice, Mimoň, Děčín, Rychnov nad Kněžnou, Uherské Hradiště, Kyjov.

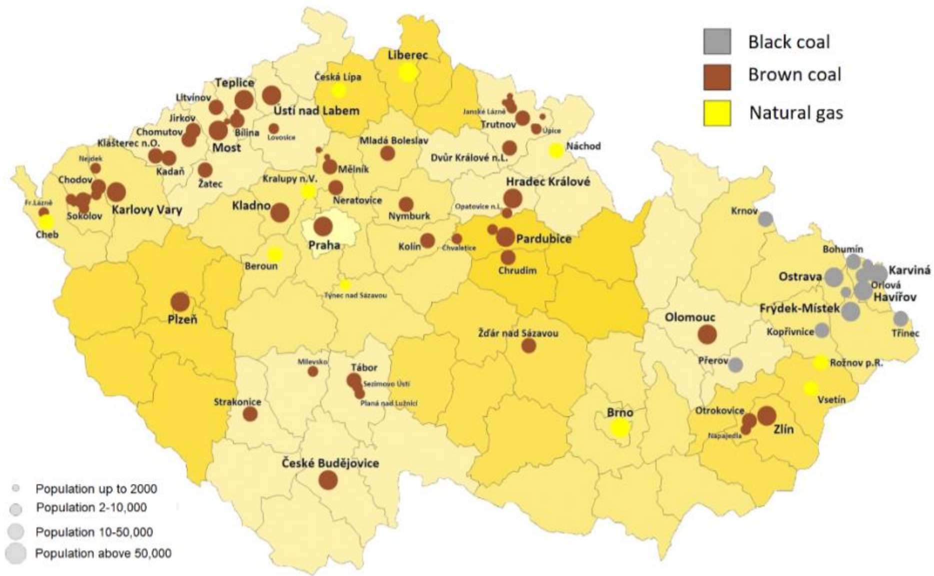
[28] Free allocation for electricity hardly applied to sources nearing the 20 MWt threshold.

Figure 4 Fossil fuel heating plants included in EU ETS in 2018



Source: TS CR

Figure 5 Fossil fuel heating plants included in EU ETS in 2020



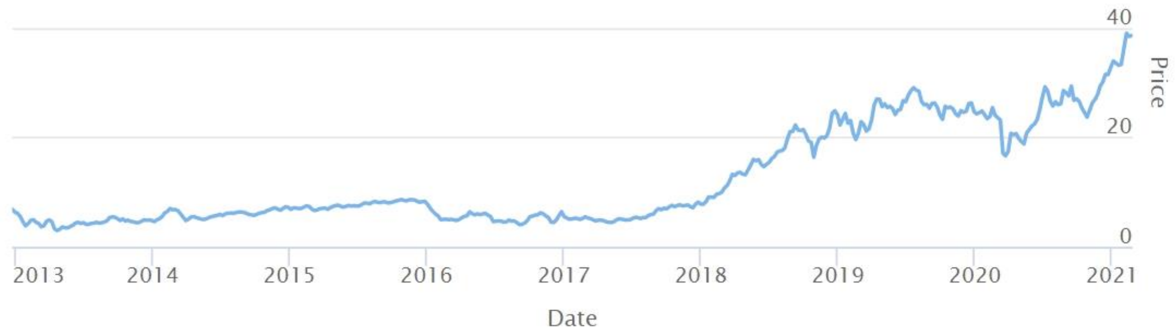
Source: TS CR

Current situation

The revised EU ETS Directive sets a transition from the 3rd trading period (2013-2020) to the 4th trading period (2021-2030). The Directive was published in March 2018 in the Official Journal of the EU, and contains primarily the following measures:

- increasing the linear reduction factor (LRF), reducing the total amount of allowances in the system from the current 1.74% to 2.2% a year
- retaining free allocation for specific sectors, including the heating sector, at the 2020 levels
- retaining the free allocation option for energy sector modernisation
- adding a new mechanism, the Modernisation Fund, to allow selected low-income EU member states (including Czechia) investment in modernisation of selected sectors.

Figure 6 Trend of spot price of EUA permit in EUR for 2013-2020[29]



The Directive revision has resulted in a rapid increase in the allowance price from 5-7 EUR in 2017 to 25 EUR at the end of 2018. Since then, the allowance price has oscillated above 20 EUR[30]. Revenues from the allowances are a major source of income for the state budget.

Costs of permits and factual regulation of heat prices

For the purposes of thermal energy price regulation, item (1.2) of Annex 1 to Energy Regulatory Office Price Decision 6/2020 on Thermal Energy Prices sets conditions under which the costs of purchasing the necessary amount of emission permits can be regarded as economically justified in the factually regulated thermal energy price.

[29] ember-climate.org/data/carbon-price-viewer/, October 2020

[30] The emission allowance price even exceed 40 EUR on 11 February 2021. The impact of the allowance price on the price of heat from the source can be documented with the following simplified example: Assuming the fuel-to-heat ratio for a coal source of 1.2 GJ/GJ, the coal emission factor of 0.1 t/GJ, the allowance price of 40 EUR and the exchanged rate of 26 CZK/EUR, the costs of CO_2 in heat from coal make approx. 125 CZK/GJ. The costs of CO_2 thus comprise up to half the heat production costs at the source.

If a thermal energy supplier has made a sale and purchase of emission permits, it is necessary to appraise the number of emission permits that have to be purchased beyond the emission permits allocated to the thermal energy generating facility and not utilized by the facility to which the greenhouse gas emission permit relates. Under said conditions, the necessary purchase of additional emission permits is appraised by no more than the average price for the calendar year 2018, based on a weighted average of all the trades executed on the spot market of the respective stock exchange in the European Union.

In determining the average price of the emission permit, the Energy Regulatory Office has used in the long run the weighted average of all trades executed on the spot market of the European Energy Exchange (EEX) located in Germany, since the exchange is selected for emission permit trading for the EU for the 3rd trading period. The average price of the emission permit for 2019 is calculated from data on trades executed on the spot market of the European Energy Exchange (EEX) as a weighted average for closing prices for each trading day, converted to CZK using the CNB exchange rate for the day, the weight being the quantity of emission permits traded for each trading day. The following table shows the resulting average price of permits.

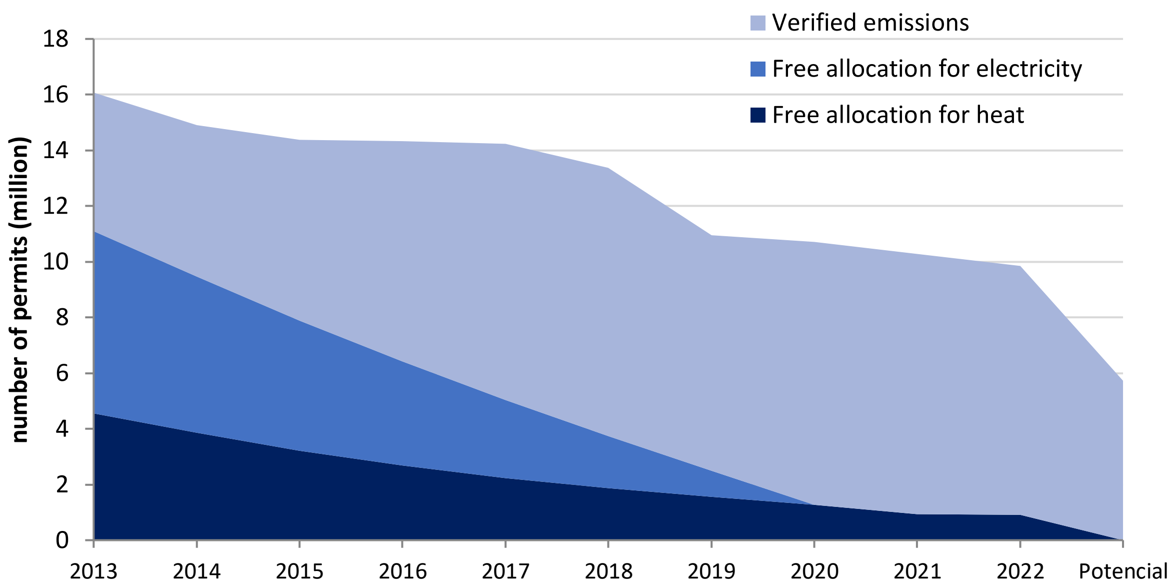
Table 4 Trend of average permit price in 3rd trading permit determined for the purposes of factual regulation of thermal energy prices by Energy Regulatory Office

Year	2013	2014	2015	2016	2017	2018	2019	2020
Average EUA price (CZK/t CO_2)	118.64	156.44	217.88	142.14	144.00	399.08	607.45	654.12

A part of the permits for heat generation are allocated free of charge. However, this share decreases linearly in accordance with the applicable EU Directive from 80% in 2013 to 30% in 2020 of the calculation value based on the heat reference level (benchmark). The heat benchmark corresponds to model CO_2 emissions from heat generation in a gas boiler with a 90% efficiency, and it is set to 62.3 EUA/TJ of heat for the period 2013-2020. The free allocation calculation then uses the cross-sectoral correction factor (for purely district heating sources) or the linear reduction factor (for district heating sources generating electricity). The result is that heating plants using coal are given much fewer free allowances for heat generation than natural gas heating plants.

Decrease in amounts of permits allocated free of charge for heat generation for 61 largest heating plants in the CR

Figure 7 Heating plants – trend of free allocation and verified emissions (2013 – 2022)



Source: TS CR, additional calculation from EUTL data; 2020-2022 estimated from available data

A further decrease in the amount of permits allocated free of charge for heat generation can be expected after 2020, but its trajectory has not yet been determined precisely.

Reducing emissions of conventional pollutants

From 2013 to the end of 2018, investments in reducing emissions from the heating sector required over 21 billion CZK, and they will continue. The billions invested have resulted in a radical reduction to air pollutant emissions. Nitrogen oxide emissions decreased by 29% between 2013 and 2017; dust emissions were 41% lower and sulphur dioxide dropped by a whole 42%.

Table 5 Trend of emissions of nitrogen oxides, sulphur oxides and dust, 2013-2018[31]

	Pollutant emissions in years [t/year]						Emission reduction between 2013 and 2018	
Pollutant	2013	2014	2015	2016	2017	2018	[t/year]	%

[31] Data from district heating sources of members of the Association for District Heating, which supply heat for over 1.1 million households.

NO_x	20,059	17,917	16,139	14,928	14,197	12,611	-7,447	-37.1 %
SO_2	41,278	36,600	34,832	24,923	23,960	20,375	-20,902	-50.6 %
Dust	1,089	865	688	569	644	534	-555	-50.9%

Compared to 1990, the heating plants now emit less than one tenth of the original amounts of sulphur, nitrogen, carbon dioxide and dust emissions in the generation of 1 GJ of heat. Thus, the environmental emission burden of district heat supply from heating plants, also given the pronounced heat savings for heating and hot water in the households, has decreased almost twenty times over the past quarter of a century.

EU legislative requirements in the area of air protection

Further strategy for district heating sources is directed primarily by legislation on air protection, where meeting of requirements for stricter emission limits may be connected with considerable investments.

Combustion sources falling into the category of medium combustion sources (1-50 MW of installed thermal capacity) are covered by the following in the area of air protection:

- European legislation, notably Directive 2015/2193 on the limitation of emissions of certain pollutants into the air from medium combustion plants (MCPD)
- Czech legislation, notably Act no. 201/2012 Coll. on Air Protection and adjacent Decrees, notably Decree no. 415/2012 on Permissible pollution levels. The Czech legislation reflects requirements of the EU legislation.

From the point of view of district heating sources, the relevant category is that of medium combustion sources above 20 MW, which have to comply simultaneously with requirements of the EU ETS (purchase of allowances) and the MPCD.

Combustion sources falling into the category of large combustion sources (above 50 MW of installed thermal capacity) are covered by the following in the area of air protection:

- European legislation, notably Directive 2010/75/EU on Industrial emissions (IED) and adjacent documents, notably BAT conclusions for large combustion plants
- Czech legislation, notably Act no. 201/2012 Coll. on Air Protection and adjacent Decrees, notably Decree no. 415/2012 on Permissible pollution levels. The Czech legislation reflects requirements of the EU legislation, but the BAT conclusions are accepted as the Commission's executive decision and are thus directly applicable (not transposed).

The requirements of the IED have been generally valid since 1 January 2016. Nevertheless, both the Directive and the Czech legislation have permitted so-called transition regimes, providing some facilities with additional time to adjust to the new requirements. The transition regime particularly relevant for district heating sources is that for plants up to 200 MW of installed thermal capacity, permitting postponement of the deadline for compliance with the stricter emission limits until 1 January 2023. In most cases, plants above 200 MW of installed thermal capacity were included in the transition regime of the "National Transition Plan", which ended on June 2020.

On 17 August 2017, the IED requirements were made even stricter for large combustion plants by publication of the BAT conclusions for large combustion plants. These requirements will have to be met within 4 years, i.e. by 17 August 2021; the new requirements are binding for plants included in the transition regimes only after the transition regimes end (particularly relevant for the heating plant transition regime).

In light of the above, we can assume a division of district heating sources in the following 4 categories by their installed thermal capacity:

1. 1-20 MWt (MCPD legislation applies and plants are outside EU ETS)
2. 20 – 50 MW (MCPD legislation applies)
3. 50 – 200 MW (IED legislation applies, and BAT conclusions as of 1 January 2023)
4. above 200 MW (IED legislation applies, and BAT conclusions as of 17 August 2021)

3.2.4 Greenhouse gas emission reduction in the heating sector until 2030

The emission trading scheme has the greatest impacts in the heating sector on coal heating plants, which supply heat for approximately 2 million of people in the Czech Republic. The mandatory purchasing of permits greatly burdens on the heating plant economy and increases the price of heat. The calculation shows that the heating plants expended approximately 5.1 billion CZK on permit purchases in 2019; the estimate for 2020 is approx. 5.6 billion CZK. Without adequate measures, these costs will continue to grow until 2030 with the increasing price of the emission permit.

Table 6 Trend of heating plant expenses on greenhouse gas emission permit purchasing

Year		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Average allowance price	CZK/EUA	119	156	218	142	144	399	607	654	1,059*	1,248 *
Permit purchase costs	million CZK	590	851	1416	1126	1,326	3,840	5,143	6178	9,895	11,14 9

Source: TS CR

* Estimates – Average permit price in 2021-2022 according to Reuters survey of 18 January 2021. Average allowance prices for 2013-2020: ERO data. Source: Calculations of the Association for District Heating based on publicly accessible information about consumption of permits, their numbers allocated free of charge and permit market price trend.

EU legislation in preparation in the area of emission reduction

On 11 December 2019, the European Commission introduced the European Green Deal – a plan to make EU economy sustainable by transforming climate and environmental challenges into opportunities in all policy areas while making the transformation equitable and inclusive for all.

Calendar of European Commission legislation proposals

March 2020	proposed Climate Act – neutrality by 2050
June 2020	evaluation of national climate and energy plans
Q3 2020	comprehensive plan to increase the climate objective 2030 (at least 50 towards 55%)
June 2021	legislative package including revised EU ETS and revised Energy Taxation Directive
2021	revised Directive 2010/75/EU on Industrial Emissions
	revised rules for public support, including environmental

Memorandum of cooperation between heating sector and gas industry

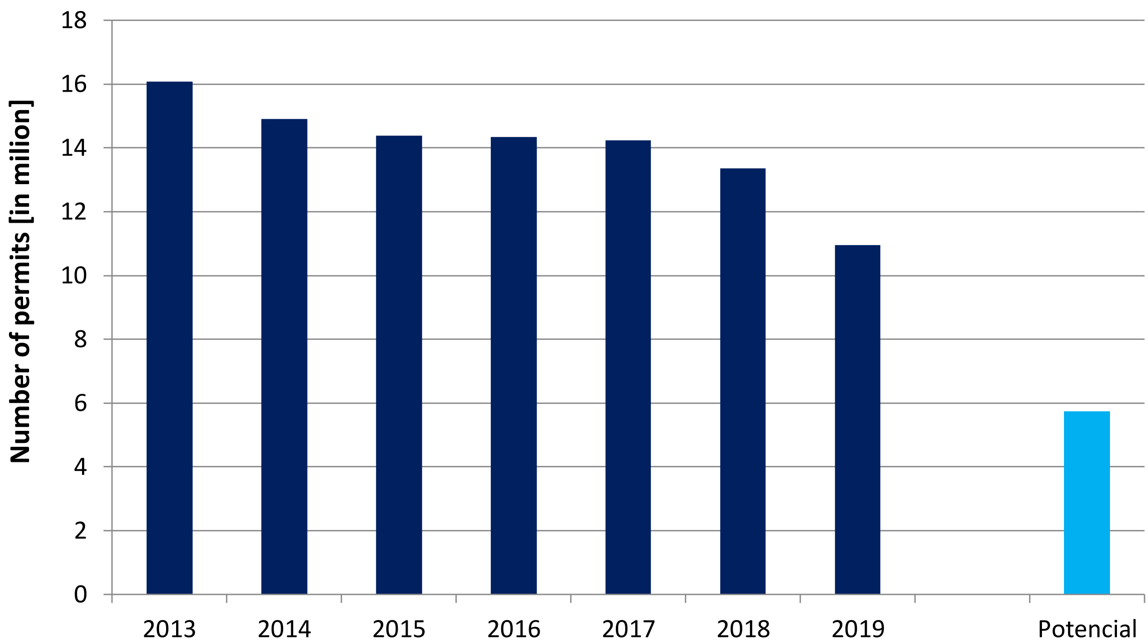
Representatives of the Association for District Heating signed a "Memorandum of cooperation for future decarbonization of the heating sector" with representatives of the Czech Gas Association on 1 July 2020. The overall transition of the heating sector from coal is a question of the next 15 years, until 2035.

The goals of the common activities are to:

- contribute to meeting the Czech Republic's international climate commitments;
- promote development of high-efficiency combined heat and power generation to make a gradual transition from coal to cleaner forms of primary energy, including natural gas;
- retain as much as possible existing district heating systems wherever they are technically and economically efficient.
- The Czech Gas Association and the Association for District Heating and their member companies shall:
- map in detail the expected future requirements on gas infrastructure;
- strive for adequate development of gas infrastructure in the required time horizon in order to prevent as much as possible any bottlenecks when transforming the Czech heating sector;
- invest billions of CZK in increasing energy efficiency of district heating systems and new technologies enabling higher flexibility of the power system.
- Signatories to the Memorandum declare that meeting the above objectives will only be possible with proactive support of public administration and regulation, and in this context they call for:
- adjustment to the settings of auctions for combined heat and power generation in the amended Act on Supported Sources;

- correct setting of parameters for using the Modernisation Fund, including its timely notifications;
- adequate reflection of the significant added value of highly efficient CHP and its growing potential for stabilisation of the power system in regulation;
- assurance of available funding from European and national funds for modernisation of plants as well as adjacent gas and district heating infrastructure.

Figure 8 Heating plants - trend of verified greenhouse gas emissions in 2013-2019 and gas installation potential[32]



Source: TS CR, additional calculation using EU TL data

Note: Emissions in the case of gas installation in coal heating plants (gas and biomass heating plants without change)

3.3 Coal Commission

The Coal Commission as an advisory body to the Government was established in July 2019. The primary objective of the Commission is to provide the Government of the Czech Republic with objective and consensual outcomes with a view to future use of brown coal in the CR, including all related aspects.

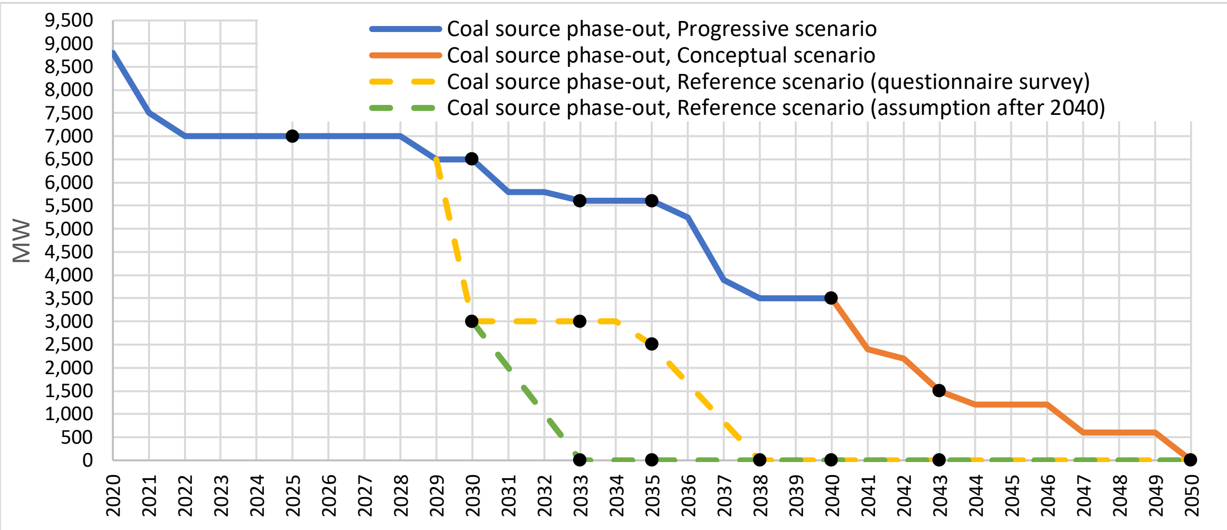
[32] This is a model of gas installation for district heating sources based on EU TL register data. The model includes 61 largest district heating sources in the EU ETS. No changes are assumed for gas and biomass heating plants.

The Coal Commission has 19 members and is composed of representatives of public administration (ministries), local self-governments (Ústí, Karlovy Vary and Moravian-Silesian Regions), representatives of the Parliament, the academic sphere, industry and non-governmental non-profit environmental organisations. Over the more than one year of the Coal Commission's existence, 24 scenarios for various options of brown coal mining and combustion phase-out have been developed, reflecting energy, environmental and social impacts on the respective regions and the Czech Republic as a whole. Out of the original 24 scenarios for the future of Czechia's energy industry, with which the Commission started on its establishment, the final selection was reduced to three options for the end of coal in the energy industry, namely:

- by 2033
- by 2038
- by 2043

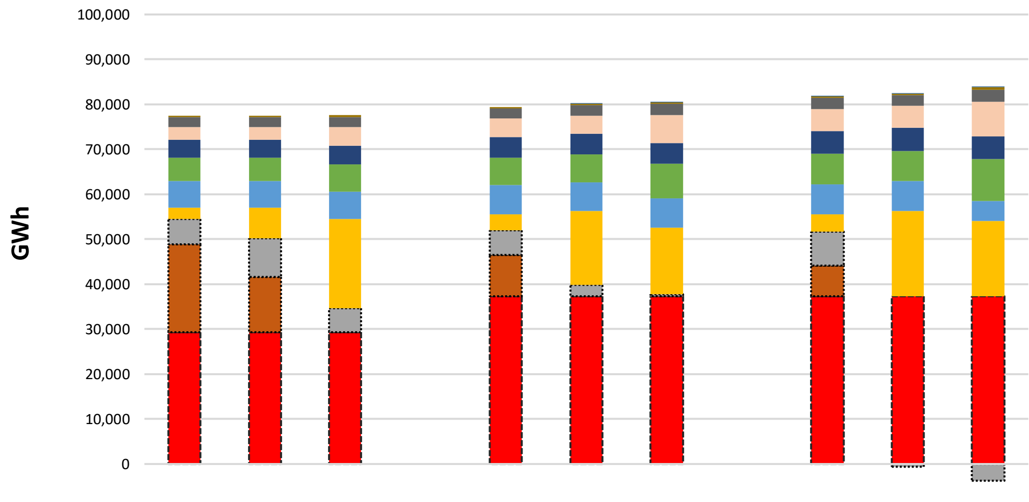
The actual impacts on the development of installed capacity of coal power plants for the above options of the end of coal in Czechia and each development scenario (progressive, conceptual and reference) are shown in the charts and figures below.

Figure 9 Coal phase-out outlook (net installed capacity) under the conceptual, reference and progressive scenarios[33]



[33] Data from the operator of Czechia's transmission system, ČEPS, a.s., for the Coal Commission meetings.

Figure 10 Electricity generation by fuel and scenario for 2033, 2038 and 2043



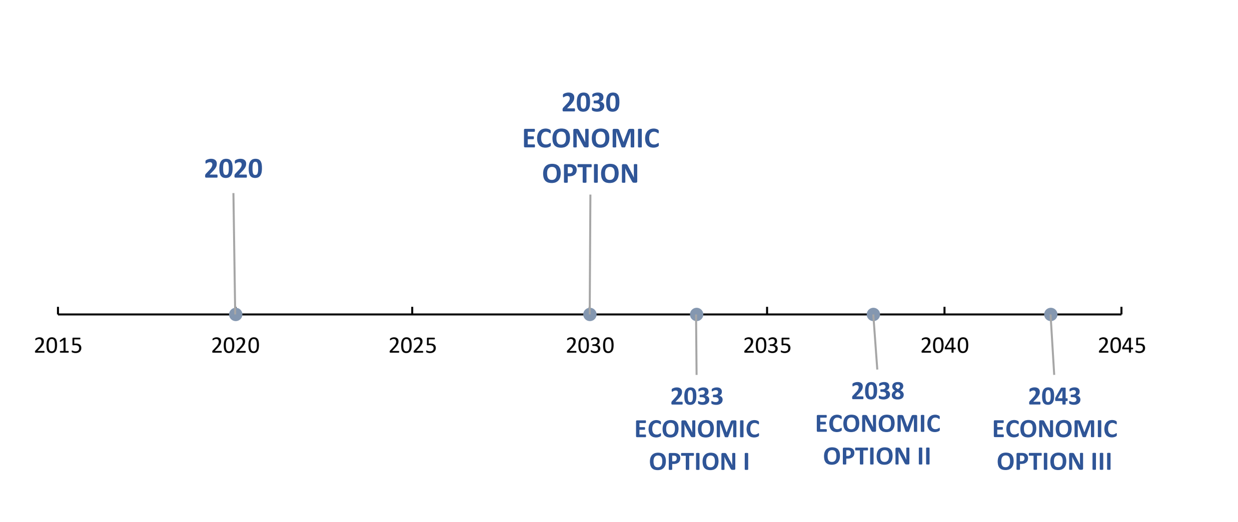
	2033 Reference	2033 Conceptual	2033 Progressive	2038 Reference	2038 Conceptual	2038 Progressive	2043 Reference	2043 Conceptual	2043 Progressive
Not supplied	0 GWh	0 GWh	0 GWh	0 GWh	1 GWh	1 GWh	61 GWh	1 GWh	2 GWh
Battery storage	350 GWh	366 GWh	404 GWh	348 GWh	256 GWh	349 GWh	349 GWh	280 GWh	490 GWh
Hydro and pumped storage power plants	2 188 GWh	2 179 GWh	2 192 GWh	2 306 GWh	2 364 GWh	2 538 GWh	2 492 GWh	2 427 GWh	2 700 GWh
Wind power plants	2 830 GWh	2 831 GWh	4 217 GWh	4 059 GWh	4 058 GWh	6 195 GWh	4 889 GWh	4 892 GWh	7 680 GWh
Other RES	4 046 GWh	4 046 GWh	4 046 GWh	4 594 GWh	4 594 GWh	4 594 GWh	5 103 GWh	5 103 GWh	5 103 GWh
Photovoltaic power plants	5 073 GWh	5 073 GWh	6 193 GWh	6 157 GWh	6 157 GWh	7 716 GWh	6 726 GWh	6 732 GWh	9 285 GWh
Heating plants and company power plants	5 986 GWh	5 986 GWh	5 986 GWh	6 468 GWh	6 468 GWh	6 468 GWh	6 678 GWh	6 678 GWh	4 478 GWh
Gas power plants	2 475 GWh	6 751 GWh	19 942 GWh	3 607 GWh	16 374 GWh	14 806 GWh	3 897 GWh	18 986 GWh	16 799 GWh
Import/export balance	5 726 GWh	8 658 GWh	5 213 GWh	5 486 GWh	2 617 GWh	563 GWh	7 611 GWh	- 656 GWh	-3 681 GWh
Coal power plants	19 450 GWh	12 240 GWh	0 GWh	9 179 GWh	0 GWh	0 GWh	6 805 GWh	0 GWh	0 GWh
Nuclear power plants	29 371 GWh	29 371 GWh	29 371 GWh	37 260 GWh	37 260 GWh	37 260 GWh	37 260 GWh	37 260 GWh	37 260 GWh
Dump/Excess	3 GWh	1 GWh	0 GWh	15 GWh	16 GWh	66 GWh	16 GWh	7 GWh	55 GWh
LOLE	0 hours	0 hours	0 hours	0 hours	2 hours	2 hours	87 hours	4 hours	3 hours
Total generation	71 770 GWh	68 844 GWh	72 350 GWh	73 997 GWh	77 530 GWh	79 926 GWh	74 200 GWh	82 358 GWh	85 995 GWh

The Commission members had very different opinions on these three final options; moreover, they said they lacked some analyses. In December 2020, however, the majority of the members (15 out of 19) supported **the year 2038** as the definitive end of brown coal combustion in the Czech Republic[34].

[34] Authors' note: The final meeting of the Coal Commission involved disagreements among members; the Environment Minister, for example, supported the end of coal five years earlier, by 2033. He said in his statement that since a fundamental change in Czechia's energy industry will happen by 2030, an earlier end of coal would be possible in his opinion. On the other hand, the Minister of Trade and Industry said that 2038 is not only a compromise by all the groups within the Coal Commission but is based on economic and environmental assumptions for building of new energy sources. In the context of the other statements, he referred not only to the assumption of development of renewables but, most importantly, the issue of construction of new nuclear sources (on the existing Dukovany site), which the State Energy Policy assumes by 2035.

Given the status of the Coal Commission as only an advisory body to the Government, the termination of coal mining and combustion in the CR has to be decided formally by the Government. However, it has not made its formal decision as of the time of writing (February 2021). It is clear from public sources that some members of the Government would support an earlier date for the end of energy use of coal in the CR than 2038.

Figure 11 Economic and political options of end of coal in the Czech Republic



This study reflects this date with a certain amount of flexibility, not only for the above reason. The Government's political attitude regarding the end of coal in Czechia is no doubt important, but the actual attitude of heating plant operators is most important in terms of future investment needs in the heating sector. In the expert survey, we found that **heating sector representatives themselves largely expect a significant decrease in the use of coal in a large part of their plants by 2030**, which is eight years earlier that assumed by the Coal Commission. The main reasons for ending the use of coal in most of the heating plants by 2030 (regardless of the Government's political decision) are purely economic conditions of operating the plants, particularly the increasing prices of emission permits. The further analysis assumes that a significant reduction in the use of coal in Czechia's heating sector will occur already around 2030.

4 Present state of climate and energy investments

The following chapter studies the flows of climate and energy investments in the heating sector in the period 2014-2019. We make use of the Taxonomy structure (Chapter 2.3) and analyse the climate and energy investments in terms of sources of funding, intermediaries and final use. Among other things, this overview is used for an analysis of the level of funding of these investments and use of support instruments and a comparison with the need for investments to meet the 2030 objectives and, most importantly, to move towards carbon neutrality by 2050.

4.1 Methodological frame and data

The investment map then presents an overview of the flows of climate and energy investments from sources of capital via intermediaries and funding instruments to final use. The diagram structure makes use of a bottom-up approach. Thus, it maps investments at the level of individual equipment sets (projects), which are then aggregated to the level of schemes, sectors and the whole territory (Czechia in this case). The boundaries of the study sector are defined in more detail in the introductory part (Section 2).

The methodology for studying climate and energy investments in this report is based on the Climate Policy Initiative a Climate investment Capacity project study[35]. For the purposes of this report, the climate and energy investments are thus defined as **expenditures by public and private players on gross fixed capital formation that lead specifically to climate change mitigation and greenhouse gas emission reduction**. Pursuant to Regulation (EU) on the European System of National and Regional Accounts[36], gross fixed capital formation includes (in the plus items) primarily purchase of fixed assets, such as buildings and infrastructure or machines and equipment. Unlike in the Regulation methodology, however, our analysis excludes intangible assets, notably research and development (see below). Moreover, we exclude other "intangible" investments and activities, such as behaviour and habit change, information activity, training and education. Due to the lack of data in this report, we exclude investments in adaptation measures, although we are aware of their importance.

The map includes investments in the **period 2014–2019**. The longer time period reflects the multi-annual nature of most of the investments in the sector and enables studying their development in time. The year 2019 is then the last year for which complete data were available at the time of writing (November 2020).

The report studies only primary investment flows, i.e., those that create new or additional assets. Thus, we exclude secondary financial flows, such costs of capital and credit repayment. The report also excludes, for example, public guarantees provided to public banks or grant equivalents of public guarantees or advantageous loans. Although inclusion of these flows would lead to seemingly greater

[35] For more details, see https://ekonom.feld.cvut.cz/cs/katedra/lide/valenmi7/cic2030/reports/cvut-mvalentova-et-al-2019-climate-energy-investment-map-czechia-2017-full-report.pdf

[36] Regulation (EU) No 549/2013 of the European Parliament and of the Council of 21 May 2013 on the European system of national and regional accounts in the European Union, Annex A (particularly Sections 3.122 – 3.129).

flows of climate and energy investments (in the public sector), it might also result in (partial) double counting of the same investments.

The overview of the present state of investment in the heating sector reflects the **classification of sustainable investment** as described in more detail in 2.3 above. We therefore divided the investments into three main categories: in accordance with the taxonomy (investments in renewables and increased energy efficiency of distribution networks), transient investments that do not cause a lock-in by 2050 (investments in natural gas plants) and investments not in accordance with the taxonomy (all investments in coal sources).

The primary source of data for the analysis of climate and energy investments in the heating sector is investments implemented as part of the **European emissions trading scheme** (EU ETS). Based on Directive 2009/29/EC, electricity producers have had to prove after 2013 that they have invested the value of the free allowances in modernisation of electricity generation, greenhouse gas emission reduction and reduction of dependence on brown coal. The National Investment Plan was thus developed in 2012, containing a list of all the investment project within the value of the emission allowances allocated free of charge[37]. Electricity producers submit reports on implemented investments for each year in the period 2013-2019. The Ministry of the Environment assesses whether they are in accordance with the allocation conditions and then publishes a summary report on the investments annually.

Additional sources of data are the two main subsidy schemes that support climate and energy investments in the heating sector. One is the **Operational Programme Enterprise and Innovation for Competitiveness** (OP PIK), together with its predecessor, the Operational Programme Enterprise and Innovation. Priority axis 3 of these programmes is focused on increasing energy efficiency and development of RES[38], and investment priority 5 specifically supports use of highly efficient combined heat and power generation. The programme supports renovation and development of district heating systems and heat distribution equipment, and implementation and increasing efficiency of combined heat and power generation systems. This priority axis does not support renovation of sources above 20 MW of thermal capacity.

The other scheme is the **Operational Programme Environment**. Priority axis 2 Improvement to air quality in human settlements has a specific goal of reducing emissions from stationary sources. This programme therefore does not support directly greenhouse gas emission reduction in the heating sector. However, projects supported from this programme (its specific priority axis) were analysed due to their nature, and relevant projects (those with an effect of greenhouse gas emission reduction) were included in the summary report (see also discussion below in 4.2.1).

Another source of data is the activity and data of COGEN Czech, an association for combined heat and power generation, uniting small CHP producers who are usually not included as applicants in the above

[37] https://www.mzp.cz/cz/bezplatna_alokace_na_elektrinu

[38] Efficient energy use, development of energy infrastructure and renewable sources of energy, support to implementation of new technologies in the area of energy use and recyclable materials. (For more details, see the Programme document for OP PIK)

schemes. Analyses of projects supported under the above programmes show that the potential overlap is absolutely minimal.

We assume that the overwhelming majority of the investments associated with greenhouse gas emission reduction pass through the above programmes or the database. For a check, the above data were then compared to data from the study of Invicta Bohemica, which publishes data on investment in the heating sector annually. These data are collected based on a questionnaire survey, but the actual nature of the individual investments is not quite unambiguous. That is why the data from the study are used only for a rough comparison of the studied data, but they do not enter the analysis as such.

The actual amount of investments in the study period will be higher; the data sources listed above do not cover the following areas in particular:

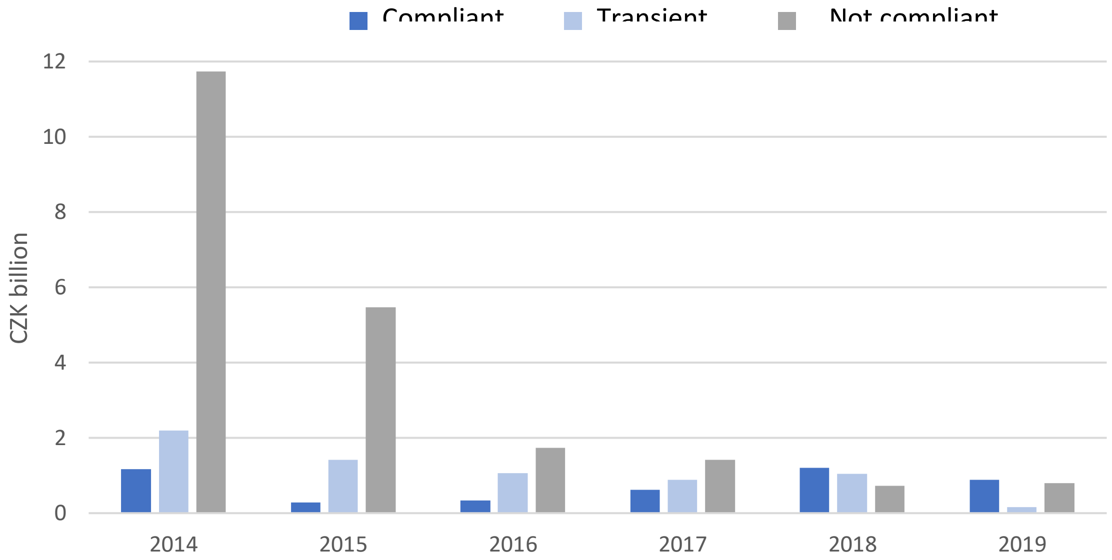
- Subsidy funds under specific subsidy brackets always relate to eligible expenditures. By default, they are determined by subtracting so-called alternative investment from the actual implementation expenditures. Within the data sources, therefore, we only consider eligible expenditures, although the actual expenditures on implementation of measures are higher. This amount can be estimated to be 15%. On the other hand, the eligible expenditures are devised so that they are factually directly related to the project, in contrast to ineligible expenditures. It can thus be speculated whether the other expenditures would be related to the project without this division.
- A number of investments could have been implemented outside the specified subsidy schemes, either due to administrative obstacles (e.g., in smaller projects) or they were implemented as part of programmes designed primarily to cover other areas (e.g., support to accumulation and battery storage) or in areas where no support was provided. This amount can be estimated to be 20%.
- Another bulk of money was expended on projects that did qualify for a subsidy but were not supported in the end due to an excess of projects (or the assessment criteria), so they had to be implemented (to a limited extent) without the subsidy. This amount can be estimated to be 5%.

4.2 Overview of climate and energy investments

In total, we identified investments in measures to reduce greenhouse gas emissions amounting to 33.1 billion CZK in the study period 2014-2019. The greatest part of the investments was implemented in 2014, which is mainly due to the amount of investments under the National Investment Plan, which made up almost half the total investments in that year. In 2016-2018 (when the NIP no longer played such a significant role), the annual amount of investments stabilized around 3 billion CZK annually (Figure 4).

From the perspective of future development of the heating sector, in particular, it is important to realize that the overwhelming majority of these investments (21.9 billion, i.e., two thirds in 2014-2019) is not in accordance with the current requirements of the EU taxonomy; that is, they were investments in greenhouse gas emission reduction from coal plants. The figure also shows, however, that the proportion of the two types of investment became equal in 2016-2019. Thus, 75% of the investments in 2018 were either in accordance with the taxonomy (investments in reducing losses in distribution networks and renewables) or of a transient nature; it was 66% in 2019. On the other hand, it is seen that the conditions of the support programmes for 2014-2020 were set so that they essentially do not match the current typology of sustainable investment, and may thus have an impact on settling these investments in the coming years.

Figure 12 Climate and energy investments in heating sector, 2014–2019 (billion CZK), breakdown by compliance with EU taxonomy



Sources: NIP, OPE, OPEIC, OPEI, COGEN, own calculations[39]

The following sections deal in more detail with sources of funding for climate and energy investments, main intermediaries and instruments used as well as methods of use the investments, their effects and specific impacts on greenhouse gas emission reduction.

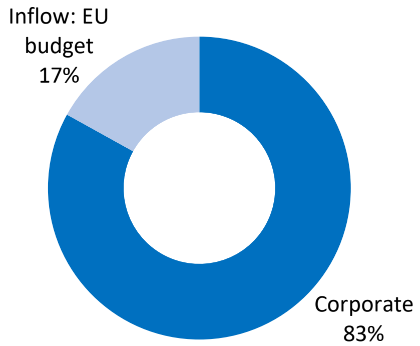
From now on, we will work in most cases only with data on investment in accordance with the taxonomy and transient investment, unless specified otherwise.

[39] NIP: https://www.mzp.cz/cz/bezplatna_alokace_na_elektrinu, OPE, OPEI and OPEIC from list of supported projects 2007 – 2013 and 2014 – 2020 (as of 1 July 2020). The data on small cogeneration plants were obtained in personal communication with Ing. Šimoník, executive director of COGEN Czech.

4.2.1 Sources of funding

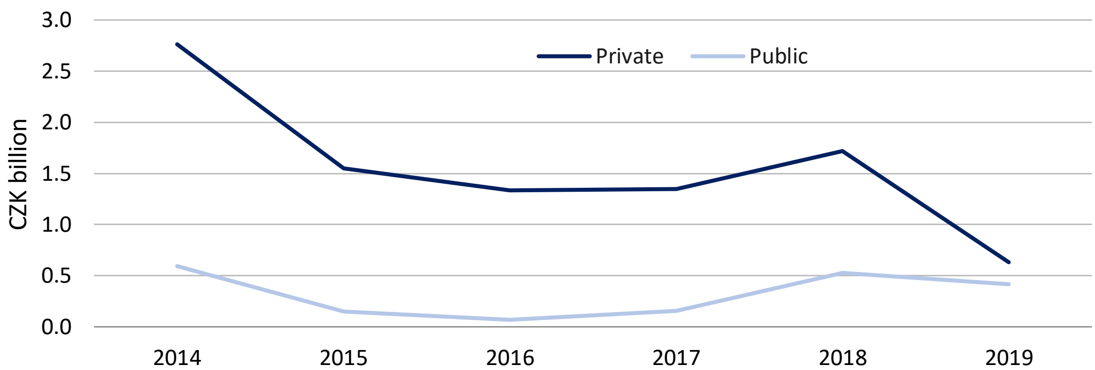
The main source of funding for climate and energy investments in the heating sector in the study period was the private sector, specifically district heating companies' own sources: it made up over 80% throughout the study period (Figure 5).

Figure 13 Share of private and public sources (2014–2018)



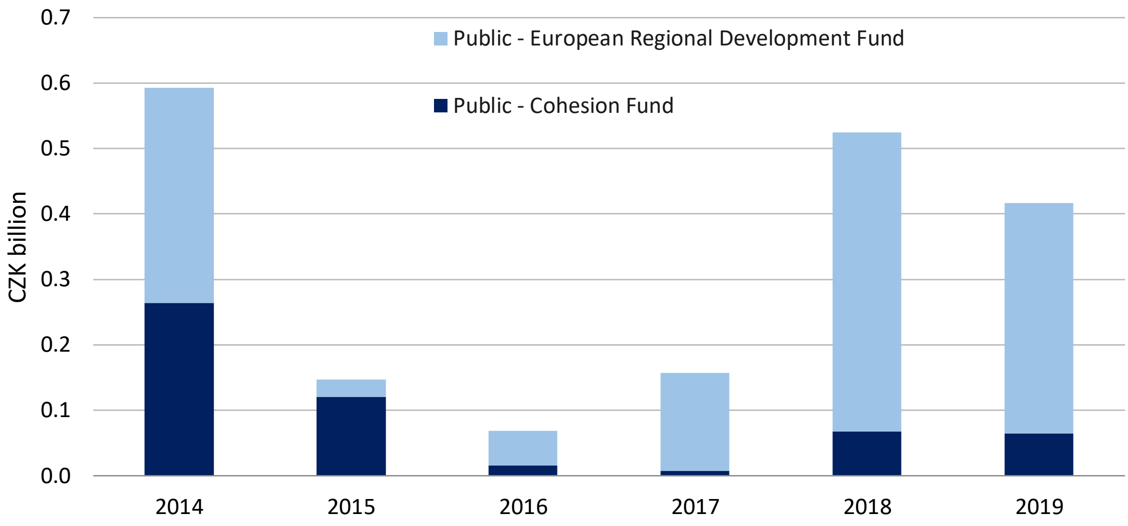
The following figure, however, shows that the share of private funding sources gradually decreases as the amount of investment under the NIP decreases in particular. In the programmes OPEI, OPEIC and OPE, the share of public funds in the total investments is around 30-35%; thus, 35% of the investment value is funded from these programmes.

Figure 14 Private and public sources of investment (2014–2019)



The public sources comprise exclusively Exclusive structural and investment funds, specifically the European Regional Development Fund, being the main source for the OPEI and OPEIC, and the Cohesion Fund, being the source for investment in the heating sector under the OPE (Figure 7). The lower figures for 2015-2017 may be caused by the late start of the Operational Programme Enterprise and Innovation for Competitiveness. Thus, projects funded in 2007-2013 were practically not in progress in those years; at the same time, most of the projects in the period 2014-2020 had not started yet. The onset of the OPEIC is visible in 2018 and 2019.

Figure 15 European sources of funding in 2014 – 2019 (billion CZK)

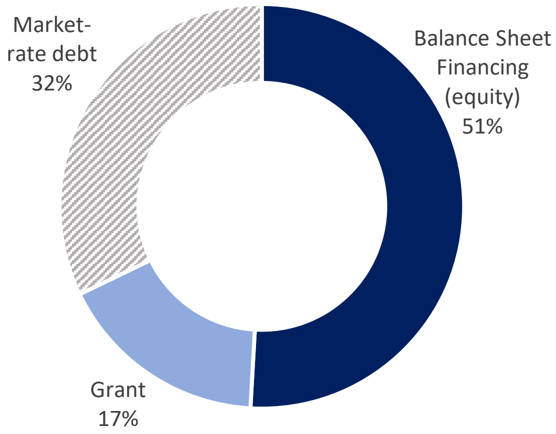


4.2.2 Instruments and intermediary entities

According to expert estimates, most of the investments were funded from own sources (50%) and covered by credit from commercial banks (Fig. 15). It has to be noted, however, the practically all investment projects for greenhouse gas emission reduction are a consequence of the existence of a financial instrument or political measure. They are the EU ETS above all, as well as specific grant schemes under operational programmes (OPE, OPEIC, previously OPEI). The main public sources that activate investments in greenhouse gas emission reduction in the heating sector are thus the National Investment Plan (as part of the EU ETS) and investment grants (direct financing of part of investment costs of a project).

The NIP and EU ETS are not manifested directly in the investment mapping system, because the actual investment is made by the district heating organisations themselves, but they do so based on and up to the value of the emission permits allocated for free[40].

Figure 16 Instruments for funding climate and energy investments (2014-2018)



4.2.3 Uses

Two basic types of investment can be seen in the heating sector: investments in the heat generation plant base and investments in development and improvement of parameters of district heating distribution systems. Both types complement one another, and are implemented in successive steps or simultaneously in the ideal case.

Investments in thermal energy sources

Since each district heating system is unique, their source base is derived primarily from their history, local effects and other development of the area, including availability of different fuel types. In terms of impacts on greenhouse gas emission reduction, we divide direct investments in the source base into three main categories: (1) fuel base change, source change; (2) increasing efficiency of fuel conversion, energy savings; (3) reducing emissions of conventional pollutants. From the taxonomy point of view, only investments in increasing efficiency of thermal energy distribution lines can be regarded as eligible. Investments in change of the fuel base from coal to gas can be regarded as transient investments (unlike, e.g., shifting from coal to biomass combustion while meeting the sustainability requirements), and reduction of conventional pollutants as ineligible.

[40] More at: https://www.mzp.cz/cz/narodni_plan_investic_cr

Fuel base change can be regarded as one of the most efficient methods of greenhouse gas emission reduction. Shifting from carbon-intensive fuels (brown coal, black coal) towards low-carbon fuels (natural gas, biomass, waste) results in significant savings of greenhouse gas emissions thanks to the lower emission factor of those fuels. From the taxonomy point of view, however, these investments are considered transient in the case of natural gas and ineligible in the case of other fossil fuels. **Increasing efficiency of fuel conversion** in a thermal energy source has a positive effect on greenhouse gas emissions. Due to the requirements of the EU and CR air protection legislation, district heating companies make investments in **reducing emissions of conventional pollutants**, notably particulate matter (PM), nitrogen oxide (NOx) and sulphur oxide (SO_2) emissions. These investments are therefore not primarily motivated by greenhouse gas emission reduction and may even have negative impacts on real greenhouse gas emissions in some cases (e.g., when own electricity consumption increases). The quantification of the impacts can assume conservatively a neutral effect on greenhouse gas emission. According to the EU Taxonomy criteria (see 2.3), however, these investments are typically not classified as sustainable, and are therefore excluded from the following data.

Investments in thermal energy distribution lines

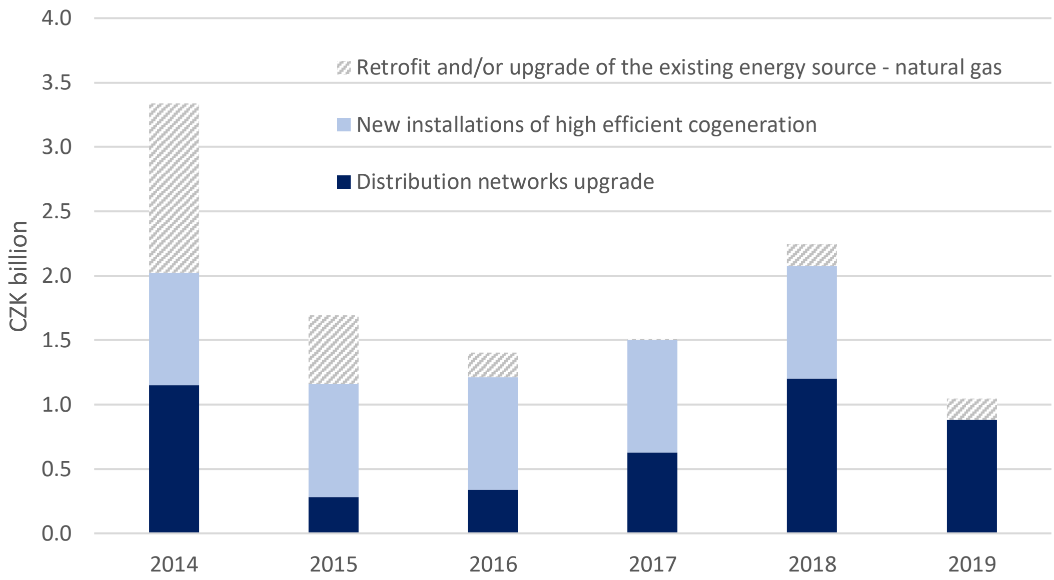
Thermal energy distribution lines are the physical connection between the heat producer and its consumer are a precondition for operation and development of district heating systems, and a key prerequisite for combined heat and power generation, which achieves primary energy savings. Thus, the effect on greenhouse gas emissions is positive. The steam distribution lines built previously have been replaced with hot-water or warm-water lines in many areas. These investment-intensive projects result to a significant reduction to losses in pipelines, which in turns reduces useless heat generation and emissions from sources[41]. According to the taxonomy, these investments can be regarded as eligible.

Investments made in 2014-2019

The investments in the study period 2014-2019 were aimed primarily at reducing losses in thermal energy distribution lines (4.48 billion CZK and 40% of total investments); they are eligible according to the taxonomy. New installations of combined heat and power generation (CHP) constitute another 39% of the investments studied (4.38 billion CZK); these are transient investments under the taxonomy. Changing the fuel to gas comprised 2.37 billion CZK (21% of the total investments; see Figure 9); these can also be regarded as transient investments under the taxonomy criteria.

[41] However, reducing the losses usually cannot compensate for the high investment expenditures on distribution line renovation. The projects are often irrecoverable. That is why maintaining/increasing CHP, achieving primary energy savings and reducing emissions requires considering a systemic method of support to these projects, e.g., in the form of investment support.

Figure 17 Use of investments studied in heating sector (2014 – 2019)



Data on expected efficiency of investment supported under OPEIC in 2016-2022.

Table 7 Expected efficiency of investment supported under OPEIC[42]

OPEIC	Initial energy consumption	Energy saving	CO_2 emission reduction	Investment	Subsidy	Investment per 1 GJ saving	Investment per 1 t CO_2 saving a year	Subsidy per 1 GJ saving	Subsidy per 1 t CO_2 saving a year
	GJ	GJ	t CO2 /year	Million CZK	Million CZK	CZK	CZK	CZK	CZK
Transient investments	438,598	248,090	25,586	522	178	1,697	16,455	553	5,360

[42] Personal communication – MPO, OPEIC.

Eligible investments	8,443,654	2,037,389	241,614	5,299	2,012	2,601	21,931	988	8,328
Total	8,882,252	2,285,479	267,200	5,821	2,190	2,547	21,786	958	8,195

The total initial energy consumption under the investments supported from the OPEIC for the period 2016-2022 was 8.9 PJ/year. According to assumptions, the supported investments should achieve energy savings of 2.3 PJ/year with the total expenditures of 5.8 billion CZK (subsidy amounting to 2.2 billion CZK). The necessary investment per 1 GJ saving is thus 2,547 CZK/GJ; the necessary subsidy per 1 GJ saving is 958 CZK/GJ. The projects also generate a CO_2 emission saving of 21.8 thousand CZK/t CO2 (8.2 thousand CZK/t CO2 of subsidies). **The transient investments according to the taxonomy achieve higher investment efficiency, as they contain projects aiming at cogeneration and modifications to the source base**. The overwhelming majority of the eligible investments according to the taxonomy are only investments in modernisation of DH distribution lines, where the effect of the expenditures will be reduced losses in pipelines.

5 Investment necessity to meet 2030 objectives

Compared to 2018 (and previous years), the situation changed dramatically in 2020: the horizon for ending coal in the heating sector before 2018 was the year 2040, which is why a large majority of DH system renovation projects focus on heat distribution lines and some on control systems. That is why projects dealing with renovation of heat sources themselves are not ready at present (with the exception of sources where this was required for other reasons than the coal phase-out, e.g., end of service life); programmes of support to investment in the sources and operating support schemes are only in development and renovation of the sources can only be expected to start approximately in 2025.

At present, the first phase of renovation projects is underway; they are projects ready for implementation or already being implemented. Some of these projects are covered by the analysis of project funding from Operational Programmes.

5.1 Procedure used for estimating necessary investments for transforming Czech heating sector by 2030

The procedure for determining the investment costs shown below is related to the definition of the term heating sector (delineation of its boundaries) as made in the Introduction to this study, the difference being that we narrowed the definition for estimating the expected investments in modernisation to cover only entities operating inside the EU ETS; i.e., we do not consider smaller sources outside the emission permit system. This is admittedly a simplification; nevertheless, we assumed that a significant part of the modernisation of smaller sources has already taken place (typically shifts from coal to natural gas or biomass)[43].

The basic concept of the methodology is similar to that used for estimating the investment costs for the RES sector to meet the 2030 objectives[44]. The basic principles of the methodology are as follows:

- The source renovation cost estimate is made using current prices (2020 prices) and then escalated to the respective year.
- The distribution of the investment costs of heating sector transformation (i.e., renovation of heat sources and heat distribution lines) in time is not known precisely (there are a number of uncertainties regarding project planning, permitting proceedings, funding allocation, etc.). Based on the current knowledge, three basic stages can be estimated:
    - a stage until approx. 2025, implementing projects planned before 2020, which do not respond to the current situation directly but were instead forced by the need for renovation of obsolete heat sources or distribution lines, or implemented

[43] Including the reason that the available support programmes were focused on renovation of sources below 20 MWt and networks.

[44] https://ekonom.feld.cvut.cz/cs/katedra/lide/valenmi7/cic2030/reports/valentova-et-al-investment-need-analysis-in-czechia-final-shortened.pdf

requirements of greening measures adopted before 2020; it can be estimated to concern projects mostly in smaller sources up to 50 MWt;
  - a stage from 2025 to 2030, with a substantial part of the renovations; this period will see renovations of approx. 70-80% of sources and distribution lines;
  - a stage from 2030 to 2035, with renovations of the last approx. 10-15% of sources and distribution lines and a definitive departure from using coal in the heating sector.

Note: The following subchapter shows an expert estimate of investment distribution in time.

Linear distribution in time is expected for each of the renovation stages.

- Similarly to the RES, the heat sources are divided into subcategories for estimating the investment costs related to renovation of sources. The key parameters for this classification are the installed thermal capacity and fuel type. Three basic categories of heat sources are assumed, namely:
  - Smaller sources: up to 50 MWt
  - Medium sources: 50-300 MWt
  - Large sources: above 300 MWt

In comparison with the methodology for estimating investment costs for RES by 2030, the methodology for the heating sector has the following deviations and specifics:

- The RES sector had explicit (albeit aggregated) goals for 2030: the National plan for energy and climate.
- There is no such explicit strategy for the heating sector transformation (only), as the heating sector is a part of the whole energy industry sector in terms of decarbonization goals, etc. Thus, the heating sector transformation is induced more by economic pressure, including the expected great increases in emission permit prices.
- Unlike the RES methodology, which was focused on estimating investment costs of NEWLY built sources, the heating sector involves almost exclusively renovations of existing heat sources and distribution lines, or their replacement with new sources. We do not assume establishment of any new district heating systems in the exercise. Concerning sources, existing ones will undergo fundamental renovation, even if new ones will be built in some cases to replace a source that will be shut down (see below).
- The method of renovation (generally transformation) of heat sources is greatly influenced by a number of external factors; combinations of some factors may lead to a situation where the original heat source is not replaced with a new (centralized) source of the same capacity, but a combination of a smaller one and decentralized sources (often resulting in the original system disintegrating into smaller ones). The emission permit price is the key factor that currently influences the heating sector transformation and its methods the most. The growing permit price generates a major pressure to end the use of coal for heat generation (for economic reasons).

Other factors with a significant influence on the form and speed of transformation include:

1. **Definition of the EU ETS system** – definition of the circle of entities that belong to the system. The current system definition, for example, means that (with the non-existence of a carbon tax for entities outside the EU ETS) it is economically advantageous to split an original

centralised system in many cases into several smaller ones with sources with a capacity below the critical limit for inclusion in the EU ETS. Such tendencies are observable even today. Changes to the EU ETS setting may fundamentally influence the form of the heating sector transformation.

2. **Implementation/absence of an environmental tax (carbon tax) for sources outside the EU ETS**. Although an environmental tax is imposed on fossil fuels, it does not apply to some sources (e.g., heat sources for own buildings). Moreover, the tax rate is minimal and fails to play a significant role. Retaining the current tax rate and rules clearly prefers smaller heat sources.
3. **Definition of operating support conditions** (e.g., in terms of rate setting for different source categories and changes in classification) will potentially influence investors' decision-making on heat source renovation (transformation) methods. Any change to the operating support conditions increases decision-making uncertainty. A legislative process is currently underway, related to setting operating support schemes (auctions) for CHP electricity and other supported activities.
4. **Emission limits for pollution sources and pollution limits for sites**. In many cases, fundamental barriers to implementation of a smaller local source (e.g., a gas heating plant) may be air pollution limits, inconsistency with land-use plans, etc. This may, on the contrary, favour existing sources on existing sites.
5. **Fuel availability** – in some cases, transformation of existing heat sources using coal is blocked by difficult availability of connection to a natural gas system or insufficient connection capacity. Biomass can be considered as an alternative in such cases, possibly in combination with waste combustion or even combustion of solid alternative fuels (SAF)[45].

In some cases, transformation of existing district heating systems will probably lead to a situation where the installed thermal capacity of a central coal source will not be replaced 1 to 1 with a new one (gas, biomass, etc.). There are two reasons for this:

- Decreasing heat demand as a consequence of changes in the structure of business sector activities (e.g., shift away from energy-intensive manufacturing).
- Splitting of a system into several ones, the original central source being replaced with a smaller one and some peripheral parts of the system becoming separate and having their own heat sources (not under the EU ETS).

Both factors, the latter in particular, are very difficult to include in the estimate of investment needs as of 2030. That is why this study works with the assumption that existing district heating sources (seen from the point of view of the whole heating sector) are renovated 1:1; i.e., the original generating capacity is replaced with new generating capacity.

The estimate of investment needs for the heating sector transformation in terms of heat sources works with other assumptions too, namely:

[45] Biomass or waste energy recovery and use of SAF should be considered as the first choice wherever possible, e.g., due to source size and availability of such fuels. Natural gas should only be considered as the second choice.

- Existing heat sources using natural gas are not undergoing fundamental renovation, only partial modifications as needed, primarily in light of compliance with emission limits, which are less investment-intensive at these sources compared to coal-based ones (notably installation of low-emission burners, etc.).
- Sources using brown coal are being replaced with natural gas, solid biomass and partially waste combustion sources.

The estimates of investment costs of heat source renovation are made using the representative method, with typical specific investment cost indicators defined.

5.2 Input data for investment need modelling

The heating sector investment needs as of 2030 are analysed in two segments: heat sources as such and heat distribution lines.

The following technologies/fuels are assumed for modernisation of existing heating plants (heat sources):

- Natural gas
- Biomass
- Waste energy recovery and SAF

The investment needs were modelled according to the above division into the categories up to 50, between 50 and 300, and above 300 MWt. This division is not applied to an entire organisational unit (e.g., heating plant), but to individual generating units (process equipment assemblies, including the actual combustion equipment, such as boilers, gas engines, etc.) that will undergo the renovation[46]. This division is chosen for reasons of the structure of available data as well as the logic of the equipment modernisation as such. In some cases, the modernisation will not concern all the generating units within the organisational unit on a site, but only some units. Moreover, their modernisation methods may differ.

In other cases, the modernisation will take place in the form of construction of a new device on the existing site; thus, existing equipment will not be renovated and only existing infrastructure on the site will be used.

Sources included in the different categories will differ within their category with their specific indicators – investment costs. It is due to both the site conditions (e.g., what parts of existing equipment can be used for modernisation) and the relatively broad span of the thermal capacity in each category. Moreover, the category up to 50 MWt is specific in that many of the existing units have been transformed due to the EU ETS settings so that they fall below the 20 MWt capacity limit and are thus not included in the EU ETS.

[46] Classification by size of individual generating devices within a district heating facility, not by the total installed thermal capacity of the whole facility.

Waste energy recovery and SAF sources, combusting waste and alternative fuels, are similarly specific. The capacity of these sources is not assumed to exceed 50 MWt[47] given the nature of the fuel, its limited availability and realistic fuel transport distances. At the same time, we assume not only a heating mode but cogeneration due to the legislative requirements. At the same time, renovation of existing facilities is not assumed for WER and SAF sources, only construction of new facilities. The WER technology uses combustion of mixed municipal waste and multi-stage exhaust cleaning, including heavy metals and dioxins. The SAF technology uses pelletized (or otherwise prepared) fuel from waste; the technology is similar to biomass-combusting equipment and projects mostly include combined combustion of SAF and biomass, ideally using fluid burners.

Modernisation in the category above 300 MWt can be reasonably expected only using natural gas, as biomass is not considered at these large sources (e.g., due to long fuel transport distances and its required quantity). The estimate of heating sector investment needs does not assume this category due to its size in light of classification by individual generating units (not by entire plants; see methodology description above).

The different modernisation types can be described as follows:

Renovation of existing facilities

Biomass heating plants: involves primarily modifications to existing equipment[48], retrofits, modification to fuel conveyors, burners, etc.

Biomass cogeneration: vastly different types of installations that cannot be easily standardized; costs are increased compared to the heating plant design due to higher requirements for materials caused by the steam design, modification to steam collection area or turbines, modifications to electric output lines.

Natural gas heating plants: modification to existing equipment, retrofits, gas connection, modified burners, etc.

Natural gas cogeneration, category up to 50 MWt: different types of installations that cannot be easily standardized; costs are increased compared to the heating plant design due to higher requirements for materials caused by the steam design, modification to steam collection area or turbines, modifications to electric output.

Natural gas cogeneration, category from 50 to 300 MWt: repowering, maximum possible use of existing equipment with additions, e.g., installation of a gas turbine using an existing steam turbine.

Natural gas cogeneration, category above 300 MWt: repowering, maximum possible use of existing equipment with additions, e.g., installation of a steam boiler using an existing steam turbine.

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[47] With the possible exception of one or two sources currently being consider, such as the consider WER on the Mělník Power Plant site.

[48] Modification includes partial use of existing infrastructure (e.g., foundations, buildings, energy supply lines, etc.). A new source means a complete new unit/source, including necessary infrastructure. That is, if only a new boiler is built, it is understood as renovation/modernisation.

Construction of new facilities

Biomass heating plants: standardized hot-water boilers, standardized deliveries.

Biomass cogeneration: complete new source, requires a steam circuit, higher requirements for equipment, installation of a turbine and associated equipment and infrastructure.

Natural gas heating plants: standardized hot-water boilers, standardized deliveries.

Natural gas cogeneration, up to 50 MWt:: complete new source, e.g., installation of gas engines including HRSG and associated infrastructure.

Natural gas cogeneration, above 50 MWt:: complete new source, e.g., installation of combined cycle, including a gas and steam turbine and associated infrastructure.

The capacity categories are divided into subcategories by the method of existing equipment modernisation, namely:

- Heating source modernisation
- Cogeneration source modernisation
- New heating source construction
- New cogeneration source construction

The three following modernisation methods are assumed in the three categories up to 50 MW, from 50 to 300 MWt as shown in the following tables. The category above 300 MWt is not assumed due to the size of the individual generating devices that does not enable optimum use in the heating sector (see methodology description above).

Table 8 Assumed heating plant modernisation methods in category below 50 MWt

	Biomass	Gas	WER	SAF
Heating plant modernisation	X	X	-	-
CHP plant modernisation	X	X	-	-
Heating plant new source	X	X	-	-
CHP plant new source	X	X	X	X

Table 9 Assumed heating plant modernisation methods in category from 50 to 300 MWt

	Biomass	Gas	WER	SAF
Heating plant modernisation	X	X	-	-
CHP plant modernisation	X	X	-	-
Heating plant new source	X	X	-	-
CHP plant new source	X	X	-	-

The estimate is made using the representative method, the data source is the TS CR survey among its members, investment projects implemented in 2010-2020 and bids in tenders for 2020. Data collected in this way are corrected with expert estimates.

Data in each capacity category and modernisation method show relatively high variability; the average is not automatically taken as the representative value, but rather the typical value as per the expert estimate (within the variation range of each category). To test the influence of the choice of representative values on the estimated total investment needs by 2030, we made two basic scenarios for specific investment costs, namely:

- a conservative scenario, reflecting the upper-bound estimate of costs by 2030, and
- an optimistic scenario, working conversely with the lower-bound estimate of costs by 2030.

The estimated typical specific investment costs for each capacity category and modernisation method in the conservative scenario are summarized in the tables below. The critical cost parameter for heating plants is the source heat output in MWt; it is the installed electric output in MWe for cogeneration plants.

Table 10 Estimated specific investment costs for each heating plant modernisation method, category below 50 MWt, conservative scenario[49]

	Biomass	Gas	WER	SAF
Heating plant modernisation [million CZK/MWt]	8.4	1.5	-	-

[49] The specific costs for gas cogeneration plants below 50 MWt and above 50 MWt match the dominant solutions, e.g., gas engines for smaller installations vs. combined cycle for larger ones.

Cogeneration plant modernisation [million CZK/MWe]	72	15	-	-
Heating plant new source [million CZK/MWt]	20	3.2	-	-
CHP plant new source [million CZK/MWe]	85	17.8	227	159

Table 11 Estimated specific investment costs for each heating plant modernisation method, category from 50 to 300 MWt, conservative scenario

	Biomass	**Gas**	**WER**	**SAF**
Heating plant modernisation [million CZK/MWt]	7.5	1.2	-	-
Cogeneration plant modernisation [million CZK/MWe]	65	14	-	-
Heating plant new source [million CZK/MWt]	18.3	2.1	-	-
CHP plant new source [million CZK/MWe]	78	25.3	-	-

The following specific investment costs were used for the optimistic scenario.

Table 12 Estimated specific investment costs for each heating plant modernisation method, category below 50 MWt, optimistic scenario

	Biomass	**Gas**	**WER**	**SAF**
Heating plant modernisation [million CZK/MWt]	8.4	1.5	-	-
Cogeneration plant modernisation [million CZK/MWe]	36	15	-	-
Heating plant new source [million CZK/MWt]	20	3.2	-	-
CHP plant new source [million CZK/MWe]	85	17.8	210	118

Table 13 Estimated specific investment costs for each heating plant modernisation method, category from 50 to 300 MWt, optimistic scenario

	Biomass	Gas	WER	SAF
Heating plant modernisation [million CZK/MWt]	7.5	1.2	-	-
Cogeneration plant modernisation [million CZK/MWe]	31	14	-	-
Heating plant new source [million CZK/MWt]	18.3	2.1	-	-
CHP plant new source [million CZK/MWe]	78	25.3	-	-

5.3 Model structure for estimating investment costs by 2030

The model is based on the MPO study[50] mapping modernisation methods in the 45 largest district heating sources in the CR. The strategy covers existing "large" public and industrial heating plants. They provided approx. 92 PJ of gross heat generation in 2018, and the heat sales from these sources was approx. 49.5 PJ in 2018 (gross electricity generation approx. 18 TWh).

The model described here uses primarily the estimates of use of different fuel types and estimates of the share of heating and cogeneration plants in heat generation and supply; see the table below.

Table 14 Estimated structure of new sources replacing existing district heating sources (MPO)

	NG	BIOM	SMW and SAF
Heat generation (TJ)	37,298	11,486	7,100
CHP (TJ)	23,165	9,082	7,100
Mono generation (TJ)	14,133	2,404	0
Electricity generation from CHP (GWh)	7,078	858	454
Installed capacity (MWe)	2,022	245	130
Consumption (million m³, thousand tonnes)	1,945	2,132	1,270

[50] Strategy for Stabilisation and Development of District Heating Systems, MPO, November 2020, draft

The investments in the category of sources with total installed capacity below 50 MWt have already been made due to the new legislation on pollutant emission limits and due to the pressure to leave the EU ETS (20 MWt threshold). The renovations were mostly made as transition to natural gas. These renovated sources will not invest very much in the source base before 2030. Investments in district heating systems can be expected in the vast majority of cases in the categories below 50 MWt and above 50 MWt at the level of individual generating equipment. Solutions at the level of individual generating equipment can be expected particularly in the category up to 300 MWt. Installation of individual generating equipment above 300 MWt will be rather exceptional even for natural gas; it cannot be expected at all for biomass and waste due to the fuel availability.

The modelling employed the following assumptions:

1. The generation division between SAF and WER is 1:1.

2. The division of projects by share of modernisation and construction of new facilities by fuel type is shown in the table below.

Table 15 Division of modernisation of existing facilities and construction of new facilities by fuel type, cogeneration

	Modernisation	New facilities
Biomass	50%	50%
Natural gas	50%	50%
Waste, WER	0%	100%
Waste, SAF	0%	100%

3. The share of cogeneration in modernisation and construction of new facilities by fuel type is shown in the following table, compiled based on the questionnaire survey among members of the TS CR in January 2021.

Table 16 Share of cogeneration in modernisation and construction of new facilities by fuel type, cogeneration

	up to 50 MWt	50 - 300 MWt
Biomass	90%	10%
Natural gas	50%	50%

Waste, WER	100%	0%[51]
Waste, SAF	100%	0%

4. Estimated structure of output from CHP by 2030 by capacity category and fuel type: table compiled based on the questionnaire survey among members of the TS CR in January 2021

Table 17 Estimated installed electric output in cogeneration by 2030, based on TS CR survey[52]

	up to 50 MWt		50 - 300 MWt		Total
	Modernisation	New	Modernisation	New	
Biomass	110	110	12	12	245
Natural gas	506	506	506	506	2,022
Waste, WER		65		0	65
Waste, SAF		65		0	65

5. Estimated shares of different fuels by capacity category for heating plants are shown in the table below.

Table 18 Estimated shares of different fuels by capacity category for heating plants

	up to 50 MWt	50 - 300 MWt
Biomass	100%	0%
Natural gas	50%	50%
Waste, WER	0%	0%
Waste, SAF	0%	0%

[51] This is not an a priori refusal of "large" WER facilities, but an assumption of non-realistic construction of individual units with a capacity of 200 kt a larger, which are not as flexible for capacity reasons and they have no simple way to collect waste. Even for the assumed "large" WER facilities (such as Mělník), we expect implementation of 2 lines for 150 kt of waste each. Then the individual facilities fall within the category below 50 MWt.

[52] These are the sources listed in the Strategy for Stabilisation and Development of District Heating Systems, MPO, November 2020. Sources of non-members of TS CR are included based on information available in the TS CR database (former members) and using expert estimates based on analogy.

6. The estimate share of modernisation of existing heating plant sources and construction of new heating plant sources by fuel type is shown in the following table, compiled based on the questionnaire survey among members of the TS CR in January 2021.

Table 19 Estimated share of modernisation of existing facilities and construction of new facilities by fuel type, heating plants

	Modernisation	New
Biomass	50%	50%
Natural gas	50%	50%
Waste, WER	0%	0%
Waste, SAF	0%	0%

Table 20 Estimated installed thermal output in heating plants by 2030, based on TS CR survey

	up to 50 MWt		50 - 300 MWt		Total
	Modernisation	New	Modernisation	New	
Biomass	119	119	0	0	238.5
Natural gas	727	727	727	727	2,908
Waste, WER	0	0	0	0	
Waste, SAF	0	0	0	0	

The conservative scenario uses the following assumptions of specific renovation costs for renovation of networks. The data source is the TS CR survey among its members for the purposes of determining the absorption potential for money from the Recovery Fund (RRF), January 2021.

Table 21 Estimated specific costs of network renovation

	Urban development	Outside cities	Mixed development
	million CZK/km	million CZK/km	million CZK/km
District heating networks	42 - 55.5	12.6 - 19.7	25.2 - 31.1
Model value, conservative scenario	31.1 million CZK/km		
Model value, optimistic scenario	25.2 million CZK/km		

At the same time, both scenarios assume a renovation pace of approx. 20 km a year. The estimate of the network renovation pace is based on renovation statistics for the last decade or so and on a conservative expert estimate of the network renovation ability. A faster pace is precluded by a number of barriers: permitting proceedings, coordination with other infrastructure investment projects in the area, etc.

The modelling of the investment costs in nominal prices (considering price increases) used the same methodology as the estimate of investment costs for meeting the RES objectives[53]. The methodology is based on division of investments into two parts: construction and process equipment. An estimate of the shares of the construction and equipment parts was made for two basic modernisation methods: renovation of an existing source and construction of a new source on the existing site, broken down by thermal output. These are expert estimates based on information about planned source modernisation methods (according to the TS CR questionnaire survey in January 2021 and other information about district heating sources. Fuel type is not included in this estimate due to limited information. The table below summarizes the estimate of the shares of the construction and equipment parts.

Table 22 Estimated division of investment costs into construction and equipment parts

Modernisation type	**Source renovation**		**New source**	
	up to 50 MWt	50-300 MWt	up to 50 MWt	50-300 MWt
Equipment	85 %	90 %	70 %	75 %
Construction	15 %	10 %	30 %	25 %

We also made an estimate of division of investments in district heating source modernisation in the time periods until 2025 (included) and between 2026 and 2030. The following table sums up these estimates.

Table 23 Estimated division of investments into time periods by capacity category

	up to 50 MWt	**50 – 300 MWt**
until 2025	60%	30%
2026-2030	40%	70%

53 https://ekonom.feld.cvut.cz/cs/katedra/lide/valenmi7/cic2030/reports/valentova-et-al-investment-need-analysis-in-czechia-final-shortened.pdf

Note: This is based on an assumption of much faster project planning, permitting proceedings and implementation of smaller sources up to 50 MWt compared to sources between 50 and 300 MWt. Investments after 2030 are not included.

The study mapping investment costs by 2030 in the area of RES and buildings[54] contains a detailed discussion of escalation coefficients for equipment and construction work prices. A 2% annual coefficient is used for all the RES categories for construction work escalation. As for the equipment part, some RES categories are significantly influenced by the learning curve effect, so the escalation coefficients are between 0 and 2% for different RES categories. Some differences in the equipment price escalation can be expected in the heating sector modernisation, depending on the fuel type used. Nevertheless, sufficient data for assessing this influence are lacking. Due to the extent of the necessary heating sector modernisation (e.g., comparing the investment amounts between 2016 and 2019), thus increasing demand for specialised equipment supplies, a lower escalation pace than for construction work cannot be expected. That is why 2% is chosen as the lower bound of the price escalation estimate for the equipment part too.

5.4 Modelling results

The investment cost modelling results for both scenarios, in 2020 prices, are summed up in the following tables for the conservative and optimistic scenarios.

*Table 24 Results of heating sector modernisation investment cost modelling until 2030, million CZK, **conservative scenario**, 2020 prices.*

	up to 50 MWt	50 - 300 MWt	TOTAL [million CZK]
Costs of new CHP sources	43,459	13,745	57,204
Costs of CHP source renovation	15,521	8,025	23,545
Costs of new heating plant sources	4,711	1,527	6,238
Costs of heating plant source renovation	2,092	872	2,965
Costs of distribution system renovation			6,220
Total model costs			96,172

*Table 25 Results of heating sector modernisation investment cost modelling until 2030, million CZK, **optimistic scenario**, 2020 prices.*

	up to 50 MWt	50 - 300 MWt	TOTAL [million CZK]

[54] Ibid.

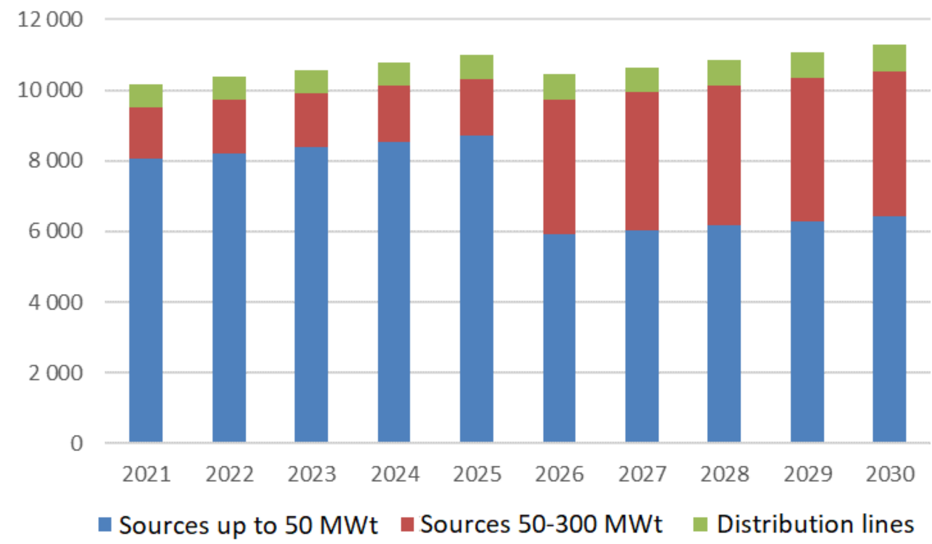
Costs of new CHP sources	39,689	13,745	53,434
Costs of CHP source renovation	11,552	7,608	19,160
Costs of new heating plant sources	4,711	1,527	6,238
Costs of heating plant source renovation	2,092	872	2,965
Costs of distribution system renovation			5,040
Total model costs			86,837

When the construction work and equipment escalation prices based on the above assumptions are included, the cumulative costs in the current prices of each year until 2030 are as follows:

- Conservative scenario: 107.2 billion CZK
- Optimistic scenario: 98.3 billion CZK

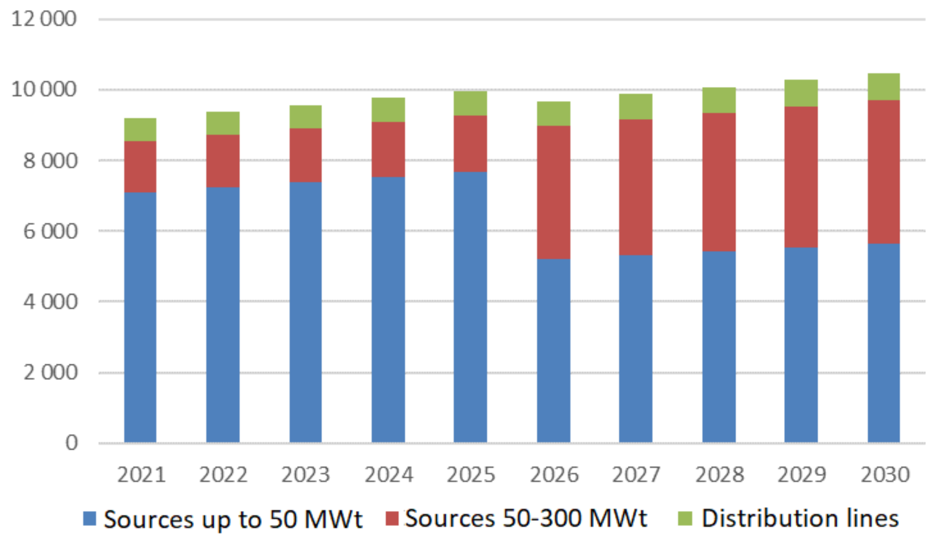
The following figures show the distribution of costs in time for both scenarios (in current year prices)[55].

Figure 18 Distribution of heating sector modernisation costs, current year prices, conservative scenario, million CZK



[55] A linear investment division is assumed in both periods (until 2025 and 2026-2030). An actual shift of some of the investment from the first period to the latter cannot be ruled out.

Figure 19 Distribution of heating sector modernisation costs, current year prices, optimistic scenario, million CZK



The following figures and tables bring more detailed information about the division of investments in the current year prices.

*Table 26 Division of heating sector modernisation costs by source category and modernisation stage, **conservative scenario**, current year prices, million CZK*

	until 2025	2026-2030
New CHP	32,060	31,653
CHP renovation	12,442	13,861
New heating sources	3,487	3,462
Heating source renovation	1,611	1,697
Distribution lines	3,302	3,645
TOTAL	52,901	54,318

*Figure 20 Distribution of heating sector modernisation costs in years in current year prices by source type and project, **conservative scenario**, million CZK*

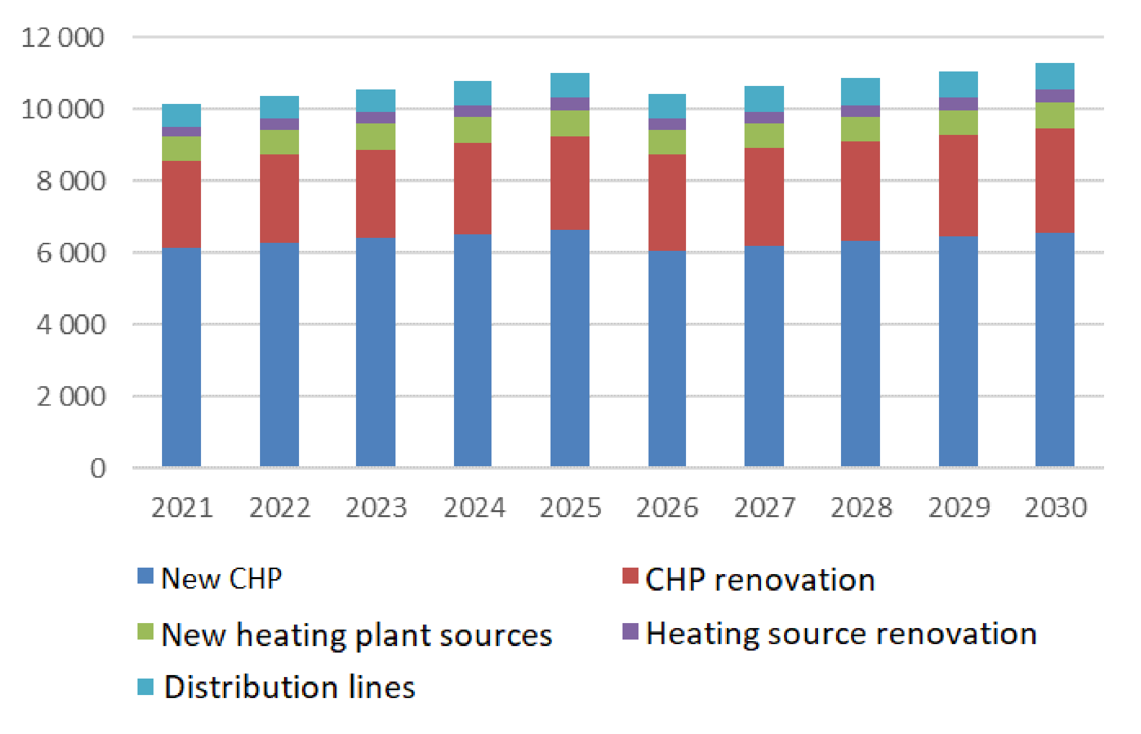
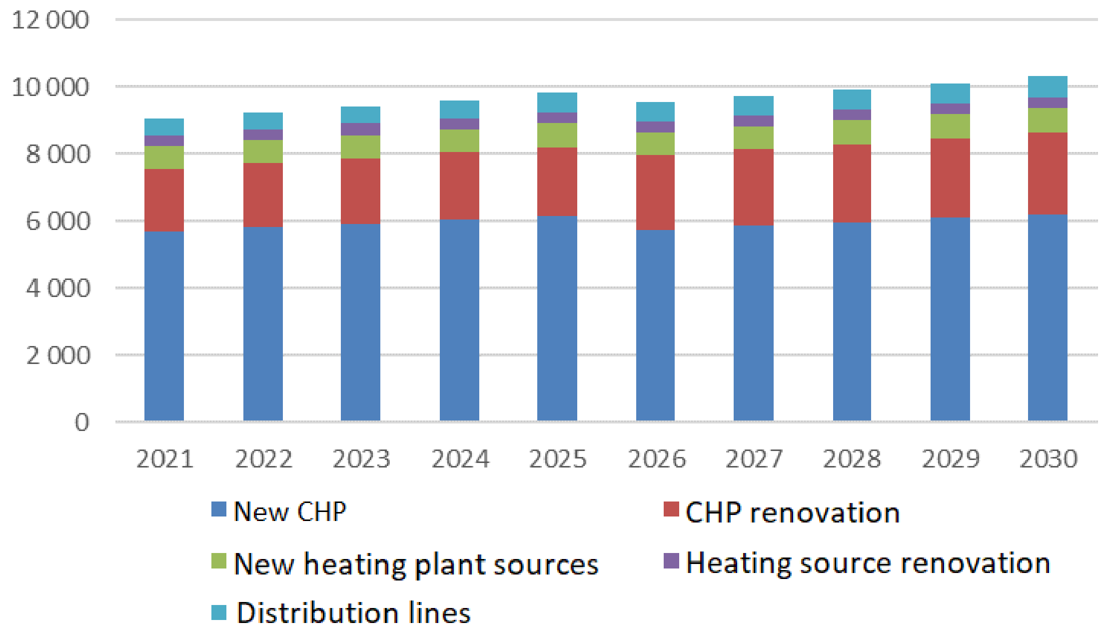


Table 27 Division of heating sector modernisation costs by source category and modernisation stage, optimistic scenario, current year prices, million CZK

	until 2025	2026-2030
New CHP	29,658	29,885
CHP renovation	9,781	11,658
New heating plant sources	3,487	3,462
Heating source renovation	1,611	1,697
Distribution lines	2,675	2,954
TOTAL	47,213	49,656

Figure 21 Distribution of heating sector modernisation costs in years in current year prices by source type and project, optimistic scenario, million CZK



6 Case studies and recommendations

The following chapter first presents two case studies: the municipal heating plant in Písek and C-Energy in Planá nad Lužnicí. These two heating plants were selected due to their decarbonization activities and attitude to diversification and decarbonization in the heating sector in general. Both companies are active and, at the same time, both represent two different types of district heating organisations (one a municipal heating plant, the other serving a wider portfolio of industrial customers). Based on the findings from the two case studies, the final subchapter brings a set of recommendations for further decarbonization of the heating sector, including use of existing and future support instruments.

6.1 Case study 1: Písek, municipal heating plant

6.1.1 History

The heating plant was established in 1987, when the primary source based on coal was commissioned, linked with an older boiler house based on heavy heating oil. A heat distribution system (steam lines in the residential development) was started in the city before the commission of the coal source. Both sources were located on different sites outside continuously developed areas.

The heating plant is a joint stock company with about 75% of the shares owned by the municipality and the rest by private shareholders – natural persons.

Installed thermal capacity of the primary source was 2x26 MWt with a max. steam supply of 2x30 ts/hour. The boilers are fuelled by brown coal, combusting low-sulphur coal dust in order to comply with emission limits. About 10-16% of biomass have been combusted together with the coal in recent years; it is mostly added in the form of sawdust or wood chips. The amount of added biomass is limited by the fuel passage capacity.

The 2x12 MWt backup source based on heavy heating oil was used as a backup for malfunctions or for covering peak heat demand on frost days. It was also used during the summer shutdown (July, August), supplying hot water for households.

The installed electric capacity is a counter-pressure system with 6 MWe + 1.6 MWe. The electricity generation in the primary source is thus fully dependent on heat supply.

A part of the heat distribution lines are steam lines (9 km, currently becoming obsolete) with a medium temperature of 130-160°C. There is also 19 km of newly renovated hot-water and warm-water lines with a heating medium temperature of 70-120°C.

The *supplied area* is a district city with a population of about 30 thousand. The developed area is a historic city core, extending into housing estates with older prefabricated buildings as well as some new high-density residential areas and scattered single-family housing. There are no large industrial or energy-intensive facilities in the area. The industrial estate is to the north of the city, and the necessary heat is supplied by local gas sources.

The overwhelming majority of consumers from the heating plant are households (60%) and retail and services (25%). Industrial customers make up only about 15% of the supply. The heat is sold to 8,000 flats and over 400 other customers. The design outdoor temperature in the area is -15°C. The heat demand is thus affected by average day temperatures in the course of the year, showing considerable seasonable variation. Heat sales to customers in the last 5 years have ranged between 350 and 380 thousand GJ. Given the customer structure, a change in the average annual temperature of 1°C will affect the heat supply by about 10%. Individual customers (service buildings as well as housing) are connected to the system continuously.

The electricity generation is 10-12 GWh/year. The electricity generated is used primarily for covering own consumption; the rest (about two thirds) is supplied into the distribution system. Depending on the heat supply, the annual fuel consumption in the existing facility was 40-50 thousand tonnes of low-sulphur coal.

6.1.2 Area heat supply concept

Minor proposals for modifications to the sources and the network have been considered in connection with stricter emission limits and the approaching end of the primary source service life. Growing emission permit prices have been another reason. The heating plant expenditures on emission permits have thus increased, in spite of their decreasing quantity, from 2 million CZK a year to over 20 million CZK a year, with an outlook of further growth.

The options proposed after 2000 have included desulphurisation of the coal source using wet limestone washing, a shift to gas both at the central source and in the form of smaller gas sources distributed around the area. At the same time, renovation of the steam network with a hot-water system was designed in order to reduce the heat losses. The proposals were developed aggregately into a strategic concept for the whole area. The intention is modernisation of the heat source, including the backup source, in order to reduce the fossil fuel consumption and the associated CO_2 emissions.

The concept has led to the need for new investments:

- The greatest investment need is the renovation of the steam distribution lines as a hot-water system to reduce the heat losses, thus reduce the heat generation by cutting the useless portion covering heat loss in the network. A hot-water system also works as a heat accumulator, enabling some reduction to the peak output of the sources. Simultaneously with the reconstruction of the pipelines, the reconstruction is underway for several dozen heat exchanger stations.
- Discontinue the heavy oil backup source and replace it with a gas boiler with an installed capacity of 19 MW.
- The primary source: instead of the desulphurisation considered before, renovate the source partly for pure biomass combustion in a separate boiler and leaving one of the two existing coal boilers in operation for a short time before its service life ends.
- The plant also introduced one additional natural gas boiler with an installed capacity of 5 MW for use in the case of failures and accidents.
- Since the primary source was partly discontinued and the other heat sources are located in various parts of the supplied area, the heating plant has been removed from the emission permit system.

6.1.3 Present state of climate and energy investment

The heavy oil source was dismantled in 2017 and replaced with a new 19 MW gas boiler. It is a full-size heat source, connected to the continuous heating system in another place than the previous primary source. In normal operation, it supplies the hospital and is used for covering heat demand in the area in summer.

A gradual reconstruction of the steam distribution lines into hot-water lines started in 2016. The last branch is to be renovated in 2021-2022.

A new 5 MW gas boiler was connected to the system in 2019 and is used in periods of low gas prices. It also serves as a backup source with a view to its location.

One coal boiler was dismantled in early 2020, and a new 10 MW hot-water biomass boiler is being built in its place. The fuel will be wood chips, obtained primarily from local sources, forest leftovers, and other purchases depending on the price as necessary. The boiler is supplied by a foreign company. The fuel supplier are local companies; the criterion of long-term sustainability of fuel supplies was an important criterion in the tender.

Once completed, the described investments will lead the current emissions of 62 thousand tonnes a year (average for last 5 years) to 27 thousand tonnes a year. Out of the total annual emission savings of 35 thousand t CO_2, 27 thousand will be at the sources. The saving due to reduced losses in the network – reduced useless heat generation – will be 8 thousand t CO_2 a year.

Overview of investment expenditures

The following overview lists investment expenditures on the individual project items along with the financing structure. Subsidy contributions are always dependent on the conditions of the specific support mechanism; they also depend on how the specific support scheme “matches” in time with the project planning and implementation.

In addition to the total amount, each investment is also shown as shares of different funding sources: total investment expenditures and within that (own sources / loan / subsidy, mostly from OPEIC) in million CZK. Credit accepted is long-term, 10-year bank credit. Guarantees for some of this credit have been given by the municipality, being the majority owner, as it is naturally interested in long-term stable heat supply.

Table 28 Investment overview, Písek heating plant

Investment type	Investment expenditures (million CZK)	Funding sources (million CZK)		
		Own sources	Credit	Subsidy
Heavy oil plant conversion to gas	40	2	38	-
Energy savings in heating plant buildings	6	4.5	-	1.5
Backup 5 MW gas source	8	2	6	-

Steam line reconstruction as hot-water line, new hot-water lines and connections[1]	270	10	170	90
Heat exchanger plant renovation, new connections	15	15	-	-
New biomass boiler	111	3	50	58
Other investments information systems, metering, vehicles, others	2-5/year	2-5	-	-

[1] EU subsidy under the Operational Programme Enterprise and Innovation for Competitiveness; investment spread into 2016-2022.

6.1.4 Strategy – projects planned for 2022

A major investment is the planned connection of the heating system to a biogas station, again reducing consumption of conventional fuels – coal and natural gas. Heat produced by the biogas station has not been used so far. Its connection to the DH system will enable supply to one of the housing estates with heat from the station renewable source. The project will include renovation of the heat transfer plants in the housing estate in order to reduce losses in the network. The expected investment amount is 37 million CZK (2/22/13).

The opportunities considered include installing a smaller CHP unit in a place that would be optimized with respect to the topology of the heating system. The other investment in consideration is heat storage, which would allow balancing the load with faster adjustments to outdoor temperature fluctuations, while enabling more even loading of the sources.

Furthermore, the plant considers construction of an installation allowing energy recovery from municipal waste. This will also address town priorities at a time when landfilling will be banned or at least significantly reduced. This investment would make it possible to both end the operation of the remaining coal boiler and significantly cut the natural gas consumption, thus CO_2 emissions. The preparation of this investment requires not only cooperation within the city, but also with municipalities in the vicinity, to gather their waste for incineration. A key question in the investment planning process is to define the annual amount of waste to be used by the facility. The assumption is approx. 25-40 thousand tonnes a year, depending on agreement with municipalities in the region.

6.1.5 Conclusions and recommendations for DH system in the area

The investment overview shows a great investment intensity of the essentially complete renovation of the system, both the sources and the network. The investment expenditures on these items over 7 years of intensive investment in 2016-2022 will total 500 million CZK. About 30% of the total is funded from various subsidy schemes, mostly the OPEIC, and a large portion of the funding comes from long-term credits; own sources make up a smaller share.

The investment strategy is based on a fundamental change in the fuel base, consisting in a shift from an originally fully coal-fired source to a combination of biomass and natural gas. One of the original coal boilers has been left to serve until the end of its lifetime, which is a few years away. Among other things, the fuel base diversification will enable response to current prices of each of the fuels, thus optimisation of the system operation.

Another necessary modernisation investment is the need to renovate the steam heat distribution lines, which were built as quite oversized in the 1980s. Given the price of heat back then, massively subsidized as part of the living costs, it was not economically interesting, for consumers in particular, to invest in any measures reducing the heat consumption in residential buildings, for instance. The subsidies to the price of heat came from revenues from electricity sales and directly from municipal budgets as well. The gradual thermal insulation of buildings and other energy-saving measures in the early 1990s reduced the heat consumption (by about 1% a year on average), and so the previously designed systems turned out to be oversized in both the source capacity and the distribution lines. These steam distribution lines could remain in operation in some parts of the network for some time in light of their technical condition, but at the expense of higher failure rate and repair intensity. However, steam distribution lines have high heat losses, particularly with lower consumption rates, so that heat is generated uselessly.

In connection with the long-term objective or reducing the carbon footprint, possibly down to climate neutrality, conversion of coal sources to natural gas is one of the paths for reducing CO_2 emissions. Moreover, this path is acceptable temporally, as the investments can be planned and made in a short time. It is not the ideal solution, though, as it reduces the emissions only to about 40-50%.

Biomass, a renewable source, can only replace a part of the demand in the area. Complete replacement with biomass would require amounts of biomass that are not available in the long run at reasonable distances and reasonable prices. Other renewables, such as heat from biogas, also have a limited potential only. Another issue is the highly probable fluctuations of forest biomass supply, caused by the current logging mostly for calamity reasons. Sizing a biomass-based source thus has to be designed with respect to more durable supply of biomass, sustainable in the long run.

Energy recovery from waste (WER) appears to be sustainable in the long run, not only in the area just described; at the same time, it contributes to waste management and long-term sustainable development. However, district heating companies cannot make this type of investment without cooperation with self-governments in the area, be it the region, district or municipality association. Differing local interests of municipalities in the area tend to be a significant problem in such cases.

Requirements for the pace of change call for cumulating demands for investment funds.

The above example of a municipal heating plant also shows that the financial demands cannot be settled without one-time investment support from subsidy schemes focused on support to greenhouse gas emission reduction.

6.2 Case study 2: C-Energy

6.2.1 History

The heating plant was originally the energy centre for the company Silon Planá (plastics, fibres). The source was built in 1958-1961, consisting in three ČKD coal boilers 3 x 55 t/hr, 2 x 6 MW TG, 100% coal, with a combined consumption of up to 300 thousand t/yr. The energy source was separated from Silon in 1996 by selling it to Thermo Ecotek Corp., US. A partial renovation was made in 1998 – increase to the boiler output, installation of a 46 MW TG, I&C, electrical. The source was acquired by AES Corp., US. in 2001 and sold to Carpaterra in 2011.

Production

The heat is supplied as steam with a pressure of 2 MPa, 1 MPa, 0.2 MPa; 350,000 GJ a year. Heat supply in the form of hot water is 250,000 GJ a year. The primary heat customers are the industrial companies Silon, Madeta, Maso Planá (KU), Kovosvit MAS. Heat is also supplied for space heating in Sezimovo Ústí, and recently also to Planá nad Lužnicí and parts of the city of Tábor. A greater majority of the heat supplied as steam is consumed for process purposes, i.e., for the industry, which is why this consumption is distributed more evenly around the year. Almost all of the heat supplied as hot water is intended for space heating.

A unification of the whole DH system of Tábor is planned for future; the heat supply will then increase to approx. 900,000 GJ a year. The annual electricity generation is 30 GWh. The company operates an local distribution system.

Four large gas CHP units were installed in 2011, enabling an expansion to the company's business to provision of supporting services not only in category MZ15 but also in MZ5 and SR.

6.2.2 Present state of climate and energy investment

The coal source was modernised in 2012-2015 by replacement of three granulated coal boilers with a 2 x 40 t/hr fluid combustion grid boiler at 45 bar / 486°C. The greening concept was aided by flue-gas desulphurisation from the coal boilers by wet limestone washing. A TG renovation increased the steam parameters, so the electric output after the renovation is 26 MWe.

The new gas source is 4x CHP with an electric output of 4 x 9.17 MWe (Rolls Royce gas motor-generators with flue-gas boilers – HRSG). In addition, a 20b / 3000C backup steam boiler was installed with an input power of 15 MWt.

The total investment of approx. 1.5 billion CZK was financed from own sources and bank credits (consortium of ČS, RB, UCB). Subsidies of approx. 300 million CZK were obtained from the EU Cohesion Fund – OP Environment, priority axis 2 - emission reduction.

Other modernisation projects in the district heating facility were implemented in 2018-2020:

- Construction of a heat line to Planá nad Lužnicí – replacement of local heat sources with heat supply from C-Energy; in operation since 8/2018, length 2.6 km, approx. 18,000 GJ;
- Construction of a hot-water line to Nad Lužnicí housing estate in Tábor, length 5 km, 80,000 GJ, in operation since 07/2020;
- Extension of the hot-water line to another area in Tábor, in construction, to be commissioned in 12/2020;
- Combined combustion of wood chips in coal boilers K5 and K6 – achieved 30% of wood chips by volume (part of IPPC), verification of achievable maximum of biomass for existing equipment without major interventions in the equipment;
- EVECONT container unit for energy recovery from unusable plastics – trial operation.

The modernisation investments also included an expansion to the heating plant operations in order to achieve further diversification and flexibility of the source:

- Installation of two more Rolls Royce gas motor-generators with flue-gas boilers, in operation since 1/2020;
    - First installation of 11.5 MW RR motors in the world;
    - Increased ability to provide a wider range supporting services (SVR);
    - Increased heat output – heat supply to Tábor DH system;
- Construction of a 22 kV substation – LDS expansion.

Flexibility

Another major investment is the installation of a 4 MW / 2.5 MWh battery storage facility and a 0.520 MWp photovoltaic power plant. It is currently the largest battery storage facility in Czechia, in operation since 9/2019.

- Output 4 MW, capacity 2.5 MWh – largest in Czechia;
- Increased heating plant output range for provision of supporting services;
- Enabling blackout start of C-Energy Planá, followed by a transition to island operation;
- C-Energy Planá and local distribution system shifting to island operation mode;
- Elimination of effects of repeated starts and short-term under- or overvoltage.

Source emission and parameter comparison, 2013 vs 2019

Table 3 below compares the air emissions of the original coal source before the modernisation and the present state.

Table 29 Air emissions of original coal source before modernisation vs present state

Comparison of selected source parameters	before renovation	after renovation
SO_2 emissions: limit/actual [mg/m^3]	1,700	400/34*

NO_X emissions: limit/actual [mg/m^3]	650	300/178*
PM emissions: limit/actual [mg/m^3]	100	20/1.2*
Heat input in coal (wood chips) [MWt]	195	71.6
Heat input in gas [MWt] incl. backup boiler K4	-	143.8
Installed electric capacity [MWe]	TG3**	TG3+6xPM+BSAE1+FVE**
	46.5	26 + 60 + 4 + 0.520
Ability to change el. output within 5 minutes [MWe]	10	78
Boiler efficiency [%]	84%	92%

* actual = results of verification in 10/ 2019

**TG: turbine generator, PM: gas motor, BSAE: battery electricity storage system, FVE: photovoltaic power plant

6.2.3 Strategy until 2030

Period 2021-2025

In the spring of 2020, C-Energy acquired a majority interest in the district heating utility Teplárna Tábor a.s. An agreement with minority shareholders is planned in the coming months, to transfer shares and property so that C-Energy becomes a 100% shareholder of Teplárna Tábor a.s., owning the heating plant in Tábor and the primary distribution lines. After that, the company will be merged with C-Energy Planá s.r.o.

One of the important aspects of this process is retention of maximum wholeness of the DH system in all of the Tábor agglomeration. Connection of the DH system and ownership connection of the sources can optimise source deployment. A decision has been made to phase out generation in Tábor, and heat for the DH system is generated primarily in the greener source in Planá nad Lužnicí.

The DH system in Tábor comprises steam lines to a great extent. A complete conversion of the steam distribution lines into hot-water lines is planned by 2025 at the latest. Besides reduced heat losses (or increased energy savings), this project will have other benefits. One of them is that there are more options and more efficient generation processes for making hot water than for making steam. A number of these technologies are installed at the Planá nad Lužnicí source (e.g., the fleet of gas motors with a combined capacity of 60 MWe, where hot water is made on the casing), so the source efficiency and utilization will increase.

Vision 2025–2030

The vision for 2025 is that C-Energy Planá has no coal in its fuel mix in 2025 and the portfolio of sources operated in the CHP mode heads towards carbon neutrality. C-Energy Planá adopted Strategy Planá 2025 in February 2021, which aims to abandon coal combustion entirely while maintaining competitiveness and price affordability, and to reduce the CO2 emissions from the current 120 thousand tonnes to 11 thousand tonnes a year in 2025.

This objective will be achieved by replacing the current coal technology with biomass (wood chip boilers). The EVECONT technology is in trial operation now: it generates 2 bar steam using energy from unrecyclable, unusable plastics. Besides, the company has a concept and technology documentation for ***waste energy recovery*** (WER) with an annual capacity of approx. 40 thousand tonnes of mixed municipal waste (MMW) a year. The WER size matches the quantity of MMW produced in the Tábor region, taking into consideration its potential decrease. The project concept is based on using MMW mostly from the near vicinity of the source so that to use waste from the near area for making energy and then consume all the energy made in the area, thus implementing the circular economy principle. The quantity of thermal energy from this medium-sized WER facility matches the heat consumption in the Tábor DH system (another reason why keep the DH system unified and expand it further). The WER design worked with the annual heat consumption in the DH system, so that the WER will generate heat even in summer at a quantity that will be 100% used in the CHP mode without forced generation of condensation electricity only to keep the WER running; this will maximize the utilization of primary energy from the MMW and also ensure optimum economic rate of return. Thus, the Planá facilities as a whole are capable of year-round heat supply from CHP for the entire Tábor agglomeration DH system. A low-emission or gas source to be used as a backup or peak source will be built in Tábor.

In addition, the Planá facility has a high degree of flexibility for provision of supporting services to the power distribution system (SVR – output balancing services), and this approach will be retained. The battery electricity storage system (BSAE) technology has proven instrumental in this. It offers a number of functionalities and opens up a whole portfolio of additional operating options for existing rotary sources. The vision is to increase the BSAE capacity for further improving the source flexibility.

6.2.4 Conclusions and recommendations for similar DH systems

Flexibility is a means for heating plants to maintain wholeness of DH systems. Banks no longer finance investments in coal sources, so heating plants have to focus on planning investments in other “clean” technologies and provision of additional energy services. The key is diversification of the fuel base, enabling operating optimisation and cost reduction. Above all, diversification enables reducing sensitivity of the DH system to external effects such as fuel price developments a prices of other inputs, including emission permits, and changes in the regulatory environment.

In connection with the long-term objective or reducing the carbon footprint, possibly down to climate neutrality, ***conversion of coal sources to natural gas*** is one of the paths for reducing CO_2 emissions.

Moreover, this path is acceptable temporally, as the investments can be planned and made in a relatively short time. It is not the ideal solution, though, as it reduces the CO_2 emissions only to about 40-50%; it is thus not the path to achieve carbon neutrality in heat supply. At the same time, conversion to gas can be a means for heating plants to achieve higher flexibility and ability to provide SVR, thus reducing costs of acquisition of permits for operation of the gas source.

Biomass as an renewable source can replace fossil fuels entirely only in smaller sources in our opinion. Sources in larger urban areas would require such quantities of biomass that are not available in the acceptable surroundings of the source, and if a large source runs on biomass only, the emission production from transporting the biomass increases disproportionately, thus essentially zeroing out the environmental effect. All the heat demand cannot be covered exclusively by biomass combustion in the analysed area either. Another issue is the highly probable fluctuations of forest biomass supply, caused by the current logging mostly for calamity reasons. Sizing a biomass-based source thus has to be designed with respect to more durable supply of biomass, sustainable in the long run. Other renewables, such as heat from biogas, also have a limited potential only.

Energy recovery from waste (WER) appears to be sustainable in the long run, not only in the areas just described; at the same time, it contributes to waste management and long-term sustainable development. However, district heating companies cannot make this type of investment without cooperation with self-governments in the area, be it the region, district or municipality association. Differing local interests of municipalities in the area tend to be a significant problem in such cases, and the solution is unfeasible without achieving accord not only in the area of waste management in the region. In some cases, use of waste heat is also possible depending on its availability.

Modern technologies (BSAE, gas motors) expand the source flexibility significantly. C-Energy has proven that BSAE has major benefits for a source, and its deployment of modern technologies shows a possible path for developing activities in DH systems. Equipment allowing a wide range of electric output control in a short time and accurate output management makes a significant contribution to reliability of electricity and heat generation and supply.

Another path to system flexibility is provision of energy services for customers.

Renovation of sources has to take into account their installed capacity with respect to heat demand development in the area and its course in time. Reduction to demand for maximum source output, thus reduction to necessary investments, can be aided by ***heat accumulation*** both at the source and in hot-water and warm-water distribution lines along with energy management at the customers.

Last but not least, ***renovation of distribution lines*** is an important investment activity, particularly on still existing steam distribution lines. Switching to heat distribution at lower temperatures will significantly reduce heat losses. Sometimes, it is also beneficial to install a steam generator next to a customer instead of transporting steam for long distances.

6.3 Recommendations for investment plans and measures in the heating sector

Based on the detailed analyses and specific findings from Písek heating plant and C-Energy heating plant in Planá nad Lužnicí, the final chapters will recommend not only measures for the heating sector, but also utilization of appropriate and available financial support instruments necessary for further decarbonization of this important energy sector.

6.3.1 Development recommendations

The expected investment plans of the heating plants in Písek and Planá nad Lužnicí indicate the direction for the Czech heating sector, which will have to cope with a major coal phase-out in the near future, among other things. This fundamental change in the fuel base for most heating plants naturally raises the question of substitutes for coal. If biomass is available within acceptable transport distances of the heating plant, we recommend replacing a part of the coal supply with biomass; nevertheless, a complete substitution is not practically feasible in light of the limited biomass potential. We regard natural gas as a more readily available fuel than biomass for most heating plants. Representatives of the Association for District Heating have signed a Memorandum of cooperation for future decarbonization of the heating sector with representatives of the Czech Gas Association. Although conversion of coal sources to gas is acceptable in the short term according to the Taxonomy principles, it is only a transition strategy in connection with the objective of climate neutrality. Therefore, we generally recommend maximum possible diversification of the fuel base. As we have demonstrated on the example of the Písek heating plant, use of heat from a nearby biogas station, for instance, can be considered to a limited extent. Nevertheless, we regard waste energy recovery as a generally more acceptable alternative fuel, as documented by the investment plans of the Planá nad Lužnicí heating plant, for example, where the energy use of mixed municipal waste will aid the circular economy principle too.

However, diversification of heating plant fuel base is not our only recommendation for maintaining DH systems. The investment activities that we deem essential for many heating plants is renovation of heat distribution lines, and a shift from steam lines to warm-water or hot-water lines. The case study of the Písek heating plant demonstrated the present state of most heating plants, where the thermal energy consumption in a number of areas gradually decreases due to energy-saving measures, such as building thermal insulation. Systems designed in the past thus turn out to be oversized, including the distribution lines. Still existing steam distribution lines in many heating plants shows large heat losses, particularly with lower consumption rates. For these reasons, we recommend paying attention to distribution line renovation in the investment plans.

The strategic framework for future investment in the heating sector of the Czech Republic should naturally also reflect and make use of available instruments support the European Union's decarbonization process. Some of these tools that the Czech Republic can use are the Modernisation Fund, National Recovery Plan and, to a limited extent, the Just Transition Fund.

6.3.2 Development financing

Modernisation Fund

The set of tools of the Green Deal, assuring the European Union's transition to a more sustainable economy, includes the Modernisation Fund, intended for ten countries in the EU[56], including the Czech Republic, pursuant to the updated Directive 2003/87/EC on establishing a scheme for greenhouse gas emission allowance trading (EU ETS). The total amount in the Fund available to the Czech Republic is approximately 154 billion CZK, which is 15.6% of the total Modernisation Fund money designated for the listed countries. The distribution of the funds is based on an Annex to the EU ETS Directive, and the Czech Republic is the second-biggest beneficiary from the EU Modernisation Fund after Poland. Generally, the aid should go to tools directed at faster transition of these countries to a low-carbon economy by 2030. With some simplification, the Fund is focused on:

- greenhouse gas emission reduction,
- energy efficiency increase, and
- increased share of renewable sources of energy in the total energy mix.

All the above measures doubtlessly also concern the heating sector. As we noted in 3.1, a number of larger cities in the Czech Republic use a central heat supply system, which has to be transformed, including in light of the general climate and energy objectives, gradually in order to achieve higher use of low-carbon energy sources, including energy from secondary sources and waste heat. Both the greenhouse gas emission reduction and the increase in the share of renewables concern the two heating plants included in our selected case studies. Generally speaking, the Modernisation Fund assumes support to these types of investment in the heating sector, specifically its Heat programme. The total expected allocation of fund to modernisation of central heat supply systems from the Modernisation Fund is 40 billion CZK[57], about 26% of the total of 154 billion mentioned above.

National Recovery Plan

The objective of the National Recovery Plan is to promote a revival and resilience of the country's economy after the Covid-19 pandemic. Money from the Fund shall mitigate the crisis impacts, promote reforms and public investments and thus contribute to restoring economic growth and job creation. The National Recovery Plan is directly related to EU financial support, so-called Recovery and Resilience Facility[58], under which approximately 670 billion EUR has been designated for all the member states. Czechia will be entitled through the National Recovery Plan to an estimated 182 billion CZK. The funds will be available until 2026, by when all the investments and reforms have to be implemented. The money should go to a wide range of measures in accordance with the digital and

[56] Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia

[57]Source: General programme document for Modernisation Fund implementation, version as of 25 January 2021.

[58] https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en

green transition of the economy. Climate-related projects should be one of the main funding areas (up to 37% of the total expenditures). Generally, these measures should aim at sustainable transport infrastructure, clean mobility, energy consumption reduction and transformation of industry, building renovation, nature protection and support to circular economy. The measures should include an industry transformation and transition to cleaner energy sources. Specifically, the MPO assumes to use the funds for construction of new photovoltaic sources, modernisation of locomotives and, last but not least, modernisation of heat distribution in district heating systems. According to available information from the Government Sustainable Development Council on 20 January 2021, the funding for the industry transformation and transition to cleaner energy sources is expected to amount to single billions of CZK, with possible further cuts, because the sum of requirements from the different ministries (January 2021) exceeded the maximum possible allocation by some 100 billion CZK. According to available information, measures in the DH systems are only assumed to cover modernisation of heat distribution lines, or replacement of steam lines with more efficient warm-water lines. The specific amount of funds designated for DH systems were not known at the time of writing (February 2021). The final version of the National Recovery Plan will be developed by April 2021 in conjunction with the negotiations with the European Commission. Regarding the purpose of this study, it has to be stressed that however great the expected total allocation of funds from the National Recovery Plan of approx. 182 billion CZK may seem, we do not assume any major allocation of funds specifically for the heating sector. In an optimistic scenario, we estimate heating plants to receive no more than about 2 billion CZK designated exclusively for renovation of distribution lines.

Just Transition Fund

The primary purpose of the Just Transition Fund is to mitigate impacts of the transformation to a carbon-neutral economy in regions where the impacts and consequences will be the most severe. That is why the Fund supports primarily comprehensive projects for territorial renovation and region-specific project on entrepreneurial environment, science and research and active employment policy. The money from the Just Transition Fund can be used in three out of the Czech Republic's fourteen regions, namely Karlovy Vary, Ústí nad Labem and Moravian-Silesian Regions. The allocation of available funds is being planned. Nevertheless, according to our information, it will not be possible to use the money from the Just Transition Fund directly for changing fuels in existing heating plants.

Operating support to combined heat and power generation

The operating support to CHP is intended to promote electricity generation as part of high-efficiency CHP, which achieves significant primary energy savings compared to separate electricity generation and heat generation in accordance with EU legislative requirements[59]. The current CHP support scheme is ending and should be superseded with a new one. Based on the quantified investment needs for sources in the EU ETS and considering the coverage of needs of the remaining district heating sources, it appears useful to support CHP as part of modernized/new sources in the period before 2030

[59] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency

with a sum of at least 20 billion CZK so as to reduce the expected investment gap between the current climate and energy investments and the investment need[60].

According to TS CR representatives, the measures described above should aim in aggregate to cover at least 60% of the currently assumed costs of transforming the heating sector by 2030, so as to reflect the adequate risks of increasing the expected investments and enable heating sector modernisation without major impacts on the price of heat for end customers.

7 Conclusion

The Heating Industry of the Czech Republic is currently facing a fundamental change in both its fuel base and ways of further functioning. The Heating Industry of the Czech Republic is currently dealing with a shift away from domestic coal use, which still has a major share in the production of supply heat. This study analyses structural changes in the heating industry as one of the Czech energy sectors. Also, the study maps the current state and amount of necessary investment funds for the transformation of heating to meet the Czech climate objectives, recommendations for diversification, and direction of the heating sector for the following years.

The main conclusions of this study are as follows:

The definition of the concept or sector of heating is not fully settled. For this study's purposes, we have included in the analysis all licensed entities, i.e. entities that do business under the ERÚ license.

Transformation/modernisation investments in the heating industry will have to be in line with the EU Taxonomy, i.e. investments must be qualified as sustainable or at least 'transitional'. The specific design and sustainability criteria for each sector are still in preparation at the time of writing and thus bring a certain element of uncertainty to heating companies' investment decision-making. It is certain that fossil fuels, including natural gas, do not meet sustainability targets.

However, there is an ongoing debate around using natural gas, which could be expected " to green" in the future. However, this "greening" is currently not clearly technologically, economically and politically anchored. In this context, the transformation of heating resources from domestic coal to natural gas combustion can only be considered as a transitional investment, which will have to be complemented in the incoming decades either by 'gas greening' or replaced by other technologies.

The climate targets for heating are not clearly defined. One of the main anchoring commitments should be a recommendation of the so-called 'Coal commission' dealing with coal mining and combustion declining in the Czech Republic. Although the Commission recommended the deadline of 2038 in December 2020, this date has not yet been confirmed by the Government of the Czech Republic, as the main approval authority. A realistic deadline for the cessation of coal use in the heating

[60] This is a conservative (minimalist) estimate. Given the estimated costs in both transformation scenarios (and in light of the potential amount of emission permits and NG and biomass prices), we could assume a higher sum of up to approx. 35 billion CZK. Nevertheless, the design decision for the new support tools will play a crucial role.

sector is expected earlier, due to other circumstances (EU climate targets, project finance, or the development of emissions trading and, in particular, the price of the emission allowance). The emission allowance price development will be one of the key factors following the change in EU ETS legislation. After 2020, a further decrease in the amount of heat production allowances allocated free of charge can be foreseen, but its trajectory is not precisely established at the time of writing.

Tracked investments in reducing greenhouse gas emissions in 2014 -2019 amounted to CZK 33.1 billion, i.e. CZK 6.6 billion per year on average. However, two-thirds of these investments are not in line with the EU Taxonomy currently under preparation. Of course, when implementing these investments, the classification of sustainable investments did not exist. These investments were fully in line with the sector's expectations and the conditions of the public programmes from which these investments were mostly co-financed. In the future, it will be necessary to address the issue of depreciation of these investments (before the end of their originally planned lifetime). In 2017-2019, investments in line with taxonomy or transitional investments already prevailed.

Support programmes are crucial for investment in the heating industry. Basically, all climate-energy investment actions are the result of the existence of a financial instrument or political measure. In particular, the EU ETS (and its part of the National Investment Plan) and specific grant schemes under operational programmes (OPE, OPEIC, formerly OPEI). In this respect, the upcoming Modernisation Fund will be crucial as an additional source of investment grnts. During the period considered, 40 % of the investments were aimed at reducing losses in thermal energy distribution systems, further 40 % were new installations of CHP, and 20 % was a change of fuel for natural gas. From the point of view of taxonomy, the last two types of investments are considered transitional.

By 2030, it will be necessary to invest approximately CZK 98-107 billion in current prices in the heating sector (resources above 20 MWt). The model foresees the reconstruction or construction of new resources for about 85% of sources (still burning coal) and about 200 km of distribution by 2030. Most of these investments are resources up to 50 MWt (approx. 2/3 of investment needs). For the modernization of heating plants – heat sources, technologies for natural gas, biomass are envisaged in particular. Simultaneously, energy recovery of waste and alternative fuels is envisaged. Roughly two-thirds of the current production of coal supply heat is expected to be replaced by reconstructions or new sources for natural gas, about a fifth of coal will be replaced by biomass, about 13% of coal supply heat production will be replaced by new sources based on energy recovery from waste and the alternative fuels.

Due to the scale of the modernisation, the overall heating industry modernisation will have to address the balance between financing provision through operators' sources and public funds. Also, the coordination of design, authorisation, construction, and construction activities must be addressed. Public funding must avoid the transfer of transformation costs to heat prices for final customers, which could significantly jeopardise the economic viability of the DH systems. In addition, there is a significant increase in investment activities in this area compared to previous years. There may be a real risk of a shortage of supply capacity on specialized companies providing this type of reconstruction and modernization work.

Selected case studies point to several **main challenges and possibilities for addressing the transformation of the heating industry:**

Flexibility is a means for heating plants to maintain the integrity of SZT systems. Key in this regard is diversification on the fuel base side, making it possible to optimise operations and reduce costs. Diversification makes it possible, in particular, to reduce the sensitivity of the SZT system to external influences such as the growth in fuel prices and other inputs, including emission allowances, changes in the regulatory environment.

In the context of achieving climate neutrality, **rebuilding coal-fired power plants to gas-fired is a time-acceptable but only transitive strategy** that leads to a reduction in emissions of only about 40-50%

Biomass as a renewable resource can only replace part of the supply. A full biomass replacement would require a quantity of biomass that is not available at reasonable distances at a reasonable price in the long term. Other renewable sources, such as biogas heat, also have limited (and usually only locally limited) potential. The dimensioning of the biomass-based source must therefore be designed with a view to a more sustainable, long-term sustainable supply of biomass.

Energy recovery of waste appears to be a long-term sustainable solution. However, heating companies cannot access this kind of investments without cooperation with the local authority. Local interests of individual municipalities in the locality of interest may be an obstacle. In some cases, it is also possible to use waste heat depending on its availability.

The speed of change in the transformation triggers a large investment need in a short time-frame. Investment needs may therefore have to be supported with one-off investment grants aimed at promoting the climate change mitigation and GHG emission reduction.

Modern technologies (e.g. battery systems) significantly expand the flexibility of the source. These technologies have significant resource benefits; they show a possible way to develop activities in the district heating. Equipment with the capability of a wide range of power regulation in a short time and the accuracy of power management contribute significantly to the reliability of electricity and heat production and supply. Another way to flexibility in the system is to provide energy services for customers.

When reconstructing resources, it is necessary to carefully consider their installed capacity concerning the development of heat needs in the site and their course. **The accumulation of heat** at the source, the use of the storage capacity of steam and hot water distribution systems, and energy management at the customer side can reduce the demands on maximum resource performance and thus reduce the intensity of the investment.

Last but not least, the **reconstruction of distribution systems** for selected systems, especially existing steam distribution systems, is an important investment activity. Switching to distribution systems with a lower medium temperature significantly lower the heat loss.

The main upcoming instrument for supporting the transformation of the heating industry is the Modernisation Fund. It is expected that about CZK 40 billion will be earmarked to support the heating industry. Another source of funding should be the Recovery and Resilience Facility to support the modernisation of heat distribution and, last but not least, the operational support scheme for cogeneration of at least CZK 20 billion (using less conservative assumptions of up to CZK 35 billion) to reduce as much as possible the expected investment gap between existing climate-energy investments and investment needs. In particular, given the investments already made, the level of aid will be important. The heating industry's transformation is reflected as far as possible in the amount of the heating price for final customers

Beyond the 2030 horizon, further changes and the process of transformation of the heating industry can be expected, for example towards large heat pumps (possibly geothermal and solar energy) or greater use of heat accumulation in heating systems, which is currently being used in terms of support services.