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Policies to Decarbonize District Heating: International Best Practices

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1.0 Executive Summary

Many countries and cities have adopted or at least considered decarbonization pathways to reduce carbon dioxide (CO_2) emissions. These pathways often highlight the building sector as an important component of decarbonizing the economy and improving energy efficiency. However, it is very difficult to decarbonize buildings. Some decarbonization plans, such as many in the EU, highlight district heating (DH) as a promising contributor to decarbonization due to its strong potential to reduce CO_2 emissions as well as increase energy efficiency in buildings. Although DH is more energy efficient than building-level boilers, it cannot be used as a stand-alone decarbonization tool. DH systems powered by fossil fuels such as coal still produce large quantities of CO_2 emissions. Thus, it is important not only to expand connections to DH networks, but also decarbonize DH systems, to ensure full emissions reduction benefits.

Ukraine has a very large DH sector. Even with all inefficiencies and a reliance on fossil fuels, the DH sector holds the potential of leapfrogging past high-emitting technologies to a low-carbon future. Ukraine can learn from the experience of European countries where efficient and low-carbon DH systems have been expanding over the past several decades.

This report analyzes and discusses best practices within DH systems throughout many countries in the European Union (EU) and beyond. Using case studies, the report outlines findings of how DH systems can impact CO_2 emission reductions and energy efficiency. These findings can be used by national policymakers and municipalities in Ukraine to illustrate the impacts from increasing connections to DH systems, and decarbonizing DH systems, on country's emission reduction and energy efficiency goals. The goal of the report is to provide a review of policies that countries and cities can use to promote the decarbonization of the DH sector in support of overall national decarbonization plans. The report includes recommendations that consider international best practices while also focusing on potential solutions to Ukraine's unique challenges in the DH sector.

Policymakers in both national and local governments can use several policy tools to achieve decarbonization goals and deep decarbonization within DH systems. These mechanisms are defined at the national level in strategic national climate documents. Governments can implement economic mechanisms such as carbon taxes and carbon trading schemes across the economy to incentivize decarbonization and create a financial framework to promote the use of low-carbon energy sources such as DH. National policies to reduce CO_2 emissions from multiple sectors, including DH, may include mandatory goals for energy efficiency and renewable energy, building retrofits and more stringent energy codes. Similarly, local governments can also promote decarbonization of the DH sector by utilizing policy mechanisms such as local plans for heat supply and demand, heat tariffs, and direct subsidies to encourage the use of carbon-free or low-carbon DH. In addition, cities can implement specific decarbonization plans to reduce emissions from all their sectors, including buildings and DH. These include direct subsidies to DH companies to implement decarbonization projects, improve management of DH systems and work with customers to optimize heat consumption.

Overall, for national decarbonization goals to be achieved, promotion of DH and decarbonization within DH systems will be crucial. Government can use combination of national and local policies to decarbonize DH systems.

2.0 Introduction

To limit the negative impacts of climate change, it is necessary to decrease amounts of global greenhouse gas (GHG) emissions from all sectors of the economy. Buildings emit a significant share of energy related CO_2. Decarbonizing buildings is difficult and costly; it requires (i) a transition from fossil fuels to electricity or renewable sources of energy (e.g., using electric heat pumps, geothermal heat pumps, or renewably sourced heat pumps), (ii) building modifications (e.g., insulation retrofits, building design changes, varying construction materials, etc.) to promote increased energy efficiency, and (iii) technological advancements. However, DH provides a unique opportunity to radically reduce emissions from heat generation, reduce carbon intensity and even create carbon-negative heat supply systems. In addition, DH makes it possible to decarbonize urban heating at a relatively low cost, while also increasing energy efficiency of buildings. The depth of these impacts makes DH a cornerstone for many decarbonization pathways.

Globally, less than 2% of delivered building heat is supplied by renewable DH systems, showing the potential for expanding DH connections in many cold regions of the world. Thus, it is crucial to expand the use of DH to achieve emission reductions and improve energy efficiency. However, to further reduce emissions, it is necessary to shift the energy mix in DH systems from fossil fuels (i.e., coal, natural gas, and oil) to renewable energy (i.e., biomass, waste heat, wind, solar, and geothermal). In addition, technological advancements can further reduce CO_2 emissions and increase energy efficiency, as combined heat and power (CHP) systems reuse waste heat generated by electricity production, leading to more energy efficiency, and the utilization of less carbon-intensive sources to produce heat energy. With replacements and upgrades of current existing heating systems, new generation DH systems could reduce CO_2 emissions from DH by about 23% by 2050, saving between $1.6-2.4 trillion in energy costs (Project Drawdown 2017).

Although GHG emissions in Ukraine have been decreasing since 1990, emissions have started to level out since 2016. In order to achieve Ukraine's goal of net-zero carbon emissions by 2060, efficient heat energy in the form of DH will be crucial. Today, DH systems serve 40% of Ukraine's population (approximately 5.5 million households), covering half of the energy demand for heating purposes in the entire country (European Union 2020). To continue the trend of emissions reductions and to reach the countrywide goal of net zero emissions, this report concludes that a further expansion of DH connections in Ukraine is critical, as well as a shift away from fossil fuel sources within DH systems toward renewable energy sources.

3.0 Methodology

The report is based on the experience of countries with advanced DH systems in applying policy instruments to decarbonize their economies and DH systems. The original group of surveyed countries is from country profiles of EuroHeat, a research organization that uses EU data and resources to promote sustainable heating and cooling in Europe and beyond. The original list of countries was narrowed down by using several criteria. First, the PNNL research team selected countries where DH systems provide heat to no less than 10% of a country's population. Second, countries which published their climate goals with the focus on buildings were also included. Finally, the team looked for examples that potentially could be used in Ukraine. Our final selection of countries includes Czechia, Denmark, Finland, Latvia, Lithuania, Poland, and Sweden. In addition, the United Kingdom was included, as the national government has set a goal for at least 17% of all heat share to be provided by district heat networks by 2030. The final selection consists of countries that either seek to promote the expansion of DH as a main tool for decarbonization particular in the buildings sector, or already do so. This report consistently looks across the selected countries for their national DH decarbonization strategies and concrete policies for reforming the DH sector.

Figure 1 shows a map of national policies and local municipal policies used to help create low-emission and energy-efficient DH systems.

Figure 1: Map of policy instruments to promote decarbonization of the DH sector

The collection of information on general decarbonization goals and policies, as well as DH specific decarbonization goals and policies, primarily came from the European Union's national energy and climate plans for 2021-2030. Each national plan outlines how an EU member state intends to address energy efficiency, promote renewable energy sources, and reduce GHG emissions. These plans analyze general economic decarbonization goals as well as outline goals and policies specifically related to the DH sector. In addition, other strategic documents, such as pledges for the National Determined Contributions (NDC2), were reviewed.

Finally, the report reviews policies and measures in cities of the selected countries, as well as from other well-established examples. Using these cities, the research team analyzed city-level commitments to transition to carbon-neutral or even carbon-negative DH systems. The report uses this information and chooses city case studies to illustrate different approaches municipal governments can develop to decarbonize DH systems. To demonstrate the trends in emission reductions from heat production over time, Annex A-1 provides data on emissions from the heat sector in selected European countries. Similarly, Annex A-2 shows total Ukraine's CO_2 emissions from the entire economy and emissions from heat-only boilers and CHP for heat production.

4.0 Economy-Wide Decarbonization Policies

Governments can use economy-wide instruments to help promote decarbonization and governments can use these instruments to help decarbonize DH systems. Economy-wide policies also provide support for innovations that are crucial to deep decarbonization within economies and DH systems. Economy-wide policies include carbon taxes, promotion of renewable energy sources, as well as technological innovations such as combined heat and power (CHP) plants.

4.1 Carbon taxes

A carbon tax is an economy-wide tool to reduce emissions. By imposing a carbon tax, the burden of pollution is shifted onto the polluters, tying emissions financially to their sources. Having to pay higher prices for daily activities due to associated costs of pollution, leaves emitters with an incentive to change their operations and pollute less. Empirical research shows that energy prices have the most impact on innovation and mechanisms used to ensure deep decarbonization. Thus, carbon prices can be used to promote decarbonization as a tax on carbon increases general prices of energy. In fact, research shows that a 10% increase in energy prices leads to an increase in the number of green energy programs by 3.4% (Ley, Stucki, and Woerter 2016).

European countries were the pioneers in applying carbon taxes (see Annex A-3). Carbon taxes can also support DH as a low-carbon source of heat, support decarbonization within DH systems via emission reductions in the building sector and generate an increase in renewable energy source shares for heating in DH by making fossil fuel sources of heat more costly. By 2019, 20% of global GHG emissions were covered under 58 carbon taxes or emissions trading schemes (see section 4.2) at the regional, national or subnational level (IRENA 2020). In general, carbon taxes can have a positive impact on decarbonizing DH systems, promoting the use of low-carbon sources of heating by making fossil fuel sourced DH much more expensive.

As more countries in Europe began to implement carbon taxes, energy source supply systems began to change as well. For example, Sweden established a carbon tax as early as 1991 with the main target being fossil fuels (i.e., oil and coal) used for heating purposes. Within the first year of the carbon taxes implementation (1991-1992), the market share of DH increased by 4%, and increased overall by 20% from 1991-2014 (Werner 2017). Sweden's carbon tax combined with investment support policies directly influenced shifts not only toward using DH, but within DH systems as well. As Sweden increased its carbon tax, the country's DH network shifted from coal sources to more renewable sources of heat such as bioenergy[1] in order to combat rising prices associated with fossil fuel energy sources (Bohlin 1998). In fact, according to the Swedish Environmental Protection Agency, "the most obvious effect of the carbon tax has been an increased use of biomass in the Swedish district heating system" (Johansson 2000). The shift away from fossil fuel sources of energy has led to 83.5% reduced carbon emissions within the building sector between 1990-2018 (Climate Watch 2019). In addition, heat generation in a combined heat and power (CHP) system is excluded from the tax. Excluding CHPs from Sweden's carbon tax incentivizes the use of these systems by making them a more cost-effective and low-carbon intensive source of heat energy.

[1] Emissions from biofuels include emissions from biofuel combustions, CO_2 uptake of soil from decaying bioenergy sources, emissions from fertilizer production and transportation.

A similar reduction of carbon emissions due to a carbon tax can be seen in Norway. After implementing its carbon tax in 1991, total greenhouse gas emissions were reduced by an annual average of just under 20% (Fernando 2019). The tax was originally set at $21/ton of emission, and has now increased to about $64/ton of emissions (World Bank 2020). Since the adoption of Norway's carbon tax, there has been a decrease in carbon emissions within the buildings sector of just under 48% between 1990-2018 (Climate Watch 2019).

Although the benefits from a carbon tax are well known, it is not enough to simply implement a carbon tax. While applying the carbon tax, it is important to make sure that the tax is high enough to have an impact on polluters. As seen in some carbon taxes such as in Poland or Ukraine, setting a carbon tax at a very low price complicates the tax systems and does not bring as much positive change in renewable energy shares within the heating sectorCarbon taxes could potentially be the most powerful tools for decarbonizing the economy, including the heat and buildings sectors, if applied effectively.

4.2 Cap-and-trade schemes

A carbon trading scheme sets an overall limit or cap on emissions that are allowed from significant sources of carbon (IEA 2020). These limits are then given to or auctioned off to companies in a specific sector in the form of emission allowances. When a company uses less emission allowances than expected, the company can then sell those excess allowances for profit. On the contrary, if a company needs more emission allowances than they acquired at auction, they can buy these allowances from the companies that emitted less than they expected. This method therefore adds profit to a company that encourages less emissions, while setting an overall cap on emissions throughout industry. While a carbon tax provides more certainty around the cost of emissions, a cap-and-trade system provides more certainty around emissions reductions. A cap-and-trade scheme can be mainly effective only if the price of carbon emissions is high enough. Like a carbon tax, if the price of carbon is set too low in a cap-and-trade scheme, then the cost of an allowance of emission does not exceed what an industry can perform, making it more profitable for an industry to emit than transition to a renewable source of energy.

The European emission trading scheme (EU ETS) is the EU mechanism for recording, trading, and using carbon allowances. The EU ETS is the biggest carbon market in the world. This program creates financial incentives for businesses to behave 'greener' by polluting less. The sectors covered by the existing EU ETS include power and heat generation, energy-intensive industrial sectors and aviation within Europe. In 2019, the EU introduced the Market Stability Reserve, which resulted in higher and more robust carbon prices. These higher prices helped ensure an emissions reduction of 9% in 2019, with 14.9% reduction attributed to electricity and heat production and 1.9% reduction in the industry sector (European Commission 2003). Auction revenues from the existing ETS go mainly to Member States' budgets, and are used predominantly to tackle climate change. Under the existing EU ETS, Member States are required to spend at least half of their auction revenues to support greenhouse gas emissions reductions, to deploy renewables and carbon capture and storage, and to improve energy efficiency and district heating.

Along with the EU ETS, the EU Commission is proposing a separate carbon trading scheme specifically for fuels distribution for road transport and buildings. Separate from the EU ETS, this trading mechanism will begin in 2025, with a cap on emissions set from 2026. With 25% of the revenue of this trading scheme going to energy efficiency of buildings and households who are struggling with higher heating fuel costs, the EU could help support the expansion of DH connections throughout the region (European Commission 2021a).

In addition to the EU's current and proposed carbon trading schemes, Article 6 of the Paris Agreement provides an opportunity to develop a cap-and-trade scheme for countries outside of regional pacts, such as Ukraine, although the terms of how it will operate have not yet been finalized. Within Article 6, three sections in particular talk about a global emission trading scheme. Article 6.2 provides an accounting framework for international cooperation, where already existing emissions trading schemes can be linked, allowing for an international transfer of carbon credits not only within countries but between countries. In addition, Article 6.4 establishes a central UN mechanism to trade credits from emissions reduction generated through specific projects. For example, one country could provide the finances needed to install a plant needed to convert heat sources from coal to renewable energy. The country that is paying would receive the emission credits for the reductions, while the country installing the renewable energy source plant receives the benefits of clean energy (less air pollution, better public health). Finally, Article 6.8 establishes a work program for non-market approaches, such as applying a tax on emissions. With Europe's new Green Deal and ambitious emissions targets, carbon prices are expected to rise. A recent survey found that economic agents expect carbon prices to increase to an average of 47 euro ($57) per ton between 2021 and 2025 and an even larger increase to 59 euro ($68) per ton between 2026 and 2030 (IETA 2021). As a result of higher carbon prices, it will be extremely crucial for countries to join emission trading schemes. When Ukraine joins the EU, the country can benefit from the international emission trading scheme as outlined by Article 6 of the Paris Agreement.

5.0 DH-Specific National Policies

Efforts to support and expand DH as well as further decarbonize DH systems require specific national policies. These policies are aimed at increasing energy efficiency of buildings and decarbonization of DH systems through various programs such as building retrofits to reduce energy consumption and establishing renewable energy support policies to lower emissions from DH systems.

5.1 Energy efficiency programs

5.1.1 Role of energy efficiency in overall decarbonization

Energy efficiency should be a priority when considering policies for decarbonization. Energy efficiency programs and policies help promote and implement projects aiming to reduce energy use. Energy efficiency can relate to the operation of a system or machine, as well as the production of a good or service. The goal of energy efficiency is to reduce overall energy demand, while also (i) lowering greenhouse gas emissions helping country goals related to decarbonization, (ii) lowering utility bills for consumers, (iii) creating jobs, and (iv) helping to stabilize electricity prices and volatility. According to the International Energy Agency's (IEA) Energy Efficiency 2018 report, if all governments adopt necessary cost-effective energy efficiency measures, GDP could double by 2040, while primary energy demand levels are only marginally higher. In addition, energy efficiency measures could lead to GHG emissions falling by 12% in 2040 compared to today's levels (IEA 2018). Regardless of a rise in population and building space through 2040, energy efficiency programs will still allow for a decrease in energy demand.

Energy efficiency is particularly important when being used to support DH as a primary source of heat. Energy efficiency policies regarding DH systems mainly pertain to reducing the amount of heat lost or wasted. This type of energy efficiency reform usually includes energy efficiency changes such as the insulation of DH pipes, energy efficiency of heat generation stations to limit the amount of heat lost from DH systems, low-temperature forms of DH, and the use of CHPs to enable electricity generation while using waste heat as a heat source. In fact, modernizing district energy systems could reduce primary energy consumption by up to 50%, and attribute to 60% of required energy sector emissions reductions by 2050 (UNEP 2015). Annex A-4 provides additional detail about the role of energy efficiency in achieving decarbonization goals.

5.1.2 Efficiency in heat generation

European countries work to improve energy efficiency in DH though promotion of combined production of heat and power at cogeneration plants (CHP). In these plants, both electricity and useful thermal energy (heating and/or cooling) come from a single source of energy by utilizing the waste heat generated from electricity production. With one source of energy, countries can more easily keep track of amounts of energy used and produced, while limiting emissions to one source (if using fossil fuels).

Several examples of well-established CHP systems can be found in Europe. In Finland, 68% of all DH production comes from CHPs. Denmark and Slovakia also have robust CHP systems, with 50% of all electricity production in Denmark attributed to CHPs (Colmenar-Santos et al. 2016), and 77% of all electricity production in Slovakia based on CHPs (Colmenar-Santos et al.

2016). Poland also has a well-established CHP system, representing 65% of total heat production in 2019 (ERO Poland 2019).

It is important to note, however, that using CHPs in the energy sector should only be a temporary transitional assistant for countries that are beginning to increase their renewable energy shares. Although CHPs generate less emissions than individual natural gas boilers per unit of heat, most CHPs still rely on fossil fuels. Thus, in the short-term, natural gas CHPs are a helpful transition energy source; however, CHPs will eventually need to be upgraded to use biofuels with carbon capture and storage (CCS) technologies to reach net zero emissions.

Many EU countries provide incentives for CHP-produced power and for renewables and waste heat, typically through incentive mechanisms like obligations on utilities to meet certain targets. Incentive-based tariffs and benchmarking can also encourage investments in efficiency, including CHP.

5.1.3 Building retrofits

DH systems generate heat for residential, commercial, and public buildings and the demand side of the DH system is equally important for decarbonization as the supply side. Although energy efficiency is possible within DH systems alone, deep decarbonization pathways rely on an increase of energy efficiency in buildings. Robust energy efficiency improvements often come in the form of building retrofits.

Buildings can last for many decades and older buildings have higher rates of energy consumption than newer buildings due to less stringent building codes in the past, no insulation checks on windows and doors, and fewer checks on overall building energy consumption. Retrofitting of buildings involves methods of thermo-modernization, such as replacing poorly insulated windows and doors, improving insulation of ceilings and floors, and installing higher rated energy efficient equipment. Within the heating sector, retrofitting is especially useful in supporting decarbonization within DH. There are three main types of retrofits: (i) existing building commissioning, (ii) standard retrofit, and (iii) deep retrofit. Existing building commissioning includes improving building operations and restructuring maintenance procedures. These changes are associated with an energy savings of up to 25%. A standard retrofit includes component-level replacements of existing equipment, the most cost-effective and lowest risk changes for a building owner. A combination package of standard retrofit measures can result in 25-45% energy savings for the building. Finally, a deep retrofit involves a whole-building approach to energy savings projects. These changes include upgrades to the building envelope and are combined with retrofits of lighting and mechanical systems. Deep retrofits can lead to 45% energy savings (Liu et al. 2011). In addition, retrofits can still provide a relatively large rate of return on investment greater than 15% (Goldman, Hopper, and Osborn 2005).

Although retrofits of buildings significantly reduce heat consumption, they often are very expensive. National governmental funding in the forms of subsidies for energy efficiency policies can be used to alleviate the financial burden associated with building retrofits, with a certain percentage of retrofit costs being covered. Most countries have energy efficiency programs for buildings with the goal to reduce energy consumption

Poland helps building owners partially cover costs of retrofits through thermo-modernization and renovation funds which support investments for improving energy efficiency of existing residential buildings. These funds come in the form of bank loans and will help owners of residential buildings spend less money on intensive energy use, by making short-term investments that will lead to long-term energy efficiency improvements (Poland 2020). Poland has also made major commitments to improving housing conditions, technical condition of housing stock, and enhancements of energy efficiency within the building sector. The national government supports thermal upgrading and renovation investments projects and has outlined long-term renovation targets for the national stock of residential buildings in the National Housing Programme. This program includes a thermo-modernization bonus available for every owner or administrator of a residential building. If owners or administrators of a residential building take a loan out to renovate their building's insulation and improve its conduciveness to renewable energy sources, the bonus covers 16% of the disbursed loan amount, with an additional 5% covering installations of renewable energy sources (Poland 2016).

In Latvia, the average annual heating energy consumption for one-apartment dwellings and multi-dwelling buildings is 139 kWh/m^2 and 137 kWh/m^2, respectively. Between January 2009 and September 2019, Latvia invested 235 million euro in renovations of multi-dwelling buildings. This investment led to reduction of average energy consumption for heating to 96 kWh/m^2 per year. This accounts for a 30.2% reduction in energy consumption (Latvia 2020).

In Czechia, only 25% of single-family buildings and only 40% of multi-family buildings have undergone energy-saving retrofits to date. To increase this percentage, the government has adopted a long-term renovation strategy for buildings. Within this strategy, three scenarios are exemplified to show the cost and impact of retrofits. The first scenario is a basic scenario with current developments of policies and measures. With this model, an energy savings of 19% is expected for all buildings by 2050. The second scenario is called an optimal model, with expected development of renovations of the building stock after the introduction of additional measures aimed mainly at changing the approach of renovations and increasing their number. This model expects an energy savings of 24% for all buildings by 2050. The final scenario is called a hypothetical model, with a rapid and thorough process of retrofits. If retrofit policies fit the hypothetical model, an energy savings of 44% is expected for all buildings by 2050 (Czech Republic 2020).

In Finland, the government has also adopted a long-term buildings renovation strategy. Within this strategy, the goal is to decarbonize the current building stock by 2050. The initial target levels for heating energy use of buildings are energy savings of 16% in 2030, 30% in 2040, and 42% in 2050, when compared to the baseline year 2020. In addition, greenhouse gas emissions from buildings are expected to reduce by 62% in 2030, 80% in 2040, and 91% in 2050, compared to the baseline year 2020. Energy efficiency improvements in renovations as well as improved building maintenance and automation practices play a large role in these emission reductions (Finland 2020).

Ukraine also has several programs to help improve energy efficiency in buildings. The two most important programs are the "warm loans" and loans from the Energy Efficiency Fund of Ukraine.

The State Targeted Economic Program for Energy Efficiency and Development of Energy Production from Renewable Energy Sources and Alternative Fuels (often referred to as the "warm loan program") was created in 2010 to reduce energy consumption by buildings, and more specifically, to reduce natural gas consumption by replacing gas boiler with ones that use biofuels. Though the majority of the loans were used to improve energy efficiency in buildings not connected to DH, about 20% of all funds were used by HOAs in multifamily buildings.

The Energy Efficiency Fund of Ukraine provides fundings for energy efficiency measures in multifamily building. Home-owners associations can apply to receive money to implement a “light” of “comprehensive” retrofit of their building. The Fund can reimburse from 40 to 70% of the money spend on thermo-modernization of the building. The analysis of the results shows that energy consumption by buildings was reduced from 20 to 50% depending on the level of building retrofits. In addition to these two largest central government programs, local governments in Ukraine provide several thousands of regional programs.

Governments can also provide financial support to install or retrofit individual heat substations (IHS). IHSs are automatized modular units that connect the main DH network to a building’s heating system and transfers heat energy from the external heat networks to the house’s floor heating and hot water supply. Technical features make IHS systems very adaptable, allowing them to sense outdoor temperatures when supplying heat, setting automatic temperature control during the day, control of heat supply temperature, heat supply regulation for floor heating, and a secure in-house system to adapt to freezing emergencies. These systems are low-cost and can reduce energy usage in buildings by around 15-30% (USAID 2021).

Many EU countries have adopted IHS systems to help decarbonize and reduce the energy intensity of the heating sector. In Poland, laws that give broad flexibility in IHS installation have been included since 2000. DH companies are the largest investors in IHSs by installing, owning, and maintaining, and while IHS installations are available to both DH companies and building owners (whom can also operate and maintain their own IHSs). The costs for proper IHS systems and management are covered by DH companies and are recovered through the established heat tariff. To help rapidly promote the installation of IHSs, the Energy Regulatory Authority of Poland (URE), has developed guidelines to eliminate central heat substations, replacing them with IHSs. Two important changes to these guidelines have been (i) mandatory contract modifications within three years between DH companies and customers which allow for the replacement of central heat substations with IHSs, and (ii) the cost of installing IHSs is now automatically included in tariffs (USAID 2021).

In the case of Latvia, IHS promotion was different since the large-scale property privatization occurred in the 1990s. Individual property owners had to invest in reconstructing buildings, including installing IHSs. The installation costs were too high, and there was an original reluctance of banks to lend money to HOAs to invest in IHSs. However, banks were comfortable with cooperating with municipalities or DH companies, which made Latvia adopt the State Investment Program in 1995. This program replaced old central heat substations with IHSs. In Riga specifically, the City Council adopted the Concept of Riga Heat Supply Development in 1997 and the Riga District Heating Rehabilitation Project in 1999, with goals to replace all central heat substations with IHSs in all multi-family building connected to the city’s heat network. With DH companies having ownership of IHSs, they leased them to building owners. The Riga City Council issued a regulation in 2000 to define the method for building owners to pay back the DH companies for all investments in internal building systems. Within this agreement, a separate agreement was signed by building owners illustrating the need to recover the costs for IHS installments and ownership. Residents agreed to pay $0.05/m^2$ per month for up to ten years. With lease payments allowing residents to repay the cost of IHSs, the ownership of IHSs could then be transferred to residents without any losses for DH companies (USAID 2021).

In Ukraine, IHS installations are seen as a major way to reform the DH systems. IHS installations can help improve energy efficiency in Ukrainian buildings drastically. IHSs can be used to control the demand of heat in households for area heating as well as the demand for hot water. The installation of IHSs can decrease heat consumption in buildings by 15-25%.

Building retrofits are crucial aspects of decarbonization particularly regarding improving energy efficiency of buildings. With improvements to building envelopes (i.e., windows, floor, and ceiling spaces), countries have seen dramatic improvements in reducing energy consumption within the building sector. In addition, the use of IHSs is one of the most effective policies to optimize heat consumption by buildings and therefore improve energy efficiency in the buildings sector.

5.2 Renewable energy programs

Renewable energy can play an important role in decarbonization of the energy sector. Solar, geothermal energy and biomass can replace fossil fuels in DH. Heat pumps that transfer the heat from the environment to buildings also can be considered as renewables when they use electricity generated by renewable sources.

National governments often set obligatory goals aimed to increase renewable energy sources in the total energy supply and in the heat sector. Such programs exist in the form of Renewable Portfolio Standards (RPS), which are a set of policies and regulations used to increase the share of renewable energy sources in energy generation. Annex A-5 provides historical data on the share of renewables in final energy consumption in European countries. These regulations can even be legally binding obligations on energy supply companies to produce a specified fraction of their energy from renewable energy sources. In some of these programs, companies who comply with these standards are granted a certificate to show proof of compliance to the regulatory body. To enforce these standards, some countries have associated financial penalties to those who do not meet renewable energy obligations. For example, Czechia has established a financial penalty of $1.81 per liter of biofuel that is not supplied (USDA 2021).

In 2009, the European Union published directive 2009/28/EC which mandates levels of renewable energy use within the European Union from 2009 to 2021. The directive required that 20% of the energy consumed within the European Union is renewable. In December 2018, the European Union signed into effect the Renewable Energy Directive 2018/2001/EU as part of the Clean Energy for All Europeans package. Within this directive, the EU aimed to become a global leader in renewables and meet emissions reduction commitments stipulated in the Paris Agreement. The directive expanded on 2020 goals of 20% renewable energy in all energy shares within the EU, increasing the goal to at least 32%, with the option to strengthen the goal by 2023 (European Commission 2018). To reach the regional goal of 32% renewable energy share within energy outputs in the EU, countries also will have to adopt renewable energy obligations. EU countries have different available resources, and as a result, they follow distinctive paths when it comes to meeting their obligations under the renewable energy directive (See Annex A-5).

Countries can set specific goals for using renewables in the DH sector. Renewable sources often used in DH systems include air source heat pumps, ground source heat pumps, solar thermal systems, biomass (wood-pellet) furnaces, and renewable natural gas. It is important to note that although biomass is renewable, it is not emissions free. Therefore, for biomass to be considered emissions free it needs to be coupled with carbon capture and storage (CCS) technology.

Based on the European energy efficiency directive, there are four different thresholds that classify a countries' DH system as 'efficient.' Each system needs to fulfil at least one of these requirements. These thresholds are: (i) 50% renewable supply, (ii) 50% excess heat recovery, (iii) 75% cogenerated heat, or (iv) 50% with a combination of renewable, excess, and cogenerated heat supply.

All European countries have mandatory goals for renewables in DH. Annex A-5 describes renewable energy policies in selected countries. More specifically, Finland has set its goal for renewable energy shares in DH at 47% for the heating and cooling sector by 2020 (IEA Bioenergy 2018a). Sweden has set a goal of 62.1% of renewable energy share in gross final consumption in the heating and cooling sector by 2020 (IEA Bioenergy 2018b). Latvia has established a goal of 50% renewable energy sources in total final energy consumption by 2030 (Latvia 2020). More specifically, within DH systems, Latvia has set goals for at least 2,000 multi-apartment residential buildings and at least 5,000 private houses with zero-emissions renewable energy source technologies installed, while increasing the share of renewable energy sources in heating and cooling by at least 0.55% per year until 2030 (Latvia 2020). Similarly, Czechia has set a renewable energy source share goal within heat supply systems of 20% by 2030, with a year-on-year growth of 1% in renewable energy sources (Czech Republic 2019).

Some countries may encourage renewable energy sources by prohibiting the use of specific fuels to heat buildings. In Denmark, since 1988, a ban on electric heating in new buildings was introduced. Expanding on this, Denmark included the ban on electric heating in existing buildings with water-based central heating systems located in areas with public DH or gas supply in 1994 (DEA 2015). Denmark also prohibited the use of oil heating since the early 2010s, while Norway put a complete ban on the use of oil and paraffin to heat buildings as of 2020 (Kerr and Winskel 2021). Germany is following suit, by adding a ban on the installation of oil-fired heating systems in buildings starting in 2026 (Germany 2019). Finland has also placed a ban on the use of coal in the power and heating sector starting in 2029 (Lindroos et al. 2021).

Ukraine has a significant untapped potential of renewables for heat production. Biomass can play a key role in replacing fossil fuels. The estimates show that only 11% of the economically feasible bioenergy potential was used in 2015 (Chepeliev et al. 2021). However, the share of biofuel for heat production is growing very fast. For example, according to energy balances of Ukraine, biofuels and waste provided 14% of heat production at heat plants in 2019, while this share was 23.9% in 2020 (Ukrstat, 2020).

Straying away from the use of fossil fuel energy sources is crucial in decarbonization efforts. For this to occur, countries must find renewable energy sources that are more efficient and less emission intense. Almost all countries have access to renewable energy sources, but that is not enough. To increase the use of renewable energy sources, many countries should implement renewable energy programs that establish renewable energy share obligations in the form of percentages of final energy production and consumption. The experience of many countries shows a higher share of renewable energy in final energy production and consumption has a large impact on emission reductions in the heat and buildings sectors.

5.3 Building energy codes and energy performance standards

Updates to building codes and energy performance standards can also help promote national decarbonization efforts. Building codes in particular help set energy efficiency rules and obligations for new buildings. These requirements can set minimal energy efficient requirements for new buildings, with the goal of decarbonizing the entire sector. This can result in buildings with increased thermal insulation and tighter sealed envelopes at windows, roofs, and floorboards. With insulation improvements, buildings require and waste less heat, furthermore, reducing emissions associated within the sector. Building codes additionally can include bans on certain types of fuel sources of heating in residential and corporate buildings. Thus, building codes can work in coordination with DH systems, to ensure that the building is the most energy efficient it can be, while also significantly reducing carbon emissions.

The EU adopted the Energy Efficiency Directive (EED, 2012/27/EU) in 2012 to establish a legal basis for 2020 targets for building efficiency. The Directive quantified the 20% energy efficiency target of the EU in terms of primary and final energy consumption levels while requiring EU countries to set their own energy efficiency targets at the national level. One of the biggest policy mechanisms in the EED were improvements to metering and billing techniques. By introducing a mandatory requirement of consumption-based cost allocation and billing of heating cooling and hot water in multi-apartment buildings with collective heating/cooling systems, the EED sought to promote energy savings by promoting behavioral change. These provisions ensured that users of residential buildings had the right incentives and information to adopt energy-efficient practices. Providing consumption feedback to energy users can influence their energy behavior, and lead to final energy consumption savings of 5-10% in residential homes (Zangheri, Serrenho, and Bertoldi 2019).

The first cohesive European legal act on energy policy in buildings was the Energy Performance of Buildings Directive (EPBD, 2002/91/EC). The EPBD was amended in 2010 resulting in the EPBD recast 2010/31/EU of 2010. This policy laid the foundation for setting minimum energy performance standards in new buildings and existing buildings under major renovation (Economidou et al. 2020). More recently, in 2018, the EPBD underwent amendments to promote even more energy efficiency and savings while setting a goal of complete building decarbonization by 2050. With this amendment, minimum energy performance standards based on a cost-optimal methodology were established. EU countries set energy performance requirements for new buildings, existing buildings undergoing major renovation, and for the replacement or retrofitting of building elements like heating and cooling systems, roofs, and walls. One major addition from the 2018 amendments to these energy performance standards was that the EPBD now required considerations of the life cycle costs of buildings. This refers not only to the investment costs but also the operational, maintenance, disposal and energy costs of buildings and building elements.

In Denmark, policymakers have been establishing building requirements since 2006. In 2008, Denmark used the EPBD to establish an energy agreement. This agreement focused on reducing energy needs of building by 25% in 2010, 25% in 2015, and another 25% in 2020, for a total reduction of 75% compared to the 2006 requirements (Wittchen et al. 2013). For existing residential buildings, common building code requirements involve overall thermal resistance of the building envelope, airtightness of the building envelop, efficiency of boilers, efficiency of heat pumps, and thermal resistance for all elements of building envelopes.

Finland also has a robust system of building codes. In particular, the code defines the maximum total energy consumption allowed per residential building as a function of its heated area. Total energy consumption is calculated by an equation which sums heating, cooling, electricity, and fuel-use, all normalized by the heated floor area. In addition, Finland’s building codes specify minimum values for building envelope components and building airtightness. With these measures, studies verify that residential building energy consumption in Finland reduced by approximately 5.7% between 2012 and 2013 (Huynh et al. 2021).

Building codes are a very useful mechanism for improving energy efficiency. As evident in many European countries, building codes are a necessary policy tool to promote efficient energy consumption within the residential sector. With more efficient buildings, DH system would need to provide less heat and as a result, use less energy. All policies focused on reduction of heat consumption by buildings connected to DH systems, lead to reduction energy inputs.

5.4 Heat tariffs

Heat tariffs are very important policy mechanisms when looking at decarbonizing the DH sector. Tariff and regulatory reform can improve the economic sustainability of the DH sector. Tariffs are important tools to promote renewables and energy efficiency. Heat tariffs can directly create mandates for the use of CHPs, renewable energy, and/or waste heat.

The process for calculating and approving tariffs can be varied country to country, or even from city to city within the same country. However, one common feature is to set tariffs on an ongoing timeline basis, as fuel prices and prices of other inputs can fluctuate easily. Well-designed regulatory approaches and heat tariffs should (i) cover the full current costs of the heat supply company, (ii) include the replacement costs and return on investment, (iii) allow sound operation and management of the DH system, (iv) be competitive with prices for other heat sources, (v) give the DH company incentives to reduce costs, (vi) give heat suppliers and customers incentives to save energy, (vii) be transparent and easily understandable, and (viii) protect consumers from unjustifiably high prices.

Certain types of approaches to tariff regulation are better at promoting efficient energy consumption than others. One mechanism that has proven to be very effective is the method of benchmarking. Benchmarking involves setting tariffs based on costs and prices at a set of peer companies. If well chosen, benchmarks can boost company efficiency without the need to estimate potential efficiency gains. Warsaw, Poland uses benchmarking to calculate heat tariffs. With this mechanism, heat prices must adhere to the level of the relevant benchmark published by the energy regulator. These tariffs last for one year, but entities may request a change of the tariff before the lapse of this period. These changes can be applied if (i) new average heat sale price for production until other than CHPs are published, or (ii) if there is a change in the existing license resulting from a significant change of conditions for carrying out the activity, such as the change of the fuel used by the energy source.

Heat tariffs can be extremely valuable for decarbonization efforts and promotion of the use of DH. Properly established heat tariffs can help promote the use of low-carbon intensive heat sources such as DH. By setting the price of heat high enough so that DH companies investing in low-carbon intensive heat sources for the DH system can recover costs they invested in a low-carbon intensive source of energy, the financial burden of developments to low-carbon intensive energy sources is alleviated from DH companies themselves. The difficulty with heat tariffs is establishing a price that is both affordable for residential customers, while also providing enough recovery benefits for DH companies that need to make improvements to DH systems to decarbonize the heating sector.

5.5 Other policies

There are various other policies to support DH and improve DH systems and their decarbonization. Other than DH support policies, demand response policies can be used to increase energy efficiency within DH systems, as well as DH-building digitalization.

5.5.1 DH support policies

Countries can take advantage of other policies in addition to the core group of policies mentioned above. These policies can aim to promote the use of DH, encourage foreign investment and conduct information campaigns.

Governments can promote development of DH systems thought strategic documents. Country-level DH strategies can describe challenges and opportunities by setting out long-term ambitions to build on our existing DH schemes and develop new ones. These strategies send clear signals to cities, investors and developers, and households on the vision of a future. National DH strategies serve as a base for city-level DH development documents.

Another example of national documents that defines the direction of DH systems development are heat supply schemes (HSS) that also can be called energy plans. Governments develop methodologies for HSS development that cities need to follow when develop their HSSs and investment plans. HSSs show the current state of the DH system, what the municipal DH system will be like in the future. They should describe what the connections and distribution system should look like (e.g. how much demand will be in the future). HSSs determine cost-effective heat supply options which reduce the amount of primary energy needed for generation, transportation, and supply of heat to consumers of a certain area. For generation, HSSs usually focus on the development, construction, operation, and maintenance of energy sources. HSSs provide information of what connections will look like within the city, and how the distribution system for the heat should be established. HSSs are also plan an important role in the tariff planning process.

5.5.2 Digitalization, demand response policies and emergency requests

Both digitalization and demand response policies can help further decarbonize DH systems. Digitalization provides ways to monitor, control and adjust heat supply to buildings. Demand responses to heat supply can be used to try to reduce demand during peak periods, which can create major investment savings.

Digitalization in general helps support DH systems shifting toward 4th generation systems. Digital systems allow DH companies to match heat supply and demand perfectly at any given time, optimize temperatures, flows and pressures in the network (Foresight Climate & Energy 2019). New IT technologies can help predict future energy consumption within the buildings sector. Modern individual heat substations allow DH companies regulate temperature based on weather forecasts, monitor heat consumption and provide consumption-based metering and billing.

Demand response policies help reduce energy consumption by making buildings ‘smarter.’ Building owners can install equipment in buildings that monitors energy consumption and turns off certain functions during certain times of the day. For example, during nights, residents are expected to use much less hot water if any, therefore a demand response system could reduce production of hot water to reduce energy use and increase energy efficiency.

Demand response programs are often used in the power system when the there is a need to rapidly reduce electricity consumption during unexpected peaks in consumption or reduced power generation. Demand responses can have different forms. Demand response could be a paid system where utilities pay customers to reduce consumption. As demand increased, the increased bit of supply that is dispatched is more and more expensive, and demand response is often a much cheaper option. Demand responses also could be voluntary programs when utilities ask customers to reduce consumption for a short period of time.

However, the same actions can be used in the heat sector. One of the most striking examples was the situation in the Ukrainian heat sector in 2018. Due to very cold weather and limited supply of natural gas in February 2018, Naftogaz of Ukraine asked DH companies and households to limit gas consumption. This campaign became known as “Turn It Down!” call. On the next day after Naftogaz’s request, natural gas consumption in the country was reduced by 14%. Several large cities significantly reduced gas consumption, for example, in Kremenchuk by 35%, Dnipro by 32%, and Mykolaiv by 19%. This could be considered as a demand response request without creating a market.

6.0 City-Level Decisions

It is very important to harmonize national DH policies and strategies with local policies to ensure the advancement of DH systems. Local decisions made by cities are as important as national decisions in terms of achieving decarbonization goals. Since cities are a major contributor to global emissions, they are also a great platform for the introduction, spread, and diffusion of decarbonization initiatives, as they offer opportunities to test new programs at smaller local levels before turning them into national or regional policies. Additionally, cities often own local DH companies and can directly impact the direction of their strategic development. They also can help define areas where DH is mandatory and establish heat tariffs that promote decarbonization. Finally, cities can use their own resources to modernize DH systems and reach ambitious climate goals such as net zero CO_2 emissions.

Many cities in the worked have developed their climate plans where they describe the role of DH systems in the overall decarbonization. Box 1 shows some examples of city climate plans with the DH focus.

Box 1. Climate plans of selected cities

2025 Climate Plan in Copenhagen, Denmark

The Copenhagen 2025 Climate Plan, adopted in 2012, aims to make Copenhagen a carbon neutral capital city by 2025. Since 2005, the city has cut carbon emissions by 35%. With the city's population expected to increase by 14% between 2016 and 2025 the city has committed to a 20% reduction in heat consumption by 2025. Despite a 9% increase in population and an increase of building space by 1 million m^2 between 2010 and 2015, the proportion of residents with DH connections in 2015 remained the same as in 2010. The city's DH company is working toward an energy efficient DH system. The city replaced a coal-fired CHP with a biomass-fired CHP to reduce emissions.

Source: (Copenhagen City Council 2012).

Carbon-Neutral Helsinki 2035 Action Plan

With the Carbon-Neutral Helsinki 2035 Action Plan, the city committed to becoming carbon neutral by 2035. The carbon neutral plan includes reducing emissions by 80% and offsetting the remaining 20% of emissions. Helsinki has committed to 82% emission reductions in the building sector by 2035. A major portion of Helsinki's plan focuses on energy efficient DH. Helsinki is promoting decarbonization in DH systems by increasing shares of renewable energy sources for heat production. In 2015, the city council decided to close a coal power plant. Going a step further, the city is now requiring its DH company to stop using coal entirely in heating production by the 2030s at the latest. Emissions from DH could be reduced by 74%. Deep energy efficiency retrofits in buildings can also have significant impacts on energy consumption.

Source: (City of Helsinki 2018).

Zero Carbon London: A 1.5°C Compatible Climate Action Plan

With the 1.5°C Compatible Climate Action Plan, London committed to becoming carbon neutral by 2050. The carbon neutral plan includes reducing emissions by 40% between 2018 and 2022. Currently, only 35% of homes achieve adequate energy efficiency performance ratings, with many expecting to still be in use by 2050. For decarbonization efforts to be successful, 70% of London's buildings need to reach energy efficiency performance standards by 2030. All new buildings should be equipped with individual heat pumps or connected to DH.

Source: (Mayor of London 2018).

6.1 Heat supply schemes and investment plans

Heat supply schemes (HSSs) are strategic documents that cities develop to inform the development of the DH system. Using methodologies developed by central governments, cities consider changes in population, its density, area of residential and commercial buildings, potential heat consumption changes due to energy efficiency measures. With HSSs, cities also can plan the transition to low-temperature DH systems, integration of smart technologies, and demand-side responses. They can anticipate the third-party access to the DH systems (for example industrial waste heat) to promote competition and lower costs. HSSs are also important because they define areas with dense population where all buildings must be connected to the DH system and where it is inefficient to have buildings connected because the demand is not dense enough. This zoning helps developers clearly set their plans and reduces uncertainty. Zoning also prevents overinvestments in infrastructure by identifying entire areas that were most viable for infrastructure development.

Denmark has a specific policy to use municipal energy planning and zoning. The planning is divided into steps. As a first step, the local municipalities were required to map the existing heat demand, the existing heat supply method, and the amounts of fuels used. The municipalities also made an estimate of future heat demand and heat supply possibilities. As a second step, the municipalities prepare options for the future heat supply. Finally, cities prepare regional heat plans that identify the priority of heat supply options in any given area and the locations for future heat supply units and networks.

In coordination with HSSs, cities use investment plans to structure the installation of additional low-carbon heat sources, utilize industrial waste as heat, and deploy renewables like solar and geothermal heat sources. These investment plans could be part of broader climate action plans. For example, Stockholm adopted the city climate action plan in 2020. As the last coal-fired plant in Stockholm was closed in April 2020, the city further want to expand renewables (IVL 2020). The company Stockholm Exergi that provide DH to the city, must phased out fossil oil and coal from its DH plants and switch to biofuels with low climate impact {Stockholm, 2020 #145}.

Ukraine adopted a new methodology for development of heat supply schemes in October 2020. Many cities in Ukraine have started developing HSSs according to this detailed methodology. USAID provides support to many cities, conduct trainings and publishes informational materials.

For a DH system to promote decarbonization within the energy sector, HSSs are critical. HSSs help determine current shortcomings in DH systems, provide recommendations of how to improve DH systems, and what the most cost-effective source of heat could be for an area. A crucial aspect for the development of DH systems provided by HSSs are improvements in recovering waste heat, reusing the waste heat recovered, and establishing heat storage units that can hold excess heat for future use. In doing so, HHSs overall help promote low-carbon DH energy systems within the heating sector.

6.2 Direct subsidies to DH companies

Municipalities can provide direct targeted subsidies to DH companies they own to implement needed reconstruction improvements. These direct subsidies often come in the form of investments in energy efficiency for the city. Providing DH companies with targeted financial support linked to investments in energy efficiency and decarbonization is much more impactful and cost-effective than blanket subsidies.

An example of direct subsidies can be seen in Warsaw, Poland. Warsaw has received financing from the EU “Clean Air Programme,” which gives Poland 25 billion euro. Up to 6,500 euro can be allocated for the replacement of heat sources and building insulation (European Union 2017). These funds can be used by DH companies, who are investing in changing heat fuel sources.

In Copenhagen, Denmark, the municipal government takes advantage of subsidies from the national government to help promote investment in energy efficient use of renewable energy in the production processes of enterprises. In the period of 2014 to 2020, the subsidy reached a total of DKK 500 million a year, with DKK 30 million per year to maintain and promote industrial CHP in industries and greenhouses. In addition, in 2020, a total of DKK 100 million will be committed to funding development and use of renewable energy technologies (Copenhagen City Council 2012). With these subsidies in place, Denmark expects final energy consumption to be reduced by 8% in 2020 compared to 2010.

With all the policies available to promote decarbonization of DH, direct subsidies (direct money transfers) provided by municipalities to DH companies can help offset initial costs associated with a decarbonization pathway Direct subsidies can also help municipalities increase their share of renewable energy within the heating sector by reducing the cost of initial investments, making the transition to low-carbon energy more affordable for utility companies. With higher investment costs associated with low-carbon energy, the price of this energy is expected to increase, making it difficult for residents to afford renewable energy sources.

7.0 Conclusions

Decarbonization of DH systems is an important way to reduce emissions from the buildings sector. Central and local governments can use a wide variety of policies to promote decarbonization of the economy in general and the DH sector in particular.

In terms of economy-wide decarbonization policies, countries can set a price of carbon associated with carbon taxes and cap-and-trade systems. Countries with high carbon prices have achieved deeper decarbonization of their economies. Not only does an increased priced of carbon reduce emissions. Carbon taxes can generate revenues that governments can use to promote energy efficiency and transition to clean energy.

Energy efficiency programs can help countries set energy efficiency targets necessary to reach prospective emission reduction goals. These programs can help ensure that energy efficiency targets are reached by providing a mechanism for accountability. When energy efficiency targets are met via specific efficiency mechanisms, the white certificates are given as an acknowledgement that the building has achieved its energy efficiency goals. These certificates can also be traded, creating a market for energy efficiency credit trading, incentivizing buildings to become more energy efficient by providing a reward for their efforts.

Renewable programs are also very effective at decreasing emissions at a national level. Renewable programs can help increase the share of renewable energy sources within various sectors, including DH. Countries can choose between air-source heat pumps, ground source heat pumps, solar thermal systems, biomass furnaces, and renewable natural gas.

Building retrofits and updates to building codes are important in reducing energy consumption in the existing building stock and in new buildings. Standard retrofits can lead to 25-45% energy savings, while deep retrofits can lead to 45% energy savings Although retrofits can be expensive, government subsidies can help reduce costs associated with these programs. Along with retrofits, building codes can also help reduce energy consumption in new buildings on a way to zero-emission buildings.

Cities also have various tools at their disposal to promote decarbonization. Cities develop heat supply schemes for strategic planning to identify most cost-effective ways to produce, transport, and supply heat. Cities set heat tariffs to help cover the costs of necessary projects within DH systems such as pipe replacements and repairs, while also ensuring that energy prices are not unjustifiably high for consumers. Municipalities can use direct subsidies for DH companies to make necessary improvements to DH systems. Direct subsidies are often justified as investments toward increasing energy efficiency within the city.

Overall, for national decarbonization goals to be achieved, promotion of DH and decarbonization within DH systems will be crucial. The national and local level policies outlined in this report, have led to reduced emissions and increased energy efficiency in many countries. The experience of different countries shows that the promotion of DH systems and their decarbonization can be an effective way to overall decarbonization.

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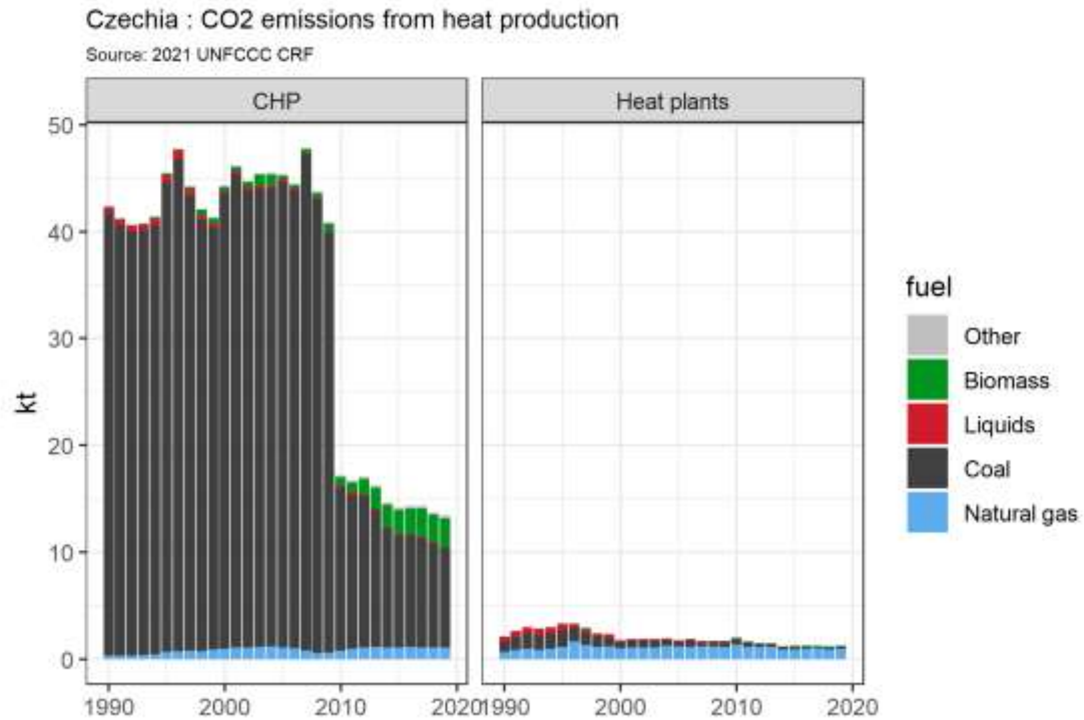
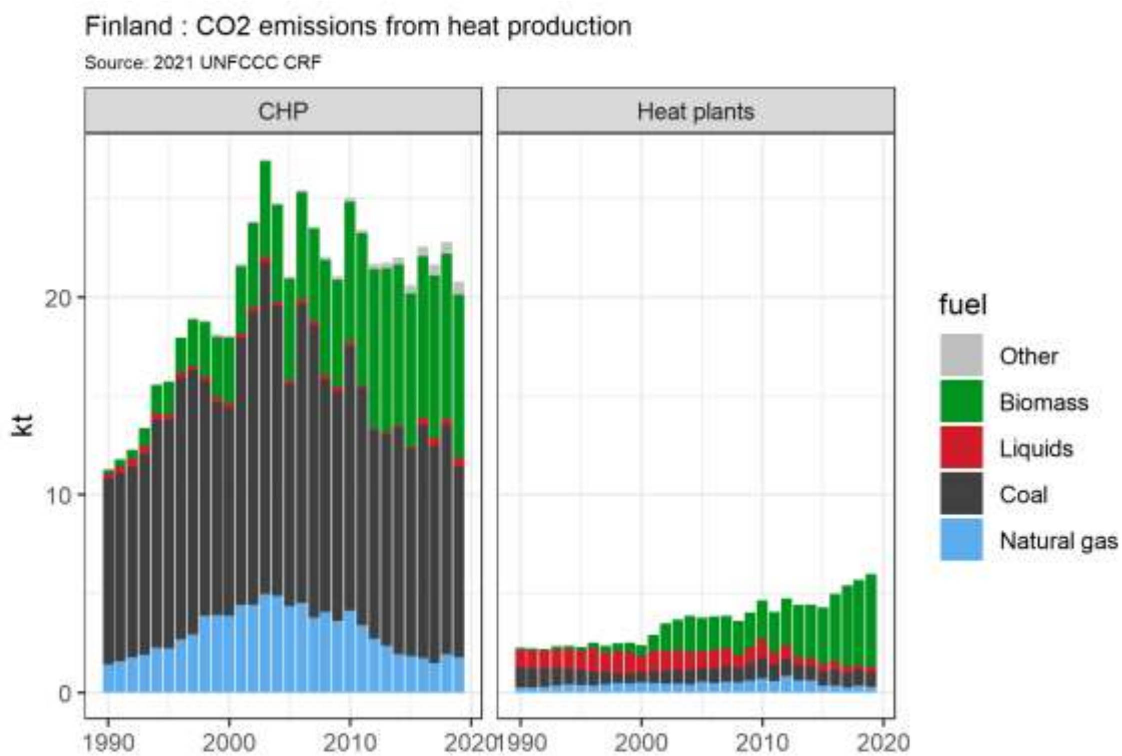
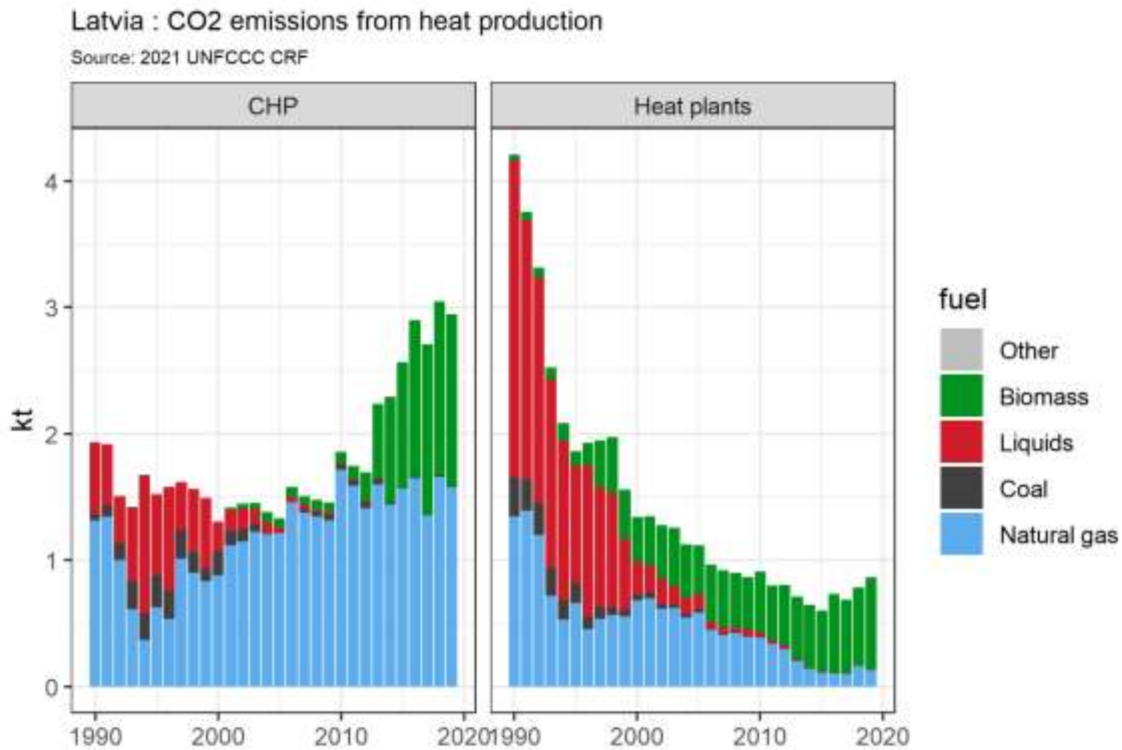
9.0 Annex

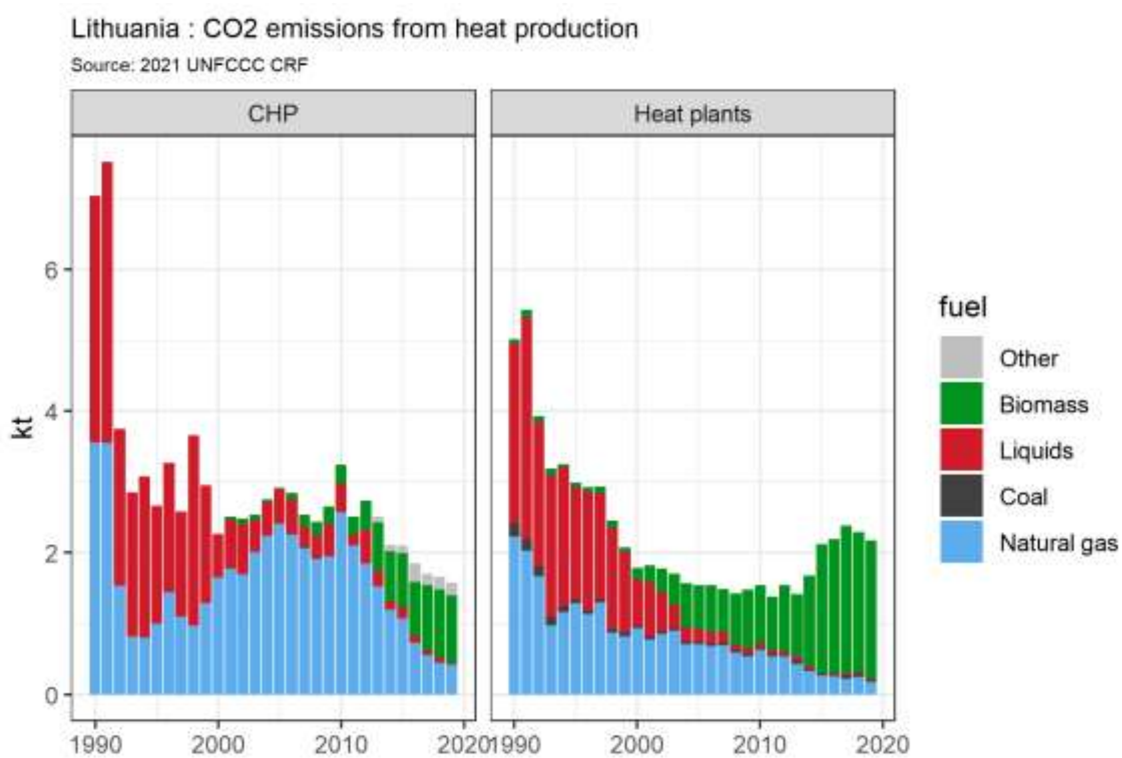
A-1: CO_2 emissions from heat production in selected countries



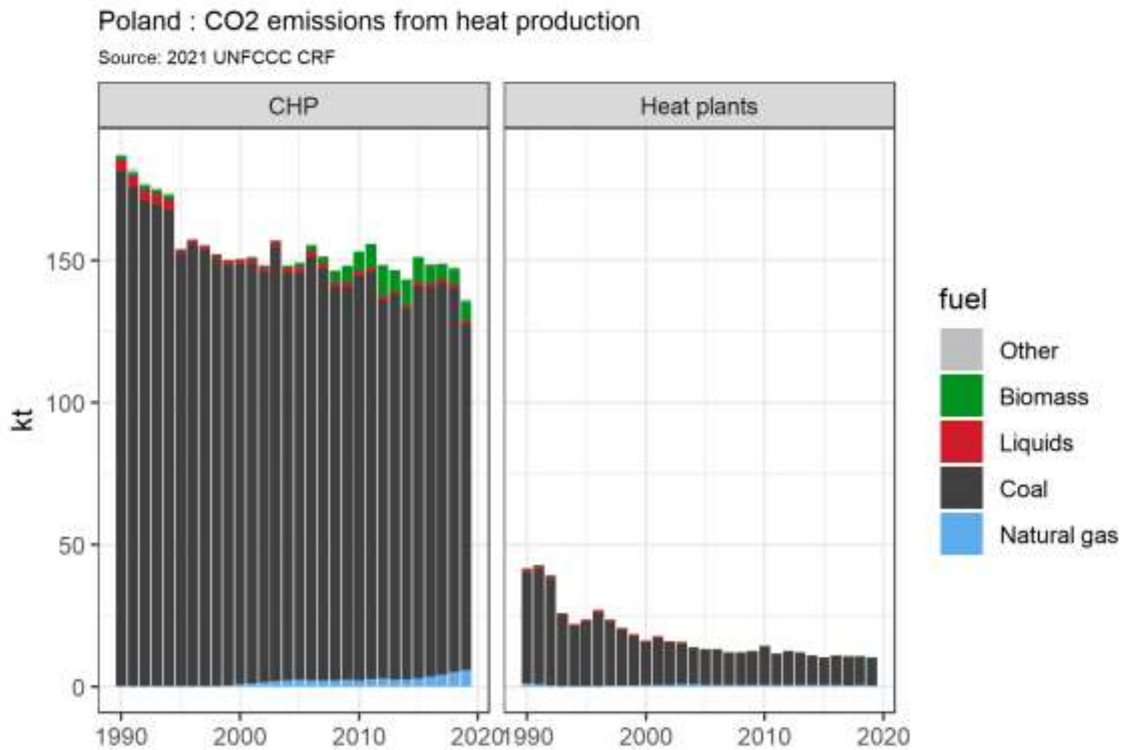


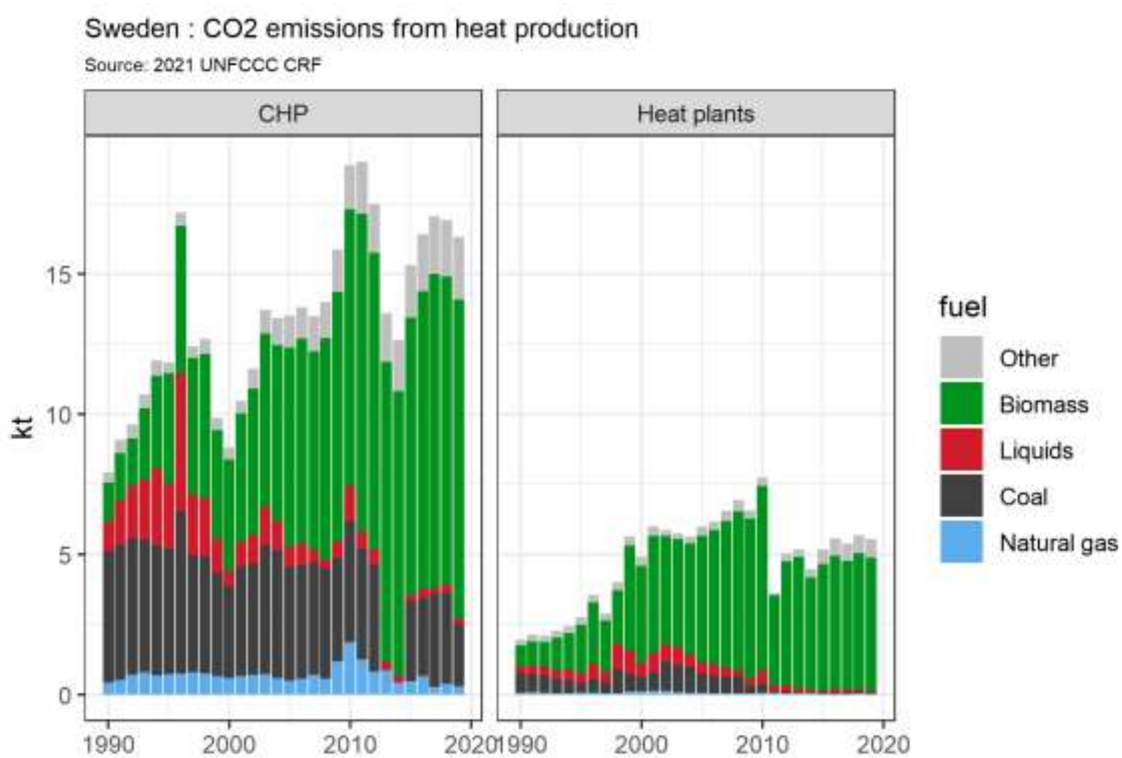


Latvia : CO2 emissions from heat production
Source: 2021 UNFCCC CRF
CHP
Heat plants
kt
0
1
2
3
4
1990
2000
2010
2020
fuel
Other
Biomass
Liquids
Coal
Natural gas

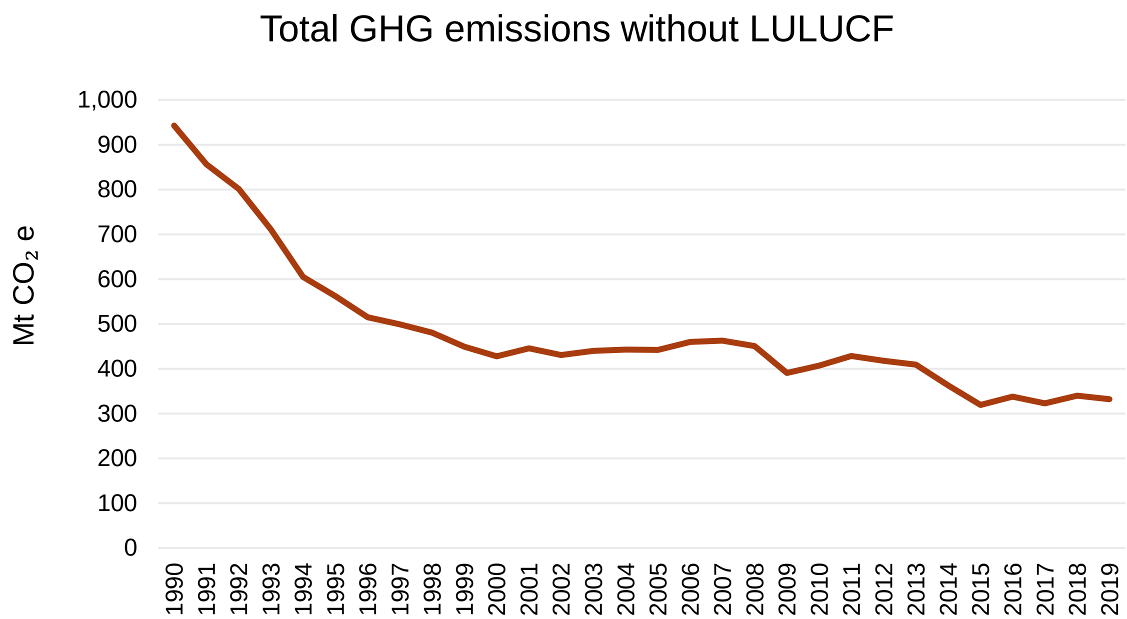


Lithuania : CO2 emissions from heat production
Source: 2021 UNFCCC CRF
CHP
Heat plants
kt
0
2
4
6
1990
2000
2010
2020
fuel
Other
Biomass
Liquids
Coal
Natural gas

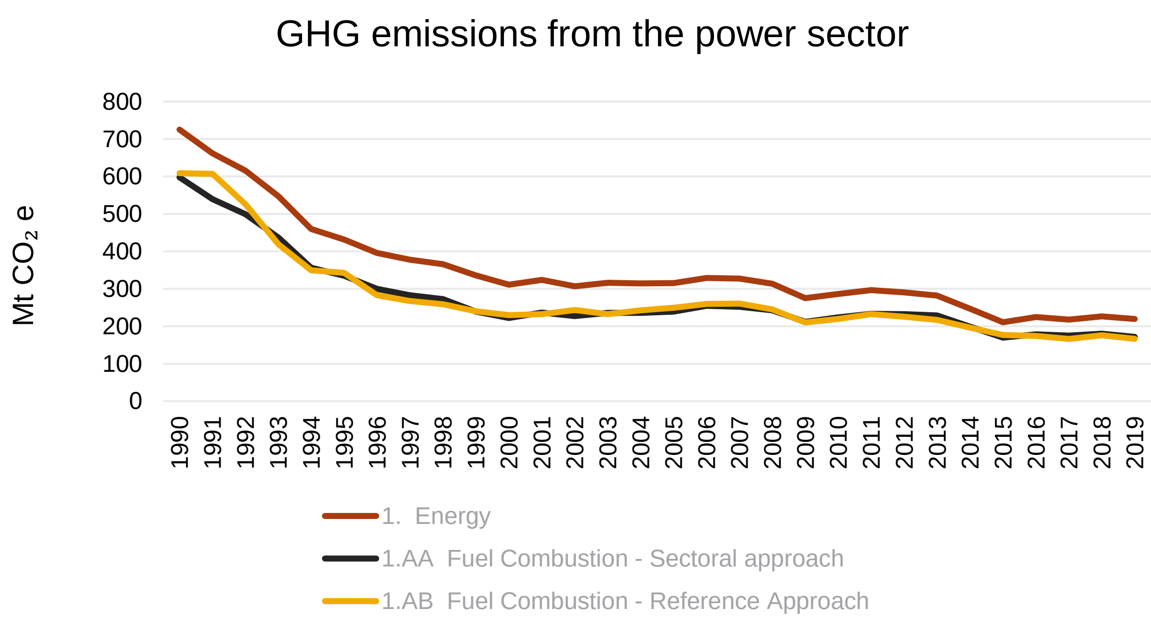

Poland : CO2 emissions from heat production
Source: 2021 UNFCCC CRF
CHP
Heat plants
kt
0
50
100
150
1990
2000
2010
2020
fuel
Other
Biomass
Liquids
Coal
Natural gas

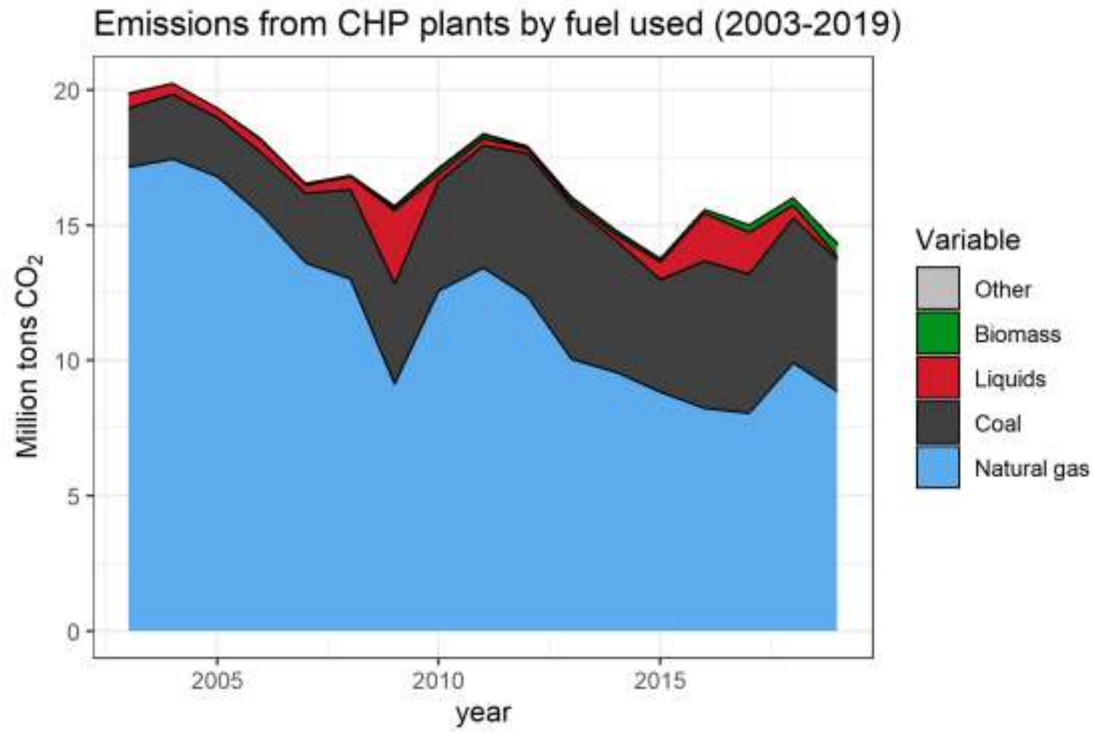

Sweden : CO2 emissions from heat production
Source: 2021 UNFCCC CRF
CHP
Heat plants
kt
0
5
10
15
1990
2000
2010
2020
fuel
Other
Biomass
Liquids
Coal
Natural gas

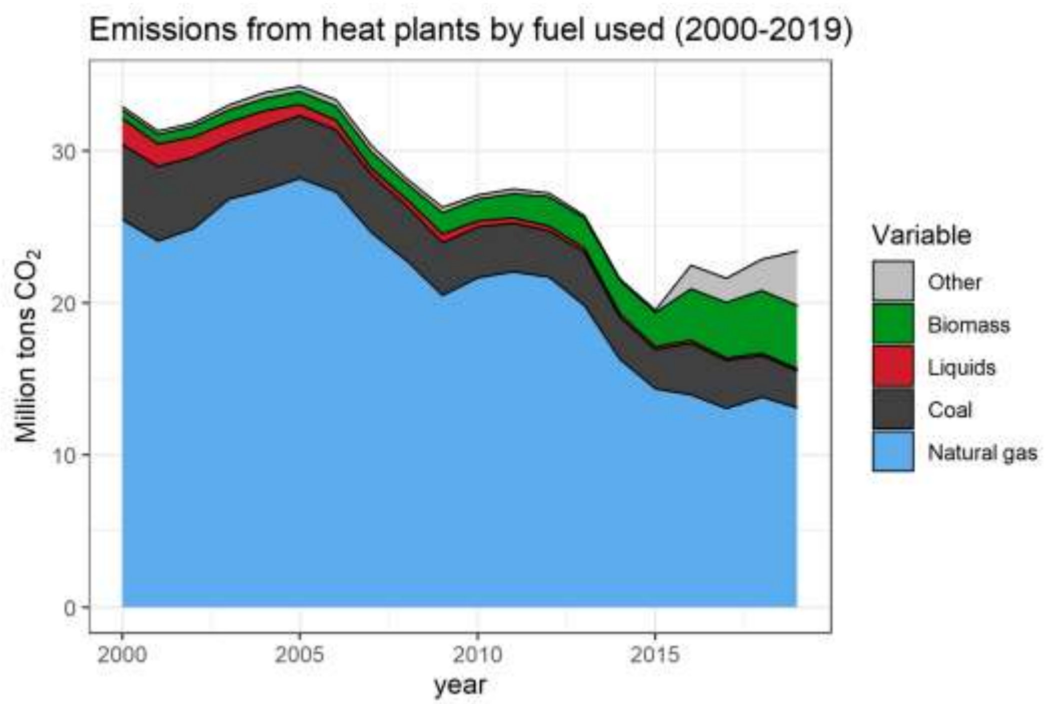
A-2: CO_2 emissions in Ukraine



GHG emissions in Ukraine have been decreasing since 1990, but have started to level out since 2016. In order to achieve Ukraine's goal of net-zero carbon emissions by 2060, efficient heat energy in the form of DH will be crucial.







Source: Ukraine. 2021 submission to United Nations Framework Convention on Climate Change. Common Reporting Format (CRF) Table. Available: https://unfccc.int/documents/273456

A-3: Carbon taxes in European countries

Country	Carbon tax rate (per ton of CO_2e)		Share (%) of GHG covered	Year of implementation
	Euro (€)	US Dollars($)*		
Denmark	23.78	28.00	35	1992
Estonia	2.00	2.36	6	2000
Finland	62.00	73.02	36	1990
France	45.00	53.00	35	2014
Iceland	29.72	35.00	55	2010
Ireland	33.50	39.45	49	2010
Latvia	12.00	14.13	3	2004
Liechtenstein	85.76	101.00	26	2008
Luxembourg	20.00	23.55	65	2021
Netherlands	30.00	35.33	12	2021
Norway	58.59	69.00	66	1991
Poland	0.07	0.08	4	1990
Portugal	24.00	28.26	29	2015
Slovenia	17.30	20.37	50	1996
Spain	15.00	17.67	3	2014
Sweden	116.33	137.00	40	1991
Switzerland	85.76	101.00	33	2008
Ukraine	0.25	0.30	71	2011
United Kingdom	21.23	25.00	23	2013
Averages	**35.91**	**42.29**	**34**	

*The carbon tax rates were converted using the EUR-USD currency conversion rate as of April 1, 2021 (USD 1 = EUR 0.84913).
Sources: The World Bank, "Carbon Pricing Dashboard," last updated April 1, 2021. https://www.carbonpricingdashboard.worldbank.org/map_data.
https://taxfoundation.org/carbon-taxes-in-europe-2021/

Sweden has the highest carbon tax among all countries that use this decarbonization tool in the world. In 2020, the tax rate was SEK1200 ($137) per ton of CO_2 emission. This high tax provides Sweden with a total of $2.3 billion a year of governmental revenue (Swedish Tax Agency (Skatteverket) 2020). The tax has helped reduce carbon emissions by 27% between 1990 and 2018, while the economy grew by 70% in the same timeframe (see Annex A-3 for trends in emissions from the heat sector). More specifically in support of DH systems, with the implementation of Sweden's carbon tax, carbon emissions in the buildings sector were reduced by 83.5% between 1990-2018 (Climate Watch 2019).

A-4: Decarbonization goals and energy efficiency

The EU has committed to becoming carbon neutral by 2050. Countries have developed a range of policies to achieve these ambitious goals of decarbonization. In December 2019, the European Union (EU) presented “A European Green Deal” with a goal of net-zero carbon emissions in all European Union countries by 2050, with an intermediate goal of 55% emissions reductions compared to 1990 levels by 2030 (European Commission 2019). For the EU to reach this ambitious goal by 2050, countries are focusing on deep decarbonization around a wide range of sectors including buildings and energy systems.

The European Union in 2007 had committed itself to a 20% reduction of energy consumption by the year 2020. As of 2019, the EU exceeded its target for 2020 by 2.6%. In 2018, the EU also made an energy efficiency commitment of at least a 32.5% reduction of energy consumption by the year 2030. Since its peak energy consumption in 2006, energy efficiency programs in the EU have helped decreased the regions energy consumption by 10.5% (European Commission 2021b).

One policy mechanism many countries within the EU utilize is ‘White Certificates’. These certificates provide a guarantee that energy savings have been achieved due to a specific measure. White Certificates also act as an accounting tool to verify compliance with energy saving targets and other obligations. White Certificates can be traded, acting as energy saving credits that can be exchanged via a market platform. Tradeable White Certificates play a large role in the total energy savings obligation within the country. One example of a successful White Certificate program is in Denmark. Denmark’s White Certificate program was a voluntary obligation based on legislative framework that private distributors of electricity, natural gas, and DH could commit to. The goal of this program was to decrease total primary energy consumption by 7% in 2020 compared to 2010 (Bundgaard et al. 2013).

White Certificates have led to substantial improvements in energy efficiency. In Italy, according to the energy regulator in 2005, 21% of energy savings are attributed to co-generation and DH improvements outline by White Certificates, in addition to the 14% of energy savings attributed to improvements in heating systems and building insulation in the households and the commercial sector (Silvia 2007).

Countries can also develop detailed national energy efficient goals and instruments. For example, Czechia has established three main goals for energy efficiency: (i) an indicative target for the size of primary energy sources, (ii) a binding energy savings target for public sector buildings, and (iii) a binding year-on-year rate of final consumption savings (Czech Republic 2019). Czechia has specific binding goals including reduced share of primary energy sources, reduced final consumption of energy, and reduced energy intensity of GDP. Overall, Czechia committed to a final energy consumption reduction of 35.7% by 2030 (Czech Republic 2019).

Similarly, Finland has set an energy efficiency target as well as a reduction in primary energy consumption. Finland’s energy efficiency target is a 3.3% reduction in final energy consumption by 2030 (Finland 2019). Aspects of Finland’s energy efficiency program include (i) government subsidies for the energy sector which support the implementation of new energy-efficient technology, (ii) annual reports on energy efficiency improvement measures, and (iii) investments toward renewable energy sources (i.e., wind, solar, and biomass) in the energy sector (Finland 2019). The energy efficiency program in Finland is also run at a municipal level, where local governments sign their own Energy Efficiency Agreements, committing to the actions and targets specified. One main Energy Efficiency Agreement within Finland is an agreement for liquid heating fuel that is sulfur-free and a mixture of bioliquids. This includes a target for the use of renewable forms of energy in both existing and new oil-heating systems, so that in 2025, renewable energy is used in at least 50% of oil-heated properties (MEAE Finland 2016).

Energy efficiency policies in selected countries

Country	Energy Efficiency Policy	Description of Policy
Denmark	**Basic ESCO:** Includes replacement of installations and regulation of energy systems and services like CTS control, monitoring, light steering, heat regulation	Has short pay-back times and relatively low investments. Do not include better insulation of buildings
	Integrative ESCO: Make energy savings with short payback time, finance investments in general building improvements	Combines low hanging fruit (better energy regulation, adjustments of ventilation, etc.) with high hanging fruit (improvements on building envelope, indoor climate, and renewable energy sources)
	Strategic ESCO: Sustainable strategies, using public-private partnerships	Disseminates ESCO-concept to other areas such as infrastructure and private buildings
	Energy taxes on all energy used for space heating and on electricity use in households: Taxes on energy help incentivize energy efficiency	Tax increases energy prices paid by consumer, gives better incentive to reduce energy consumption.
	Danish Climate Agreement for Energy and Industry (June 22, 2020): Expansion and launch of subsidy schemes	Subsidy schemes can be used for buildings, private enterprises. There is a subsidy scheme to replace oil and gas boilers with heat pumps and DH
	Building Code (2018): Codes set for buildings	Absolute target for energy consumption set in new buildings, for existing buildings, codes have efficiency requirements to be met when a building is renovated
	Digital tools at SparEnergy.dk: Offers information tools for energy efficiency	Can help show users how to improve energy efficiency
	Competitive subsidy scheme related to residential buildings: Subsidy scheme for residential buildings	Helps achieve energy savings through renovation and conversion to heat pumps. Duration of scheme is until 2026
	Subsidy scheme to replace oil boilers with heat pumps: Subsidy to replace oil boilers	Replace oil boilers with heat pumps in buildings located in areas without access to DH or the gas grid. Duration of scheme is 2021-2024
	Buildinghub: Improve availability of data on energy consumption	Public consumption data regarding electricity and heating on a digital platform. Will be published within hourly values. Combine building data with consumption data to provide a foundation for data driven solution within energy efficiency and flexible energy solutions.
Czechia	**State Programme in Support of Energy Savings (Efekt):** Contributes to national energy savings target	Main support is concentrated on action with indirect effects on energy savings, such as public awareness, education expert and free advice
	New Green Savings Programme: Administered by State Environmental Fund.	Focuses on energy savings and the efficient use of energy sources in structures. Expected savings of 10.3 PJ in 2014-2020, 5 PJ in 2020-2030.
Finland	**Weighting factors for energy consumption:** Energy consumption is calculated using primary energy factors for different energy sources.	Fossil fuels – 1.0 weighting factor Electricity – 1.2 weighting factor DH – 0.5 weighting factor

		DC – 0.28 weighting factor RE – 0.5 weighting factor
	Energy Performance Certificates: Required for all new buildings and for the sale or rental of existing buildings. For a new single-family house, cost of an EPC is about 150-200 euro, and for an existing single-family house, around 300-360 euro.	Class A: Energy consumption </= 75 kWh/m^2 per year Class B: Energy consumption between 76 and 100 kWh/m^2 per year Class C: Energy consumption between 101 and 130 kWh/m^2 per year Class D: Energy consumption between 131 and 160 kWh/m^2 per year Class E: Energy consumption between 161 and 190 kWh/m^2 per year Class F: Energy consumption between 191 and 240 kWh/m^2 per year Class G: Energy consumption >/= to 24 kWh/m^2 per year
Latvia	**Energy Audits (EA) and Energy Efficiency Improvement in Large Enterprises:** Particularly in Industry, Services, Transport sectors.	Entity will provide annual reports on implemented energy efficiency measures and energy savings reached. Entity shall implement at least 3 energy efficiency measures by April 2020. Expected impact is high.
	Energy Management Services (EMS) in Entities (Merchants): Used with entities such as large electricity consumers	Entity shall provide annual report on implemented energy efficiency measures and shall implement at least 3 energy efficiency measures by April 2022. Expected impact is medium
	Efficiency Requirements for DH systems: Minimum efficiency factors (average annual) for DH production technologies and max heat loss for pipeline networks.	Cabinet of Ministers Regulation states minimum efficiency factors for DH production technologies and maximum heat loss for pipelines networks. Expected savings, impact is medium.
Lithuania	**Labeling of energy consumption-related products:** Informs final consumers about energy consuming products.	Enables residents to choose more energy-efficient devices. Expected savings, impact is low.
	Thermal Technique of Envelopes of the Buildings (2005-2013): Regulates the thermal technical designing of building enclosures (thermal insulation)	Especially impactful for buildings where temperature inside during the heating season is kept higher than outside. Expected savings, impact is high
	Programme for renovation/upgrading of multi-apartment buildings: Supports energy efficiency measures within multi-apartment buildings.	Includes reconstruction and change of heat and hot water supply systems, installation of equipment using renewable energy sources, improvement of heat insulation of pipework, reconstruction of ventilation system, roof and wall insulation, etc. Expected savings, impact is medium
	Energy efficiency improvement in the household sector (Special Programme for Climate Change): Support projects aimed at increasing energy efficiency.	Supports general repair of cold and hot water supply systems, change and reconstruction of ventilation systems, change of windows and outside doors, insulation of roofs, floor and walls, installation of solar collectors, wind power plants, geothermal plants, and installation of biomass boilers. Expected savings, impact is low.
Poland	**Energy efficiency improvement scheme (White Certificates) under the Energy Efficiency Law (EEL):** Energy sales companies are required to	Improves energy efficiency in: (i) increasing energy savings by end-users, (ii) increase energy savings by energy producers from devices used for their

	obtain energy efficiency certificates called "White Certificates."	production needs, (iii) reducing the electricity, heat or natural gas loss in transmission or distribution.
	Priority Programme Improvement of Air Quality (Part II): Reduce/avoid CO_2 emissions in public buildings by reducing energy consumption	Deployment of RES , with expected reduction in primary energy consumption and CO_2 emissions
	Thermo-modernization and Renovation Fund: Financial assistance for investors undertaking thermo-modernization projects	Helps support and fund projects aimed at reducing energy consumption and CO_2 emissions.
	Thermo-modernization Bonus: Allows for deduction of taxes if modernization projects are planned	Tax relief allows income revenues from the expenses related to implementation of thermo-modernization project in single-family residential buildings
	"Clean Air" Programme: Aimed at improving air quality in Poland but has energy consumption targets as well.	Improve energy efficiency and reduce or avoid emissions of dust and other pollutants introduced into the atmosphere by single-family houses
Sweden	**Energy performance certificate:** Needed prior to a sale, or rental, must be done 2 years after a new building is constructed	Class A: energy performance </= 50% of requirements for new building Class B: Energy performance between 50% and 75% of requirements for new building Class C: Energy performance between 75% and 100% of requirements for new building Class D: Energy performance between 100% and 135% of requirements for new building Class E: Energy performance between 135% and 180% of requirements for new building. Class F: energy performance is between 180 and 235% of requirements for new building. Class G: Energy performance is > 235% of requirements for new building.
United Kingdom	**Supplier Obligations – Energy Company Obligation (ECO):** The Energy Company Obligation (ECO) is an energy efficiency obligation. The basic concept of ECO is that central government imposes an obligation on large energy suppliers (gas and electricity) to deliver energy efficiency (for example; solid wall insulation, loft insulation) and heating measures to domestic households in Great Britain.	scheme came into force on 2018 and will run until March 2022. The new scheme focuses on providing support to low income, vulnerable and fuel poor households. As part of this change, the carbon focused Carbon Emissions Reduction Obligation (CERO) has been removed. The scheme's target now relates to energy efficiency, fuel poverty and bill savings
	Energy Savings Opportunity Scheme (ESOS): ESOS is a mandatory energy assessment scheme for organizations in the UK qualified as having 'large undertakings' The Environment Agency is the UK scheme administrator	It is a mandatory programme that requires energy audits for 'large enterprises'. These audits are of the energy used by buildings, industrial processes and transport to identify cost effective energy saving measures.
	Building Regulations 2016: The building regulations apply to extensions, conversions, renovation of the building envelope and replacement boilers and windows	These require new buildings to meet a minimum standard for thermal transmittance for walls, roofs, windows and doors, together with efficient heating systems. Existing buildings must meet similar standards, when extensions are planned together with standards for replacement heating systems
	Smart metering and Billing (for households and SMEs): The Department for Business, Energy and Industrial Strategy (BEIS) is leading a rollout of	The Smart Metering Programme is being delivered in two phases. The first phase was the Foundation Stage, during which the Government engaged with

	smart meters with support from the industry regulator, Ofgem	the energy industry, consumer groups and other stakeholders to put commercial and regulatory frameworks in place to support smart metering. The second phase is the main roll-out stage.
	The Green Homes Grant: To stimulate economic recovery from the coronavirus pandemic, and to meet national net zero targets, the UK government introduced the Green Homes Grant	The grant scheme is worth a total of £2 billion, and provides local authorities and homeowners with funds to retrofit or renovate homes with energy efficient and low-carbon technologies
	UK Emissions Trading Scheme	At the end of 2021, the UK will transition from using the EU ETS to operating its own carbon market

A-5: Renewable energy policies

Share of renewable energy resources in final energy consumption (%) in European countries

Country	2005	2016	2020
Austria	23.3	33.5	34.2
Belgium	2.2	8.7	13
Bulgaria	9.4	18.8	16
Cyprus	2.9	9.3	13
Czechia	6.1	14.9	14
Denmark	17	32.2	30.4
Estonia	18	28.8	25
Finland	28.5	38.7	38.0
France	10.3	16	23
Germany	5.8	14.8	19.6
Greece	6.9	15.2	18
Hungary	4.3	14.2	14.7
Iceland	63.4	*Omitted	*Omitted
Ireland	3.1	9.5	16
Italy	5.2	17.3	17
Latvia	32.6	37.2	40
Lithuania	15	25.6	24
Luxembourg	0.9	5.4	11
Malta	0.0	6	10
Netherlands	2.4	6	14.5
Norway	60.1	*Omitted	*Omitted
Poland	7.2	11.3	15.9
Portugal	20.5	28.5	34.5
Romania	17.8	25	24
Slovakia	6.7	12	14
Slovenia	16	21.3	25.3
Spain	8.7	17.3	20.8
Sweden	39.8	53.8	50.2
United Kingdom	1.3	9.3	15d

Sources:
https://ec.europa.eu/eurostat/databrowser/view/t2020_31/default/table?lang=en
https://visualise.jrc.ec.europa.eu/t/NREAPs/views/RESsharetrajectory/RES_shares_trajectories?:isGuestRedirectFromVizportal=y&:embed=y
*2005 RES Shares come from Eurostat data, 2016 and 2020 RES goals come from visualise.jrc.ec.europa.eu

Renewable energy policies in selected countries

Country	Renewable Energy Policy	Description of Policy
Denmark	**Direct premium tariff for biogas:** Supports use of biogas as a low-carbon source of heat	Biogas used for transport, heating or industrial processes receives a subsidy of DKK 75/GJ, upgraded biogas injected into gas grid receives subsidy of DKK 155/GJ.
	Tax exemptions for biomass: Supports use of biomass as a low-carbon source of heat	Biomass used in heat production is tax-free, both in DH and in residential use. Provides support to switch from fossil fuels to biomass.
	Prohibition of oil-fired and gas-fired boilers in buildings: From 2013 for new buildings, from 2016 in existing buildings	Supports use of Renewable Energy Sources for heating in buildings.
Czechia	**Subsidy I (Operation Programme Entrepreneurship and Innovation for Competitiveness 2014-2020):** Supports construction or reconstruction of electricity or heat generating plants, for which the energy produced is primarily intended for distribution rather than own consumption.	*CHP from biomass and biomass heating stations:* Small Company (<49 employees): **80% of eligible expenses** Medium Company (50-249 employees): **70% of eligible expenses** Large Company (250+ employees): **60% of eligible expenses** *Heat and biogas extraction from existing biogas plants:* Small Company: **50% of eligible expenses** Medium Company: **45% of eligible expenses** Large Company: **40% of eligible expenses**
	Subsidy II (Operation Programme Environment 2014-2020): Grants subsidies for projects that support RE use.	Allocates investment grants from ERDF. Biomass and solar are eligible. Subsidies can go up to the total project's eligible expenditures. Individual projects are eligible for support.
	Exemption from Real Estate Tax: Tax exemption to support RE use.	Properties used solely for the generation of heat from biogas, biomass, hydrothermal, geothermal energy or heat pumps are exempt from real estate tax.
	RES-H building obligations: Owners of buildings, housing associations, or building contractors are obliged to obtain energy performance certificates.	Supports use of RE sources to heat buildings. Must retrieve an energy performance certificate to rent or sell a building.
Finland	**Increased fixed "heat bonus":** Support of biogas and biomass over fossil fuel energy sources.	CHP plants are eligible if plant produced both electricity and usable heat, and if they achieve an efficiency rate of at least 50%, or even 75% if the capacity of the generators is >/= 1 MVA. Heat bonus is fixed at **€ 50 per MWh** for CHP plants working on biogas, **€ 20 per MWh** for CHP plants working on wood fuel.
	Subsidy I (State grant for investment in RES): Called "Energy Aid" and supports investments in RES production facilities and research projects.	Available for projects which promote use or production of RES, advance EE and reduce the environmental effects caused by energy production and use. All forms of renewable energy are eligible. Support can make up to 30% of the project's overall cost but can increase up to 40% if project uses new technology. Support allocated to research can make up to 40% of the project's total cost.
Latvia	**Law on Excise Duties:** Natural gas supplied to end-user subject to excise tax. Tax rate reduced if used for heating.	Amount of tax paid is reduced if biogas is used or heating. Tax rate for 2018 was **€1.65/MWh**.

	Law on the Value Added Tax (VAT): Tax imposed on certain economic activities used to support RES with reductions in tax.	Supply of biomass and biogas for household needs, **tax rate is reduced from 21% to 12% of final spending** on household needs of energy.
	RES-H building obligations: RE source requirements for new and existing buildings.	Helps promote the use of RE sources. Energy certification must be carried out for buildings undergoing construction, reconstruction, or renovation.
Lithuania	**Feed-in Tariff:** For biogas injected into the natural gas system (*Law on Energy from Renewable Sources*)	Biogas produced is purchased at the feed-in tariffs set by the National Commission for Energy Control and Prices (NCC) on a yearly basis. This tariff is lower than natural gas, to promote the use of biogas.
	Loan from Climate Change Special Programme: Supports projects aiming to reduce CO_2 emissions	No less than 40% of funds from this program are intended to be used to support RE projects. All forms of renewable energy are eligible for this loan scheme, with **no maximum amount of loan credit** set.
	Priority purchase of heat produced from RES: PSO to produce and purchase heat from RE sources.	Heat suppliers are obliged to purchase all RES heat generated by independent heat producers that is cheaper than the heat produced by the heat supplier himself and which satisfies environmental and quality requirements as well as standards for the security of supply.
	Subsidy from Climate Change Special Programme: Available to all RE sources.	Max. level of funding for applicants not engaged in economic and commercial activities is **€1.45 million** and for applicants engaged in economic and commercial activities **€200 thousand.** Amount of subsidy may not exceed 80% of eligible project costs.
	Exemption from the Environmental Pollution Tax: Tax exemption for use of biomass and biogas.	Environmental pollution tax for stationary sources of pollution shall be paid by all operators of combustion installations with a rated thermal input equal to or greater than 20 MW but not exceeding 50 MW, and operators of combustion plants which contain a solid fuel-fired boiler with a furnace thermal efficiency equal to or greater than 0.5 MW but not exceeding 20 MW. Operators using biogas, solid and liquid biomass are exempt from environmental pollution tax.
Poland	**Loan from National Fund for Environmental Protection and Water Management:** Grants low-interest loans to support purchase and installation of renewable energy sources. All sources of RE are eligible.	<u>*Biogas:*</u> **€5.82 million/MW** for installations with capacity 40kWe-100kWe. **€4.66 million/MW** for installations with capacity 100kWe-300kWe. **€3.73 million/MW** for installations with capacity 300kWe-2MWe. <u>*Biomass (cogeneration):*</u> **€1.63 million/MW** for installations with capacity 40kWe-500kWe. **€3.49 million/MW** for installations with capacity between 500kWe-5MWe. **€4.66 million/MW** for installations with Organic Rankine Cycle (ORC). <u>*Biomass (Heat Source):*</u> **€0.37 million/MW** for installations with capacity between 300 kWt and 1 MWt, without systems for fuel prep, condition of exhaust fumes and heat storage. **€1.40 million/MW** for installations with capacity between 300 kWt and 1 MWt with systems for fuel prep, condition of exhaust fumes and heat storage. **€2.80 million/MW** for installations with capacity between 1MWt-20MWt.

		<u>Geothermal:</u> **€3.6 million/MW** for installations with capacity between 5MWt-20MWt. <u>Aerothermal:</u> **€1.4 million/MW** for installations with capacity between 40 kWe-3MWe <u>Hydrothermal:</u> **€2.80 million/MW** for installations with capacity up to 1MWe. **€3.49 million/MW** for installations with capacity over 1MWe. <u>Solar thermal:</u> **€1.86 million/MW** for installations with capacity between 40kWp-200kWp. **€1.98 million/MW** for installations on buildings with capacity between 200kWp-1MWp. **€1.40 million/MW** for installations on ground with a capacity between 200 kWp-1MWp.
	Loan from National fund for Environmental Protection and Water Management – "Efficient Heating and Cooling": All RE sources except geothermal are eligible.	Granted to projects that use at least 50% energy from renewable sources, or 50% waste heat, or 75% heat from cogeneration, or a combination of such energy and heat at 50%. Loans can cover a maximum of 85% of eligible investment costs and can range from **€833.3 thousand to €93.13 million**.
	Subsidy from National Fund for Environmental Protection and Water Management – Prosumer: Supports purchase and installation of small and micro-RES installations for needs of residential single-family or multi-family houses. Using both loans and subsidies, may cover up to 100% of eligible costs.	Maximum eligible investment costs for residential buildings in case of installations using biomass: **€23,281** for private persons, **€69,843** for homeowner associations or housing cooperatives. Max investment costs eligible for heat pumps: **€698-1,281/kW.** Max investment costs eligible for solar thermal: **€466/kW.**
	Subsidy for thermal rehabilitation grants: Supporters building renovations which increase energy efficiency or the use of renewable energy sources for heating purposes. All RES are eligible. Shall reduce building's annual energy demand, energy losses or annual costs of heat production.	Subsidy is equal to **20% of loan received** for implementation of thermal rehabilitation. May not exceed 16% of total costs of the modernization work and may not exceed twice the amount of the energy audit.
Sweden	**Income Tax reduction:** Residents are eligible for an income tax reduction of installation works in apartment and single-family houses	Eligible measures are installation of renewable energy devices and replacement of conventional heating sources with renewables. Only labor costs are deductible. May deduce eligible costs from one's income tax at beginning of the following year or apply for a provision tax credit that is given before the costs have to be covered. Amount of reduction paid will be offset against the income tax at the beginning of the following year. All renewables are eligible, and tax reduction can cover **30% of labor costs**, </= **€4,858 per year.**
	Energy and CO_2 Tax: Tax exemption for renewable energy sources.	Biomass and biogas are explicitly excluded, but all renewables are eligible for exclusion.
	Nitrous Oxide Tax: Tax on producers of heat that emit nitrogen oxides.	All renewable energy sources are exempt from the tax.

United Kingdom	**The Renewable Heat Incentive (RHI):** The Renewable Heat Incentive (RHI) is the main instrument for funding RES-H sources in the United Kingdom by supporting RES-H installations with a fixed amount per kWth produced. The scheme consists of two parts: The Non-Domestic RHI (UK) and the Domestic RHI (UK and Northern Ireland until 2016).	While the Non-Domestic RHI provides payments to industry, businesses and public sector organisations, is the Domestic RHI open to homeowners, private landlords, social landlords and self-builders. In addition, the Department for Business, Energy & Industrial Strategy (BEIS) plans to introduce changes to the Non-Domestic/Domestic Renewable Heat Incentive (RHI) scheme Regulations that came into effect in September 2017. Further amendments are introduced in 2018. *Eligible technologies:* Aerothermal energy: Eligible (air source heat pumps). The coefficient of performance must be at least 2.9 and seasonal performance factor of at least 2.5. For plants under 45 kWth certification and accreditation under the Microgeneration Certification Scheme (MCS) is required (reg. 10 RHISR 2018). Hydrothermal energy: Eligible (heat pumps using surface water as source). The coefficient of performance must be at least 2.9 and seasonal performance factor shall be at least 2.5. For plants under 45 kWth certification and accreditation under the Microgeneration Certification Scheme (MCS) is required. Biomass energy: Eligible (solid biomass). For plants under 45 kWth certification and accreditation under the Microgeneration Certification Scheme (MCS) is required (reg. 5 RHISR 2018). No capacity limitations are imposed, though capacity impacts on the tariff level in Great Britain. In Great Britain, plants that have submitted their applications for accreditation on or after 24 September 2013, should additionally obtain environmental permits or an RHI emission certificate (reg. 5(1)(c) RHISR 2018). Solid biomass contained in waste (in Great Britain) is also eligible (reg. 7 RHISR 2018). In Great Britain, CHP plants using solid biomass (excluding solid biomass contained in waste) alone or in combination with any other source of energy provided that the combustion unit is new and was first commissioned as part of CHP system on or after 04 December 2013. Geothermal energy: **Shallow Geothermal:** Eligible (heat pumps using the heat in the ground as energy source). The coefficient of performance must be at least 2.9 and the seasonal performance factor shall be at least 2.5. For plants under 45 kWth certification and accreditation under the Microgeneration Certification Scheme (MCS) is required (reg. 9 RHISR 2018). Share ground loop systems i.e. a system in which a ground loop provides heat energy through a hydraulic connection to two or more ground source heat pumps installed in separate or the same premises are also eligible. **Deep Geothermal:** Eligible, if the plant generates heat using naturally occurring energy located and extracted from at least 500 meters beneath the surface of solid earth.

		<u>Solar energy:</u> Eligible up to a capacity of 200 kWth. For plants under 45 kWth certification and accreditation under the Microgeneration Certification Scheme (MCS) is required. **<u>Tariffs:</u>** <u>Aerothermal Energy:</u> Tariff rates for air-source heat pumps from 22 May 2018: In Great Britain: All capacities (commissioned on or after 04 December 2013): p 2.69 (€ct 3.04) per kWth. <u>Hydrothermal Energy:</u> Tariff rates from 22 May 2018: All capacities: First 12 months: p 9.36 (€ct 10.58) per kWth Afterwards: p 2.79 (€ct 3.15) per kWth <u>Biomass Energy:</u> *Small commercial biomass (solid biomass including solid biomass contained in waste) (less than 200 kWth):* First 12 months: p 3.05 (€ct 3.45) per kWth Afterwards: p 2.14 (€ct 2.42) per kWth *Medium commercial biomass (200 kWth and above and less than 1MWth):* First 12 months: p 3.05 (€ct 3.45) per kWth Afterwards p 2.14 (€ct 2.42) per kWth *Large commercial biomass (1MWth and above):* First 12 months: p 3.05 (€ct 3.45)per kWth Afterwards p 2.14 (€ct 2.42) per kWth Solid biomass CHP systems (commissioned on or after 04/12/2013): p 4.42 (€ct 5) per kWth <u>Geothermal Energy:</u> *Shallow geothermal:* First 12 months: p 9.36 (€ct 10.58) per kWth Afterwards p 2.79 (€ct 3.15) per kWth *Deep geothermal, including CHP systems generating heat and power from geothermal energy (all capacities commissioned on or after 04 December 2013):* p 5.38 (€c 6.08) per kWth <u>Solar Thermal Energy:</u> All solar collectors (less than 200 kWth): p 10.75 (€ct 12.15) per kWth <u>Biogas Energy:</u> *Biomethane injection (first 40,000 MWh):* p 5.6 (€ct 6.33) per kWth *Biomethane injection (next 40,000 MWh):* p 3.29 (€ct 3.72) per kWth *Biomethane injection (remaining MWh):* p 2.53 (€ct 2.86) per kWth *Small biogas combustion (less than 200 kWth):* p 4.64 (€ct 5.25)per kWth *Medium biogas combustion commissioned on or after 04 December 2013 (200 kWth and above and less than 600 kWth):* p 3.64 (€ct 4.12) per kWth *Large biogas combustion commissioned on or after 04 December2013 (600 kWth and above):* p 1.36 (€ct 0.95) per kWth

	Microgeneration Certification Scheme	Aimed at providing an assessment and an approval that a RES installation complies with specific standards. Depending on the technology, requirements may vary, but are nevertheless usually linked to an internationally recognized standard.