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Europe and Central Asia

Toward a Framework for the Sustainable Heating Transition

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Europe and Central Asia: Toward a Framework for the Sustainable Heating Transition

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List of Abbreviations

ALB	Albania
ARM	Armenia
AZE	Azerbaijan
BGR	Bulgaria
BIH	Bosnia and Herzegovina
BLR	Belarus
BLS	building-level substation
CAPEX	capital expenditure
CAPP	Clean Air Priority Program (Poland)
CHP	combined heat and power
CMCC	Euro-Mediterranean Center on Climate Change
CPI	consumer price inflation
DH	district heating
DHW	domestic hot water
EBRD	European Bank for Reconstruction and Development
EC	European Commission
ECA	Europe and Central Asia
EIRR	economic internal rate of return
EERF	energy efficiency revolving fund
EERSF	Energy Efficiency and Renewable Sources Fund (Bulgaria)
EJ	exajoule
ESA	energy service agreement
ESMAP	Energy Sector Management Assistance Program (World Bank)
ESCO	energy service company
EU	European Union
g	gram
GEO	Georgia
GHG	greenhouse gas
GJ	gigajoule
HDD	heating degree days
HOA	homeowner association
HRE	Heat Roadmap Europe
HRV	Croatia
IEA	International Energy Agency
IFIs	international financing institutions
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
KAZ	Kazakhstan
KfW	Kreditanstalt für Wiederaufbau
KGZ	Kyrgyzstan
LCOH	levelized cost of heating
LIHC	low-income-high-cost
LTRS	long-term renovation strategy
MassCEC	Massachusetts Clean Energy Center
M&V	measurement and verification
MDA	Moldova
MFB	multifamily building

MKD	North Macedonia
MNE	Montenegro
MWh	megawatt-hour
NAP	national adaptation plan
NECP	national energy and climate plan
NDCs	nationally determined contributions
NO_x	nitrogen oxides
NPV	net present value
NZE	net-zero emissions
NZEB	net-zero-emissions buildings
O&M	operations and maintenance
PIP	performance improvement plan
$PM_{2.5}$	particulate matter with a diameter of less than 2.5 µm
PM_{10}	particulate matter with a diameter of less than 10 µm
POL	Poland
PPP	public private partnership
PV	photovoltaic
RE	renewable energy
ROU	Romania
RUS	Russian Federation
SEC	specific energy consumption
SFH	single-family home
SHR	sustainable heating roadmap
SO_x	sulfur oxides
SRB	Serbia
TES	thermal energy storage
TJK	Tajikistan
TKM	Turkmenistan
TWh	terawatt-hour
TUR	Türkiye
UKR	Ukraine
UZB	Uzbekistan
VAT	value-added tax
XKX	Kosovo

Overview

In the long, cold winters in many parts of the Europe and Central Asia (ECA) region, heating is critical to life and for livelihoods, but it is currently not sustainable. Energy use for space heating has expanded to 24 percent of total regional energy demand today—of which about 72 percent is consumed in the residential sector and the remainder in commercial and public buildings. Fossil fuels—natural gas and coal—have overwhelmingly met this energy need. Compounded by an aging and energy inefficient building stock, the heating sector has generated a significant level of emissions, both locally and globally. Across the region, air pollution, particularly in urban areas, is a serious threat that causes 302,000 deaths and incurs a welfare cost of 7 percent of GDP annually. Annual gross CO_2 emissions from ECA heating of buildings are estimated to be about 22 percent of total regional emissions, or 678 $MtCO_2$, of which 75 percent is attributed to the residential sector.

In urban areas, most households currently heat their homes with district heating (DH), electricity, and gas boilers, while in rural areas most households rely on firewood or coal stoves and boilers. About 30 percent of ECA's population is served by DH utilities, which are heavily dependent on fossil fuels (97 percent) and suffer from aging infrastructure and poor financial viability. Outside Russia, there are about 2,300 utilities serving about 14.8 percent of the population. Those buildings not served by DH rely mostly on underpriced coal and unregulated firewood burned in inefficient, polluting boilers or stoves. Despite low prices, the inefficient buildings and heating systems have made heating less affordable, with about 34 percent of residents spending 10 percent or more of their average monthly expenditure on energy bills, a typical threshold for energy poverty. The low elasticity of energy consumption means that many households are at risk of falling into absolute poverty when energy prices rise. When heating prices do become unaffordable, as witnessed during the recent energy crisis, households are left with two unappealing choices: reduce the heating levels in the home or revert to dirtier, cheaper fuels.

Addressing the considerable challenges in heating is an urgent imperative for policymakers to ensure heating services are affordable, efficient, and clean which can in turn bring enormous development benefits. The decarbonization pathways in ECA countries to net zero by mid-century are intertwined with sustainable heating. Many of the existing institutions, systems, fuels, and technologies will have to undergo a massive shift to achieve this goal, as will enabling policies, financing, business models and communications. Given the limited time remaining, these changes must be initiated this decade and at scale. Some notable progress has been made, with newer technologies and approaches already being tried and tested and lessons being derived and shared. While such efforts are not yet at the scale necessary, harnessing them could offer substantial benefits—in terms of fuel and cost savings due to energy efficiency, reduced CO_2 emissions, maintenance savings, and health benefits (due to reductions in NO_x, SO_x and $PM_{2.5}$). In addition, other important socioeconomic benefits can be gained from such investments—such as improved energy security, lower energy subsidies, reduced energy poverty, extended building lifetimes, higher property prices, better comfort, and more green jobs.

The cost of the sustainable heating transition by 2050 is in the range of US$2-2.5 trillion and will require substantial subsidies. The transition costs are not evenly spread across the region, with Russia having among the highest costs, at about US$900 billion due to its high heating demand and broad DH coverage, and the Western Balkans and Southern Caucasus with the lowest investment costs, at approximately US$100 and US$60 billion, respectively. Most of the investment costs will have to be borne by DH utilities, heating customers and building owners. However, given prevailing energy price and other market distortions, there is a critically important role for a government response (e.g., policies, subsidies and other support) to enable and help catalyze this transition. To estimate the transition costs, three scenarios were developed to estimate the cost of the efforts required to renovate 14 billion m^2 of building floor area, upgrade DH systems, and replace individual heating systems. The economic net present value is projected to be approximately US$402-440 billion, and the economic internal rate of return was estimated to be 9.0-10.1 percent. The subsidies required to make many of the investments financially viable would be about US$1.54-$1.67 trillion, which represents about 59-68 percent of the total transition costs. While this appears high, these figures represent only about 1.3 percent of the region's annual GDP—and about 50 percent of the subsidies that ECA countries are already spending on fossil-fuel subsidies (US$115 billion annually) if current subsidies are maintained through 2050.

Unfortunately, there are a number of barriers that that have made the transition to sustainable heating particularly difficult. These include policy, infrastructure, economic and financial, technical, and informational barriers—such as distorted energy prices; lack of infrastructure (e.g., for DH, gas); stalled DH reforms leading to poor, inefficient service; long asset lifetimes; chronic past underinvestment and under-maintenance (e.g., DH systems, buildings); lack of affordable financing options; multijurisdictional responsibilities; unregulated biomass/firewood; behavioral inertia; and lack of know-how and access to credible information.

This report presents a unique deep dive into sustainable heating pathways. It draws from World Bank's long history of engagement in heating in ECA, combined with a new analysis of the current context in 23 countries, DH survey, economic and financial analysis of sustainable heating options, and interviews with heating experts.

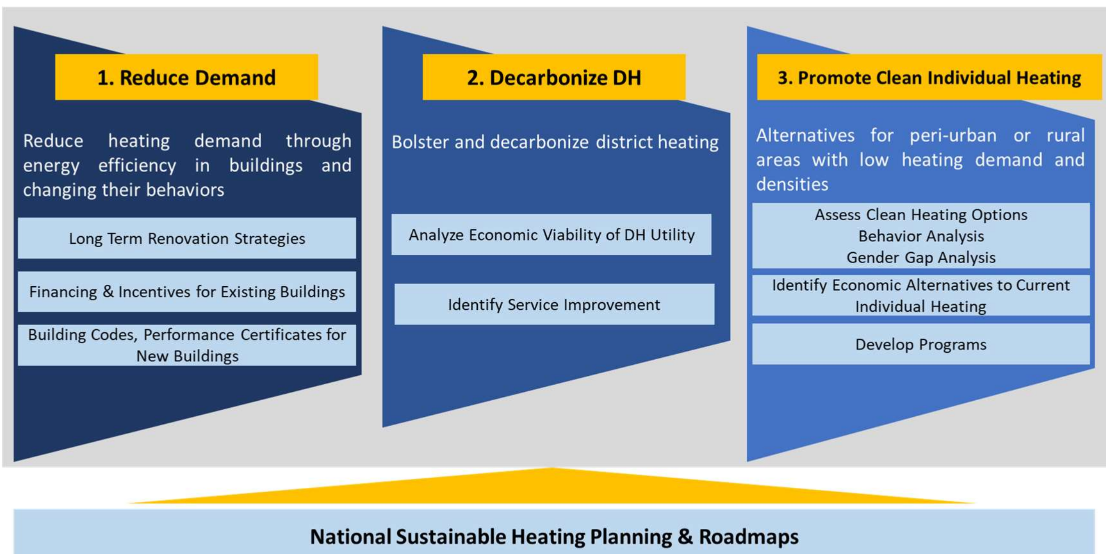
Sustainable heating framework

While fossil fuels remain the dominant heating fuels in the DH sector in the region, there is an emerging range of possible fuels, technologies, and technological improvements to consider. These include renewable energy sources (e.g., geothermal, solar, biomass), industrial and urban waste heat, waste incineration, biogas (e.g., landfills, wastewater treatment), heat pumps, and hydrogen. District heating networks are also experimenting with lower-temperature systems, building-level substations, adding domestic hot water and/or district cooling and heat storage, as well as possibilities for a more integrated energy sector that couples electricity with heating.

Which clean heating solution has the lowest economic cost for households is highly context-specific and depends on, among other things, the access to existing DH networks, the availability of internal piping and radiators in the building, the cost of energy fuels, and the availability of affordable renewable resources. For buildings that are already connected to a heating network, or in areas with high heat-demand densities, DH often represents the lowest-cost solution, in both financial and economic terms. Where DH is not available or viable, air-air heat pumps often provide the most affordable option. For *urban single-family homes (SFHs)*, air-to-air heat pumps generally have the lowest levelized cost of heating (LCOH) for homes without internal heat distribution systems; for SFHs with internal piping, condensing gas boilers tend to have the lowest levelized cost. The situation is similar for *urban multifamily buildings (MFBs)*: air-to-air heat pumps were most economic for buildings without internal piping, whereas condensing gas boilers often had the lowest economic levelized cost in buildings with internal distribution systems. In *rural SFHs*, air-to-air heat pumps and eco-design biomass (wood) stoves generally had the lowest economic levelized cost. But there is a significant variance in results among the different countries for the same technologies and fuels. For example, LCOH results tend to be significantly lower in Armenia, Kyrgyz Republic, and Uzbekistan compared to Poland, Serbia, and Türkiye due to the significant difference in the cost of energy fuels in each country.

Governments should structure their strategies to promote sustainable heating around three pillars: (i) reduce heating demand through energy efficiency in buildings and changing user behaviors, (ii) bolster and decarbonize centralized DH where viable, and (iii) promote clean building-level heating systems where *centralized heating is not economic.* First, the renovation of existing buildings and integrating energy efficiency requirements into codes for new buildings are critical to reduce heating demand. For public buildings, these investments generally have payback periods of under 15-20 years; for MFBs and SFBs, payback periods can be longer, largely due to the need for parallel structural and other repairs. Second, for DH companies, the viability of continued and expanded DH will depend on the operational and financial performance of the incumbent service provider(s), customer and heat demand densities, availability of concentrated and economic clean heating sources (e.g., renewable energy-based heating, waste heat), and other factors. Third, in areas where DH is not economically least-cost or viable (such as peri-urban or rural areas with low heating demand and densities), governments will need to identify least-cost economic alternatives (e.g., heat pumps, eco-design biomass stoves) and develop policies and programs to support their adoption.

Figure Ov.1: Framework for sustainable heating



Recommendations for implementing a sustainable heating framework

Public sector planning and regulations, programs including incentives and financing, communications and outreach, and training will be important elements of a holistic government response to enable the sustainable heating transition. Government interventions should include comprehensive programs guided by long-term policies and targets, strategies, action plans, and roadmaps. These should be combined with higher-level sector reforms to improve governance and incentives, enabling reforms to incentivize market-based uptake of sustainable heating solutions, and measures to promote energy efficiency along the heating value chain.

Investments in the public sector can help stimulate markets, demonstrate new technologies and approaches, and lead by example. Many countries have used such an approach to promote energy efficiency, initiating programs in the public sector to train energy auditors and designers, develop new financing modalities (such as revolving funds, budget capture schemes, public energy service companies (ESCOs), or on-bill utility financing) and implementation models, provide stable demand for higher-efficiency products (which often leads to more competition and lower prices), and develop other tools to assist in the further development of the market (e.g., energy calculators, audit templates, case studies, checklists, measurement and verification protocols).

Sustainable heating programs for the residential segment should be tailored to the specific market conditions, barriers, and opportunities in the country, drawing from the wealth of international experience and considering the needs of the poor. A combination of incentive schemes (e.g., partial investment grants, rebates, interest subsidies, tax incentives) and financing mechanisms should be designed as core elements of energy efficiency and sustainable heating programs; these programs are often delivered through financial intermediaries (such as development, commercial or community banks), tax agencies (through tax credits or exemptions), public agencies or third parties appointed by the government (such as energy-efficiency or environmental funds, or energy agencies), or through private companies (such as equipment vendors or energy utilities). A centralized institutional approach, such as an energy efficiency fund, has the advantage that—if appropriately resourced—the entity can serve as a "one-stop shop" for financing, incentives, information, and technical expertise for clean heating solutions. Financing programs should be complemented by activities that help communicate the programs, recruit participants and promote changes in behaviors, share technical good practice and lessons, lower transaction costs through standardized audits and other templates, offer training, and conduct monitoring and reporting. Government programs must also include components explicitly designed to serve the poor, with suitable financing, delivery, and outreach efforts tailored to meet their needs and take into account gender differences.

Countries should prepare strategies and roadmaps for the sustainable heating transition. Without such strategies, the right policies, market and investment plans, etc. cannot be effectively formulated. And without a clear vision articulated and coordinated by the government, businesses, households, utilities, and others are likely to make suboptimal investment decisions regarding their heating supply. Such strategies need to consider future heating demand, demographic shifts, likely housing typologies, access to clean heating sources, technologies options, and other information. Efforts should also be made to develop improved repositories of national data to provide the basis for analyses and prioritization of heating solutions. Building on these analytics, sustainable heating roadmaps (SHRs) offer an integrated approach to developing low-carbon heating infrastructure and plans using modern analytical tools to help governments make decisions in a more systematic and data-driven way.

Reforms are a critical step in the transition. The gradual phase-out of fossil fuel subsidies, removal of direct and indirect subsidies for electricity and DH, universal consumption-based billing for DH, pricing of biomass, etc. are necessary to provide the proper price signals to incentivize the switch to more sustainable fuels, technologies, and energy efficiency. Adequate pricing of externalities associated with unsustainable fuels and fuel use, such as environmental and health impacts, will also be important to ensure that optimal heating solutions are prioritized. In such cases, measures need to be introduced to protect the poor and vulnerable. Homeowner association legislation for MFBs also require reforms to enable them to make renovation decisions, sign contracts, borrow and collect fees.

Energy efficiency measures to reduce heat demand are necessary to optimize the cost of the transition. Demand could be reduced by 45-55 percent depending on the policy ambitions and commitments. While this will help facilitate and lower the costs of the sustainable heating transition, it will also have implications for heating fuel choices and technologies, especially for DH. A massive mobilization of institutions and investments will be needed to scale up building renovation programs, encourage deeper renovations (including net-zero-energy buildings), and improve building codes. About 3.5 percent of the total remaining building stock will have to be renovated each year (about 3.7 million buildings each year, assuming about 106 million buildings in the region) at a cost of about US$45-76 billion annually.

Technical standards should be raised to increase the availability of energy-efficient heating equipment in the market. Because efficiency levels alone may not be sufficient to incentivize the purchase of more-efficient models, efforts should be made to remove the less-efficient ones from the market through regulatory standards. This would mean discouraging the use of conventional wood stoves and boilers, conventional gas stoves, and electric heaters in favor of eco-design wood stoves/boilers, condensing gas boilers, and heat pumps. Where government financing or incentives are planned, eligibility criteria should tie these funds to the more-efficient models. Use of strategies such as bulk procurement/distribution or manufacturer partnerships can help promote more-efficient models while reducing consumer prices.

Programs need to be designed to make judicious use of public funds to stimulate markets and change behaviors. Given the huge investment needs, subsidy schemes need to be well targeted and (except for the very poor) temporary. The transition to sustainable heating will require strong government commitment, investment, and action, but the focus should be on overcoming key market barriers and affordability concerns. For most building owners, the combination of energy efficiency and sustainable heating is likely to yield energy cost savings that can be used to recover a portion of the investments. This can then allow governments to work with banks and other financial institutions to develop appropriate financial products (possibly blended with subsidies and risk-sharing mechanisms as needed) to support these household investments. Investments in decarbonizing DH should also seek some commercial financing where possible, especially for creditworthy DH system operators. Well-designed communications and outreach can be used to help instill changes in behavior regarding investments in energy efficiency, heating technologies, and fuels. These should be based on market and household surveys, tailored to local customs and norms, and adjusted for target income levels, gender and age.

Executive Summary

Introduction

The heating sector in the World Bank's Europe and Central Asia (ECA) Region is unsustainable. District heating (DH), where available, relies heavily on coal and natural gas, often provides substandard levels of service, and is typically unable to fully recover its costs. Households that do not have access to DH rely mostly on underpriced coal and unregulated firewood, burned in boilers or stoves that are almost always inefficient and polluting. On the demand-side, only a small fraction of the building stock has been renovated; as a result, buildings often consume 2-3 times more energy per square meter than those in Western Europe—despite the fact that most countries in ECA have a lower overall per capita energy use. This makes heating unaffordable for many of its citizens. There is thus an urgent need to transition to more sustainable heating.

For this report, "sustainable" heating solutions are those that are widely affordable, reliable, efficient, low-emission, and consistent with carbon neutrality by mid-century. This report reviews the status and trends of space heating in ECA; identifies common regional barriers to sustainable heating; assesses heating options (including costs and technical viability); and proposes a framework, with policies and programs, for planning the transition. The report is designed primarily for policy makers and practitioners in the region who work in the heating sector. Where possible, given the broad mix of countries, options are provided that accommodate a range of economic conditions, institutional capacities, dependency on fossil fuels, availability of local resources, and other factors. The report includes data and analysis for all 23 ECA countries, where available, to illustrate the diversity of contexts and pathways to sustainability.

Addressing the considerable challenges in the transition to sustainable heating is an urgent imperative for policymakers to ensure heating services can be affordable, efficient, and clean. The decarbonization pathways in ECA countries to net zero by mid-century necessitate the transition to sustainable heating. Thus, many of the existing institutions, systems, fuels, and technologies will have to undergo a massive shift to achieve this goal, as will enabling policies, financing, business models and communications. Given the limited time remaining, the transition must be started this decade and at scale. This is also an emerging opportunity as notable progress has been made, and technologies and approaches are already being tried and tested and lessons learned.

Transition costs

The investment required for the sustainable heating transition in the ECA region would be in the trillions of US dollars, but its benefits are projected to be even greater. Most of the costs will have to be borne by DH utilities, heating customers and building owners. However, there is a role for targeted government subsidies and support to enable this transition given many market distortions and barriers. Three scenarios were developed that estimate the cost of the transition—including renovating 14 billion m^2 of building floor area (about 95 percent of building stock), upgrading DH networks and heating fuels, and replacing individual systems with sustainable heating options by 2050—at US$2.0-2.5 trillion. The economic net present value (NPV), which includes energy savings as well as environmental and health benefits, is projected to be approximately US$402-440 billion, and the economic internal rate of return is estimated to be 9.0-10.2 percent. Broader socioeconomic benefits would make the benefits even larger—

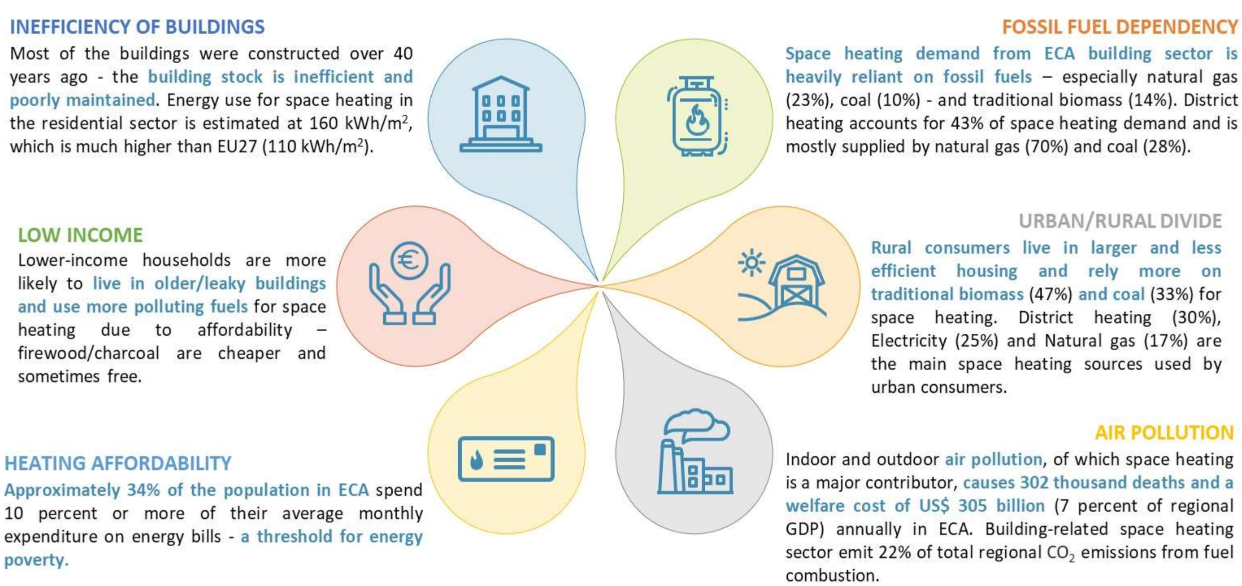
e.g., improved energy security, lower energy subsidies, reduced energy poverty, extended building lifetimes, higher property prices, better comfort, job creation, etc.

The subsidies needed to support the transition would be about 1.3 percent of the region's annual GDP, or about half of the region's fossil-fuel subsidies through 2050. A financial analysis was conducted in order to determine the level of subsidies that may be required to achieve a positive financial NPV for the transition. On this basis, the calculated subsidies were US$1.54-1.67 trillion (about 1.3 percent of regional annual GDP), which represents about 59-68 percent of the total transition costs. While this appears high, this amount represents about 50 percent of the funding that ECA countries will spend on fossil-fuel subsidies (US$115 billion annually) if current subsidy levels are maintained through 2050. Therefore, the cost of the transition is manageable and achievable, with the right policies and government actions.

Current status of space heating in ECA

The heating sector is among the most energy- and carbon-intensive sectors in the region, and accounts for approximately 24 percent of total regional energy demand. The current status of space heating in ECA is precarious (Figure ES.1). The high energy and carbon intensity is due to cold climates and long heating seasons, fossil-fuel-dependent systems, chronic under-maintenance and repairs, and the very old and inefficient building stock. As a result, the current annual regional space heating demand is estimated to be 2,625 TWh, or around 24 percent of total energy demand; of this, about 72 percent (1,889 TWh) is consumed in the residential sector and the remaining 28 percent (736 TWh) in commercial and public buildings. In terms of the heated floor area, the average specific energy consumption for space heating in residential buildings is estimated to be about 160 kWh/m^2, which is much higher than Canada (114 kWh/m^2), the EU27 (110 kWh/m^2), the United States (70 kWh/m^2), or Japan (33 kWh/m^2).

Figure ES.1: Status of Space Heating in ECA

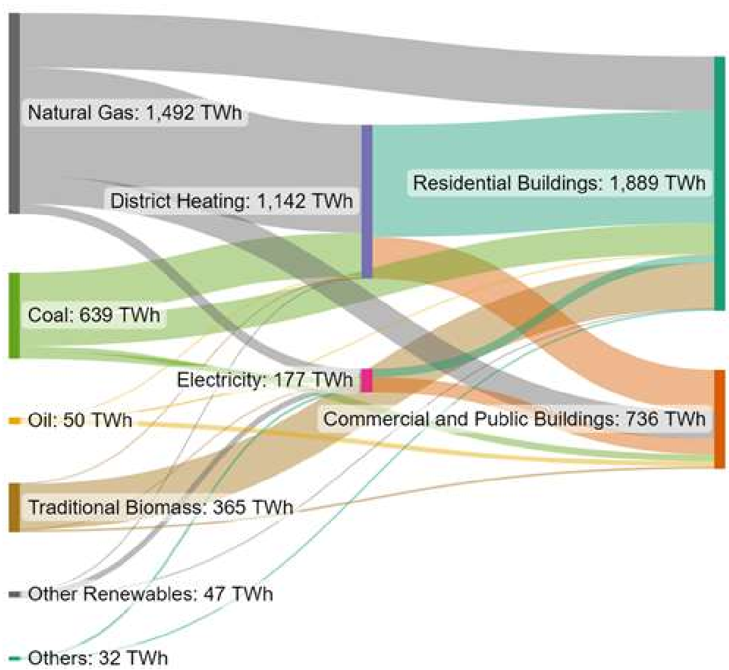


Source: Authors.

ECA also has a very large, diverse and aging building stock of about 106 million buildings. It comprises 15 billion m^2 of floor space, of which 12 billion m^2 are residential buildings (divided into 156 million dwellings) and 3 billion m^2 are commercial and public buildings. For the 22 countries for which data are available, people in seven countries reside primarily in multifamily apartment buildings (MFBs), while in the remaining 15 countries, more than half of the dwellings are single-family homes (SFHs). Sixteen countries have a majority of their residential buildings located in urban areas; six have half or more of their dwellings located in rural areas. Floor space also varies considerably; for example, floor space is four times higher per capita in Bosnia and Herzegovina than in the Kyrgyz Republic. Except for a few countries (such as Kosovo, Albania, Montenegro, Kyrgyz Republic and Bosnia and Herzegovina), most of the building stock in ECA was constructed prior to 1980, when energy-efficient building standards were either not enacted or not enforced.

Space heating in ECA is still heavily reliant on fossil fuels (especially natural gas and coal) and traditional biomass (predominantly firewood). As show in Figure ES.2, more than 83 percent of space heating is derived from fossil fuels. With DH and electricity disaggregated, the regional space heating demand is mostly supplied by natural gas (57 percent), coal (24 percent) and traditional biomass (14 percent). Within the region, however, the fuel mix varies considerably. Some countries, such as Türkiye and Georgia, primarily rely on natural gas to heat their homes (54 percent). For others, such as Kyrgyzstan, Poland, and Tajikistan, coal is the main heating fuel (70 percent, 40 percent, and 34 percent, respectively). However, due to limitations of heating infrastructure (DH and gas networks) and affordability, traditional biomass continues to be a prominent fuel in households across the region. Most of the Western Balkan countries' households depend upon traditional biomass for space heating (e.g., 76 percent in Bosnia and Herzegovina, 72 percent in Kosovo, 70 percent in Montenegro). Central/DH is more common in Russia and Belarus, where such systems serve over 60 percent of their populations; these systems predominantly rely on natural gas.

Figure ES.2: Estimated Space-Heating Supply in the ECA Building Sector, by Fuel (Sankey Diagram)



***Source*:** World Bank estimation based on best available data.

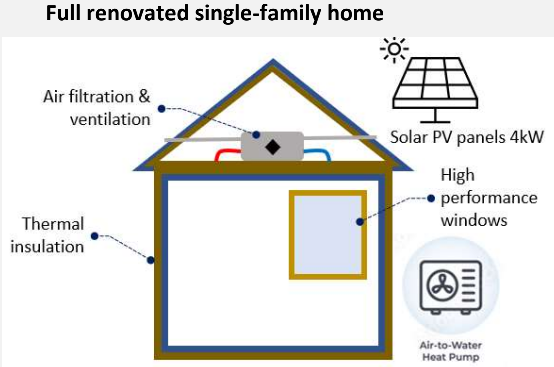
The heavy reliance on fossil fuels and traditional biomass for space heating has led to significant levels of emissions. Across the region, air pollution is a serious threat, causing 302,000 deaths and incurring a welfare cost of US$305 billion (7 percent of GDP) annually. About 50 percent of fine particulate matter (PM) emissions is generated from burning solid fuels in individual SFHs. The impacts are even worse in urban and peri-urban areas. In Skopje, for example, the burning of solid fuels for residential space heating is responsible for nearly 90 percent of all $PM_{2.5}$ and PM_{10} emissions, while in Poland it is over 80 percent in many of the more polluted regions. High fossil-fuel use also leads to high greenhouse gas (GHG) emissions. The annual ECA buildings-related space heating gross CO_2 emissions from fuel combustion were estimated to be about 22 percent of the total regional emissions, or 678 $MtCO_2$, of which 75 percent (508 $MtCO_2$) is attributed to the residential sector and the remaining 25 percent (170 $MtCO_2$) to commercial and public buildings.

High exposure to imported fossil fuels at global prices, in combination with the cold climate and inefficient energy use, affects energy affordability and energy poverty in ECA countries. Energy poverty is a combination of factors that cause a household to have above-average energy needs and costs—high energy losses in the home, low-efficiency appliances, high and sometimes volatile energy costs, and low-income levels. Low-income households tend to live in older, uninsulated houses with poor windows and doors and tend to use lower-efficiency heating technologies and purchase dirtier fuels (e.g., coal, firewood). This means low-income households may not be able to keep their homes adequately warm and may require larger investments to transition to sustainable heating equipment or face higher ongoing expenditures if they switch to cleaner fuels. About 34 percent of residents spend 10 percent or more of their average monthly expenditure on energy bills, a typical threshold for energy poverty. (Box ES.1 shows this implicit energy-inefficiency tax on the poor based on a World Bank analysis made for Poland). Even before the recent energy crisis, the poorest households allocated as much as 60 percent of their budget on essentials such as food, housing, and energy, which left little discretionary spending for better heating and insulation. The low elasticity of energy consumption means that many households are at risk of falling into absolute poverty when energy prices rise, as was evident after the Russian invasion of Ukraine in 2022. When heating becomes unaffordable, households are often left with two unappealing choices: reduce the heating levels in the home or revert to dirtier fuels. Kosovo reported over 40 percent of its population could not keep their homes adequately warm in 2018; Bulgaria, North Macedonia, and Albania reported underheating figures of 23, 24 and 36 percent, respectively, in 2020-22.

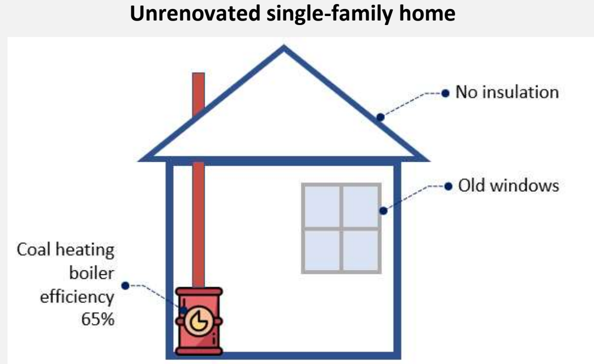
Box ES.1: The implicit energy inefficiency tax on the poor

Consider two homes, one which has undergone a full renovation and one which has not been upgraded:

Full renovated single-family home



Unrenovated single-family home



Annual energy bill: *0-US$461.5/year* *US$2,501.3 per year*

The home on the left has been fully thermally renovated (including wall and roof insulation, and window replacement), and installed air filtration and ventilation systems, an air-water heat pump, and rooftop solar photovoltaic (PV) panels. The house would meet all requirements for thermal comfort and indoor air quality. The cost of the investment is US$35,398 with a simple payback period of about 14.2 years. Depending on the net metering or net billing system in place, which would allow the homeowner to sell the unused solar electricity to the grid to offset their bill, the monthly energy cost would be US$0-38.5 (US$0-461.5 per year).

In the second case, there would be no investment cost. The house uses coal for heating but would typically be unable to keep the home sufficiently warm. There would likely be some concerns about indoor air quality, and the home would likely be in violation of emissions standards, contributing to poor outdoor air quality. The monthly energy bill to heat the home using coal would average US$208.4 (US$2,501.3 per year).

Because lower-income families cannot afford simple energy-efficiency investments or more-efficient heating systems, they are burdened with chronic heat losses in their homes. This leads to higher energy bills and lower quality of heating, creating a vicious cycle. However, when allowed to invest in energy efficiency with affordable options, many do opt to invest.

District heating

District heating provides heating services in dense, urban areas with an estimated 139.3 million customers (about 30.1 percent of the population) in the ECA region. There are more than 52,000 DH utilities in the region, but most are in Russia; excluding Russia, there are about 2,300 utilities. Most DH in the region is generated from fossil fuels; over 97 percent of the region's combined heat and power plants (CHPs) and heat-only plants rely on fossil fuels. Of this, 66 percent is from natural gas and 28.5 percent is from coal—often burned in very old plants, which makes the systems very inefficient and polluting. However, because DH is one of the more difficult-to-abate sectors, other regions also show high fossil-fuel dependencies: China stands at 99.4 percent (93.6 percent coal), Europe at about 66.6 percent (22.9 percent coal), and the US/Canada at 86.8 percent (8.9 percent coal). Despite the high prevailing dependence on fossil fuels, the EU and other countries still view DH as a critical element of their sustainable heating strategy (Box ES.2).

Box ES.2: District Heating in the EU

To meet ambitious EU energy and climate goals, a complete transformation of the energy sector will be necessary. This includes the heating and cooling sectors, which account for about 50 percent of energy demand, of which two-thirds is based on fossil fuels. Gas is the predominant fuel, followed by coal. Biomass accounts for about 12 percent of heating use, but much of it is not certified and burned in older, less-efficient stoves and boilers. DH accounts for about 12 percent of heat supply. The EU does provide indicative targets and encourages incentives to increase DH coverage in urban areas, but generally does not specify requirements for the network heating fuels.

Some recent developments in the EU include:

- Sweden (52 percent), Denmark (50 percent), Finland (42 percent) and Lithuania (42 percent) have the highest share of DH. Denmark has worked to increase DH from about 50 percent of dwellings (mid-1990s) to about 67 percent (2022), with about 600 heat-producing companies and 354 DH (58 municipal-owned, 286 customer-owned coops and 10 private).
- Most, about 70 percent, rely on CHPs for heat production in DH systems. While some are very coal dependent (e.g., Poland, Czech Republic, Slovakia), others use very limited fossil fuels (e.g., Sweden has a high share of large heat pumps, while France relies on geothermal and waste incineration).
- Most systems are relatively old but still efficient, with higher DH distribution losses in Denmark (21 percent), the Netherlands (14 percent), Finland (13 percent) and Italy (13 percent), and lower in others (Austria, Estonia at around 5 percent).
- Gradual shifts to more sustainable DH are becoming more common in the EU. Austria, Croatia, Estonia, Finland, France, and Sweden have all built CHPs that use agricultural waste, wood, or peat to fuel biomass CHPs; Finland has been operating a waste incineration CHP since 2014 and a waste gasification plant since 2012; Denmark commissioned a new solar collector plant in 2019 and now has over 70 percent of DH heat supply from geothermal, biomass, waste and renewable energy (RE) -based waste heat; Austria has several thermal storage units (thermal energy storage towers, pit storage); and several European DH utilities are expanding to include district cooling in the summer months.

- Germany received EU funding in late 2022 to provide incentives for the development of heat supply based on RE and waste heat to achieve 75 percent of the DH network fueled by green energy by 2028.

The EU is also proposing a range of schemes and mandates to support decarbonization plans for DH with national-level targets, carbon taxes on fossil fuels used for heating, incentives for using waste heat, improved urban planning, incentives for customers to connect to DH, and other measures. The EU's Renewable Energy Directive also calls for an annual increase in RE for heating and cooling of 1.3 percent each year.

A survey was conducted in a sample of 18 DH utilities in the region from Bulgaria, Kyrgyz Republic, Poland, and Serbia to assess their financial and operational performance. A short list of indicators was developed covering financial aspects (e.g., cost recovery, liquidity and profitability) and operations (e.g., system efficiency, network configuration). Data was collected for a five-year period (2017-21) to observe trends. The results were then converted to scores (0-100) based on comparisons with regional benchmarks. A score of 70 or higher was considered to be good. The results are summarized in Table ES.1 along with recommended actions.

Table ES.1: Summary of District Heating Utility Survey Results and Recommended Actions

Groups	Definition	Key Actions
Group 1 (3 utilities)	Good financial and operational performance	• A mapping of cleaner heating sources against projected heat demand • Medium-term building renovation plans • Consider more advanced reforms (e.g., unbundling of heat generation and distribution, private sector participation, cost-reflective heat tariffs
Group 2 (5 utilities)	Good financial performance only	• Improved corporate governance—utility management and operations, tighter regulatory operational benchmarks, data platform development • Investment program with benchmarks to improve efficiencies in heat generation and distribution, expand and densify the network, and transition to building-level substations • Heat demand assessments, expansion plans integrated into urban planning • Tariff reform (to help boost revenues to finance investment program)
Group 3 (3 utilities)	Good operational performance only	• Improved sector governance—tariff methodologies, regulatory strengthening, transparency and institutional strengthening (including performance improvement plans or PIPs) • Reforms in tariff methodologies and levels, with strong communications to build public support, and parallel service improvements • Improved metering, billing and collections • Efforts to reduce fuel supply costs and improve efficiency of heat generation • Financial restructuring (when debt service levels are high)
Group 4 (7 utilities)	Poor financial and operational performance	• Improved sector governance—utility management and operations, tighter regulatory operational benchmarks, tariff methodologies, regulatory strengthening, transparency and institutional strengthening • Critical assessment of necessary reforms, potential load increase/reduction, cost profiles of cleaner heating sources to confirm economic viability of DH before additional investments made • Development of PIPs; cost recovery measures to be accompanied by: (i) visible improvements in service quality and efficiency, (ii) clear communications with customers, (iii) parallel programs to support energy efficiency, iv) expanded social protection measures for the poorest customers

The results show there is wide variation in utility performance across the region and within countries but only three fully met regional benchmarks. In some cases, past performance assessments and improvement plans have led to substantial progress in operations, cost recovery, and other parameters. Unfortunately, in many other cases, very old assets combined with an inefficient building stock, high costs, low tariffs (and consumers with limited ability to pay), and a lack of political will for necessary reforms have collectively led to poor performance. Given expected improvements in building efficiencies, demographic shifts, and other changes, some smaller DH systems could potentially be uneconomic going forward or would require levels of subsidies that the national or local governments are unwilling or unable to mobilize. In such cases, a critical assessment may be needed to determine if such systems can be made sustainable. If not, a managed phasedown of DH may have to be considered. For DH systems that remain economic, large investments in cleaner heating sources and modernization of networks would be needed; governments will need to help mobilize financing for such investments.

While fossil fuels remain the dominant heating fuels in the DH sector in the region, there is an emerging range of possible fuels, technologies, and technological improvements with the potential to improve sustainability, as well as a range of policy options designed to incentivize DH system decarbonization and improved environmental sustainability. These include renewable energy (RE) sources (e.g., geothermal, solar, biomass), industrial or urban waste heat, waste incineration, biogas (e.g., landfills, wastewater treatment), hydrogen, and electricity (large heat pumps). District heating networks could also consider transitioning to lower-temperature systems, transitioning to building-level substations, and adding domestic hot water and/or district cooling and heat storage. There may also be possibilities for a more-integrated energy sector (coupling electricity and heating, for example) to benefit from periods with excess RE electricity supply by converting it to stored heat.

Individual or building-level heating

Economic and financial analyses were conducted to assess the levelized cost of heating (LCOH) for individual heating systems for sample MFBs and SFHs in urban and rural areas in six countries: Armenia, Kyrgyz Republic, Poland, Serbia, Türkiye, and Uzbekistan. In areas where DH was not available or viable, the analysis compared traditional heating systems (e.g., coal stoves/boilers, firewood stoves/boilers, gas boilers, electric heaters) with more sustainable heating options. The financial analyses determined which heating options were most cost-effective from an individual consumer's cashflow perspective, while the economic analyses determined the most viable technologies considering externalities such as GHG emissions and health damages due to air pollution.

Air-air heat pumps and eco-design biomass stoves were shown to be the most economic options; condensing gas boilers were least-cost in a few cases when the country's grid emissions were very high, or homes lacked internal hot-water piping systems. The LCOH analyses found that (i) where available, DH provided the lowest cost in almost all locations and building types, both in financial and economic terms; (ii) for *urban SFHs*, air-to-air heat pumps generally had the lowest LCOH for homes without internal heat distribution systems, whereas condensing gas boilers often had the lowest LCOH (both economic and financial) for homes with internal piping; (iii) for *urban MFBs*, air-to-air heat pumps were most economic for MFBs without internal piping, and condensing gas boilers often had the lowest economic LCOH in buildings with internal distribution systems; (iv) in *rural SFHs*, air-to-air heat pumps and eco-design biomass (wood) stoves generally had the lowest economic LCOH. Sensitivity analyses were also conducted to determine the impacts of the results on energy efficiency as well as changes in the investment price (CAPEX) and energy prices (OPEX). Some findings include:

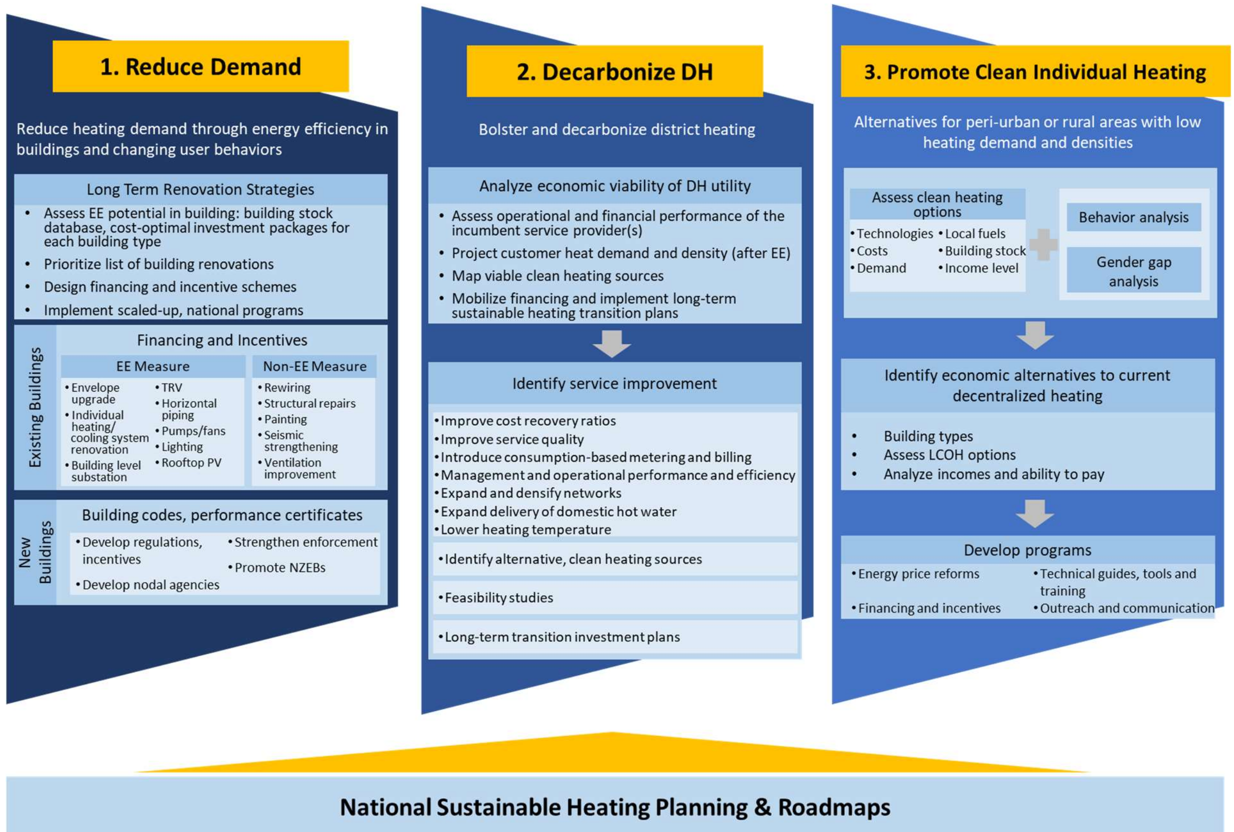
- *Fuel pricing is critical*. The biggest driver of the sustainable energy LCOH rankings is energy prices. Even with the most efficient technologies, customers will be deterred from switching to more sustainable heating options if conventional fuel prices are artificially low—whether it is coal, wood, electricity, or DH. Distorted pricing substantially skews the rankings of heating technologies and fuels and can incentivize some fuels over others, regardless of which is cleaner or more economic. Thus, the elimination or phasing out of fossil fuel, electricity, and DH subsidies remains important for the sustainable heating transition.

- *Energy efficiency should be encouraged*. The analysis also shows that levelized costs and payback periods are affected by combining the replacement of heating systems with thermal renovations. In some cases, energy efficiency investments can actually cause payback periods to increase since the heat load is reduced and the investment costs of the energy efficiency measures is significantly higher. However, such investments can reduce the peak heat demand (and thus heating system size), reduce monthly heating bills, and improve indoor comfort levels. Therefore, combining heating systems and energy efficiency should be encouraged.
- *Recognize externalities*. Governments should consider economic least-cost options in their sustainable heating plans. Given the high social costs of dirtier fuels, the introduction of a mechanism to account for environmental externalities, such as a carbon tax, would encourage the adoption of cleaner technologies and fuels. This includes electricity costs in countries where electricity generation is predominantly coal-based (e.g., Poland, Serbia).
- *Consider other factors*. While the analysis was limited to space heating, the recognition of additional service needs (such as domestic hot water or space cooling) and other consumer preferences (such as predictability of cleaner fuel supplies and prices, social norms, or affordable financing) should be taken into account, as these can impact fuel and technology choices.

Sustainable heating framework:

The proposed framework for sustainable heating is based on three sequential pillars: (i) reduce heating demand through energy efficiency in buildings and changing user behaviors, (ii) bolster and decarbonize centralized DH where viable, and (iii) promote clean building-level heating systems where centralized heating is not economic (Figure ES.3).

Figure ES.3: Framework for sustainable heating



Source: Authors.

(i) *Reduce demand*. Energy efficiency in the building sector remains one of the lowest-cost options for helping meet the sustainable heating challenge by substantially reducing heat demand, through renovating existing buildings and enacting codes for new buildings. It was estimated that the space heating load demand in the ECA region could drop by about 55 percent through energy efficiency in buildings, implying substantially less investments for new, cleaner heating systems. Many ECA countries have a package of policy documents, including long-term renovation strategies (LTRSs), designed to promote building renovations. However, the pace of renovations and introduction of financing schemes remain largely behind schedule and must be urgently accelerated, with a greater focus on deep renovations.

(ii) *Bolster and decarbonize district heating*. For most dense urban areas, DH remains the most economically viable option, and is the most affordable option for urban residents. However, since most DH is fully dependent on fossil fuels, the future economic viability of transitioning to sustainable DH will have to be assessed. These feasibility studies should consider several factors, such as the operational and financial performance of the incumbent service provider(s), current and projected customer and heat demand densities, availability of concentrated and economic alternative clean heating sources, and potential for further efficiency gains. For those DH systems that would remain economically viable, additional analyses would be needed to (i) determine how best to bolster the DH systems and provision of services; (ii) identify alternative, clean, and affordable heating sources that could be tapped to offset the existing heating production; and (iii) conduct feasibility studies to transition to these cleaner options and develop and implement a long-term transition plan. Of course, continued population growth and urbanization may create new opportunities for new DH systems to be introduced if there are clean sources of heating available. If some systems are either found to be uneconomic or would become no longer economically viable (based on demand reductions or other factors), alternative arrangements may be needed (e.g., possible reduction in DH service area, break up of system into smaller networks, possible managed phaseout of DH in unviable areas). For the latter, alternative heating systems (e.g., heat pumps) would have to be made available to households, along with programs to support parallel building renovations, financing programs for the heating systems, and parallel investments in supporting infrastructure (i.e., the electricity grid in the case of heat pumps).

(iii) *Promote clean individual heating*. In areas where DH is not economically least-cost or viable, such as peri-urban or rural areas with low heating demand and densities, governments will need to identify least-cost economic alternatives, and develop policies and programs to support their adoption. In developing programs to help encourage the adoption of these cleaner heating options, market studies will need to be carried out to understand current heating technologies and costs, heating demand, availability and costs of local fuels, information on the building stock, and income levels. Likely technologies include heat pumps and sustainable biomass boilers and stoves. Programs should contain a mix of policy and regulatory measures, financing, incentives, information and training.

Sustainable heating roadmaps (SHRs) offer an integrated approach to developing low-carbon heating infrastructure and plans using modern analytical tools to help governments make decisions in a more systematic and data-driven way. A more-recently-developed analytical approach to the geospatial prioritization of energy efficiency, DH, and individual heating solutions is to undertake a detailed analysis on heat demand in a country or region and overlay that with available sustainable-heat resources in order to match demand and supply. Researchers at Aalborg University have developed a methodology for SHRs that uses geospatial tools, integrated resource mapping, and long-term data-driven planning to help governments incorporate a complex set of technical, economic, environmental, and social considerations into one integrated platform and allow a country's or region's economic resource potential to be optimized. It can also bring together national and local objectives and plans to be integrated—looking across building strategies, energy efficiency potential, areas that can be supplied with central and individual heating, RE and other heat source potential, heat and population demand trends, etc. into one consolidated roadmap.

Designing government programs

There are a number of policy, infrastructure, economic and financial, technical and informational barriers that that have made the transition to sustainable heating particularly difficult. These include: (i) low energy prices, (ii) lack of infrastructure (e.g., for DH, gas, internal piping); (iii) stalled DH reforms leading to poor, inefficient service; (iv) long asset lifetimes; (v) chronic past underinvestment and under-maintenance of DH systems, buildings; (vi) lack of financing and affordable options; (vii) multijurisdictional responsibilities; (viii) unregulated biomass/firewood; (ix) behavioral inertia; and (x) lack of know-how and information.

Given the wide range of barriers, a comprehensive government response is necessary to address policies and regulations, infrastructure planning, programs including incentives and financing, communications

and outreach, and training. Government interventions should be guided by long-term policies and targets, strategies, action plans and roadmaps to ensure the pace and depth of the transition can meet national ambitions. These should be combined with higher-level sector reforms to improve governance and incentives, enabling reforms to incentivize market-based uptake of sustainable heating solutions, and measures to promote energy efficiency along the heating value chain. Central governments should play a critical role in the establishment of a national vision and the coordination and strengthening of (i) sub-national heating sector policies and initiatives and (ii) the management of regional/municipal DH utilities. This then sets a framework through which municipal and other subnational government bodies can develop and implement local plans and enforce regulations. If the sustainable heating measures and options are not available, affordable, and relatively simple to adopt, households may be unlikely to switch.

Governments should pursue a multi-pronged approach comprising parallel programs for public, commercial, and residential buildings. Many governments often start with programs in public buildings first—to demonstrate sustainable heating technologies, approaches, and benefits, and to lead by example. Many countries have used such an approach for energy efficiency, initiating programs in the public sector to train energy auditors and designers, develop new financing modalities (such as revolving funds, budget capture schemes, public energy service companies (ESCOs), or on-bill utility financing) and implementation models, provide stable demand for higher efficiency products (which often leads to more competition and lower prices), and develop other tools to assist in the further development of the market (e.g., energy calculators, audit templates, case studies, checklists, measurement and verification protocols). Because of the demonstration potential, these programs should seek best practices—e.g., deep renovations and comprehensive sustainable heating measures, best available technologies, etc.—with strong dissemination of measures, costs, benefits, and lessons.

In the residential sector, where much of the potential lies, sustainable heating programs for should be tailored to the specific market conditions, barriers, and opportunities in the country, drawing from the wealth of international experiences and good practices. A combination of incentive schemes (e.g., tax rebates, grants) and financing mechanisms should be designed as core elements of sustainable heating programs. The scale and choice of incentives should be tailored to the targeted population—informed by market studies and household surveys, which are generally the best tools for identifying household practices, needs, and constraints. A centralized institutional approach, such as an energy efficiency fund, has the advantage that—if appropriately resourced—the entity can serve as a "one-stop shop" for financing, incentives, information, and technical expertise for clean heating solutions. These should be complemented by activities to help market the programs recruit participants and change behaviors, share technical good practice and lessons, lower transaction costs through standardized audits and other templates, offer training, and carry out monitoring and reporting. Having good-quality and sufficiently resourced institutions and materials can greatly improve program participant recruitment and implementation.

Residential heating programs should be designed to also address the needs of the poor. As noted earlier, about one-third of ECA households are energy-poor and eight countries report having more than 42 percent of their residents as spending 10 percent or more of their household income on energy. For the sustainable heating transition, this creates a huge risk that (i) the energy-poor may already be unable to afford to adequately heat their homes and meet their energy needs, and (ii) these households will be more likely to use traditional and unsustainable fuels, such as coal and firewood, and less able to afford a shift to more sustainable heating options. Therefore, government programs must be designed to explicitly serve this group with suitable financing, delivery, and outreach efforts tailored to meet their needs.

Government programs should also couple financing and financial incentives with technical assistance such as energy audits, guides, training, etc. to help homeowners make more informed choices and help lower their transaction costs. Such technical support should facilitate all aspects of participation in the government programs, from the application stage through audits and designs to procurement, installation and commissioning. Support should be provided to address potential supply-side bottlenecks, including training and certification of technicians, to ensure quality of renovations, equipment selection and installations. Public outreach and behavior-change campaigns are also critical to ensure strong program participation and help "nudge" consumer decisions. Households also need to be made aware of the program eligibility criteria, procedures, financial incentives, financing options, and technology choices and their relative costs and benefits.

Gender considerations in the design of heating programs is crucial to reduce the persistent gender wage gap and female unemployment rates, increase women's labor force participation, and tackle various energy needs. A previous World Bank regional study found that there is a gap between men and women regarding awareness and knowledge of energy efficiency and their ability to take actions to improve energy use in their households. This gap puts women, particularly those in female-headed households, at a disadvantage, as they are less likely to apply and benefit from such programs. Therefore, programs should ensure that female-headed households have equal access to financing mechanisms, incentives, and program information and outreach. It is crucial to strengthen administrative systems—e.g., for information, grievance, and redress—to reduce the influence of traditional "gender norms" in interactions with institutions. Communication campaigns regarding heating programs should be designed to target both men and women, and presented with simple language and communicated through local channels—local news outlets, public offices, building managers, and local utility service centers.

To ensure government programs are efficient and effective, several complementary, enabling reforms are often needed to level the playing field for sustainable heating solutions and reduce their incremental cost. These include measures to (i) phase out energy subsidies and price distortions; (ii) incorporate externalities in energy pricing; (iii) further reforms in the DH sector; (iv) support sustainable, certified biomass harvesting and use; (v) strengthen building codes and certifications; (vi) introduce energy efficiency performance standards for heating appliances; (vii) enhance air quality standards and enforcement; (viii) improve social safety nets; (ix) introduce prosumer regulations (e.g., for rooftop solar PV); (x) improve HOA legislation; and (xi) upgrade business and worker skills.

Emerging lessons and conclusions

The transition to sustainable heating will be a major challenge in the global shift to carbon neutrality by mid-century, requiring a massive shift in institutions, systems, fuels and technologies, as well as in enabling policies, financing, business models and communications. While notable progress has been made, and emerging technologies and approaches are already being tried and tested and lessons learned, such efforts are not yet at the scale and level of ambition needed.

The following are key takeaways from the data collection and analyses in the report:

1. *Heating in ECA is not sustainable today*. The quality, sustainability, and affordability of heating in the region remain very poor. Inefficient building stocks, old and dilapidated heating networks,

high dependency on fossil fuels, lack of affordability and sufficient heating, and local and global environmental impacts exact a huge toll on its citizens—particularly the poor. The cost of inaction would be enormous.

2. *Many countries lack plans and the needed institutional infrastructure for the sustainable heating transition.* While many countries have a range of decarbonization plans and strategies, most do not sufficiently address the heating sector. Without such strategies, developing the right policies, investment plans, market development, etc. cannot be effectively done. And without a clear vision articulated and coordinated by the government, businesses, households, utilities and others are likely to make suboptimal investment decisions regarding their heating supply. Such strategies need to consider future heating demand, demographic shifts, likely housing typologies, access to clean heating sources, technology options, and other information. Efforts should also be made to develop improved repositories of national data and implementable roadmaps and plans.
3. *Reforms are a critical step in the transition.* Until now, large fossil-fuel, electricity and heating subsidies have muted the benefits of energy efficiency and disincentivized the transition. Thus, the gradual phase-out of fossil fuel subsidies, removal of direct and indirect subsidies for electricity and DH, universal consumption-based billing for DH, pricing of biomass, etc. are all critical to provide the proper price signals to incentivize the switch to more sustainable fuels, technologies and energy efficiency. Adequate pricing of externalities associated with unsustainable fuels and fuel use, such as environmental and health impacts, will also be important to ensure the optimal heating solutions are prioritized. In such cases, measures need to be introduced to protect the poor and vulnerable. Homeowner association legislation for MFBs also require reforms to enable them to make renovation decisions, sign contracts, borrow and collect fees.
4. *Heat demand must be substantially reduced by 2050 through energy efficiency.* Without energy efficiency, the cost of the transition would be orders of magnitude higher. But a combination of warming temperatures, more-efficient new buildings (including demolition of very old buildings that are not viable for refurbishment), renovated existing buildings, newer heating technologies, more-efficient DH networks, and other factors can contribute to a substantial reduction in heat demand, estimated at 45-55 percent depending on the policy ambitions and commitments. Huge investments will be needed to scale up building-renovation programs, encourage deeper renovations (including net-zero-emissions buildings, or NZEBs), improve building codes, and other measures which will require massive mobilization of institutions and investments. With less than 27 years remaining until 2050, and with on average less than 5 percent of the regional building stock renovated, this implies a massive acceleration in pace—3.5 percent of the total remaining building stock will have to be renovated each year at a cost of about US$45-76 billion annually. While most of the transition will be in the residential sector, investments in the public sector can help stimulate markets, demonstrate new technologies and approaches, and lead by example. For residential buildings, some share of public financing for investment subsidies will be necessary given the higher payback periods for older buildings and the need for structural and other repairs. However, given the limitations on available public financing, efforts will have to be made to leverage commercial financing for private buildings.
5. *District heating should be bolstered where economically viable*. In dense urban areas, DH will likely remain the most economic option. However, the poor historical performance of many DH utilities in the region, coupled with the huge projected reductions in heat demand and the need to identify and develop cleaner sources of heating, will necessitate a paradigm shift. Systemic reforms are likely to be needed before financing major new DH investments in order to effect governance,

regulatory, operational, and financial performance improvements. SHRs are also recommended as a way to combine geospatial data with potential clean-heating source mapping and demand centers in order to identify viable areas for DH coverage and to determine which potentially cheaper RE and clean energy sources could be used to offset fossil fuels. This would help determine appropriate policies, plans, and programs, which could then be developed for these systems as well as suitable fuels for the peri-urban and non-urban areas. Reform-minded utilities should be supported through the transition where economically viable; others may have to be substantially restructured, broken into smaller systems, or even phased out over time. If, in some areas, DH is not fully economic but offers the most affordable and politically desirable option, then agreeing on a suitable package of reforms, coupled with shifting to cleaner heating sources where available, may be the best near-term option until lower-cost heating technologies and systems become more commercially available.

6. *Where DH is not viable, economic least-cost decentralized heating should be promoted.* Based on the results of the SHRs, economically least-cost heating alternatives should be promoted, such as eco-design biomass stoves and boilers (where sufficient woody and/or agricultural resources exist) or heat pumps. Such programs should be tailored to the specific market conditions, barriers and opportunities in the country. If biomass is the preferred option, governments must do more to mandate high-efficiency and eco-stoves/eco-boilers, set fuel-quality standards, and certify sustainably harvested biomass products (e.g., wood chips, pellets). For heat pumps, while their carbon footprint is still tied to that of the local grid, existing commitments and investment plans to increase the level of RE will make grids cleaner over time. However, their upfront cost remains the principal barrier, and efforts will be needed to help bring down costs, offer incentives, and provide suitable financing to make them more affordable. All options should be bundled with energy efficiency investments to make them more affordable and designed so that they provide greater support for the poorest and most vulnerable households.
7. *Technical standards should be raised to increase the availability of efficient heating equipment in the market.* In addition to cleaner fuels, more-efficient heating appliances and systems are needed to manage heat demand and help make heating bills more affordable. Therefore, efforts should be made to remove the less-efficient models from the market through regulatory standards. This includes conventional wood stoves and boilers, conventional gas stoves, and electric heaters in favor of eco-design wood stoves/boilers, condensing gas boilers, and heat pumps. Where government financing or incentives are planned, eligibility criteria should tie these funds to the most efficient models. Use of strategies such as bulk procurement or manufacturer partnerships can help promote more-efficient models and bring down consumer prices.
8. *Programs need to be designed to make judicious use of public funds to stimulate markets and change behaviors.* The transition to sustainable heating will require strong government commitment, investment, and action, but the focus should be on overcoming key market barriers and affordability concerns. For most building owners, the combination of energy efficiency and sustainable heating is likely to yield energy cost savings which can be used to recover all or a portion of the investments. This can then allow governments to work with banks and other financial institutions to develop appropriate financial products, possibly blended with subsidies and risk-sharing mechanisms as needed to support these household investments. Where subsidy schemes are needed, they should be well targeted and (except for the very poor) temporary. Well-designed communications and outreach can be used to help instill changes in behavior about investments in energy efficiency, heating technologies, and fuels. These should be based on market and household surveys, tailored to local customs and norms and adjusted for target income levels, gender, and age.

In terms of fuels, some general recommendations are proposed:

(i) ***Coal is increasingly uneconomic, and plans should be put in place to phase out its use for heating.*** The analyses in the report show that coal-based heating is no longer economically least-cost for building-level or individual heating systems due largely to the environmental costs—in terms of both air pollution and GHG emissions. Therefore, efforts need to be made to phase out coal while introducing programs to facilitate adoption of cleaner heating fuels, technologies, and energy efficiency measures. The most efficient policies are outright bans on the sale of coal to households, a ban on the sale of new coal boilers, and a plan to phase out existing coal boilers (with incentives to switch to cleaner options). Where this is not possible, more-gradual plans to phase out coal (by introducing price reforms, a carbon tax on coal, taxes on coal boilers/stoves, etc., with parallel subsidies for cleaner fuels) are recommended. For coal-based DH, including coal-fired, heat-only boilers and CHPs, efforts should be made (as noted earlier) to implement an agreed set of reforms, strengthen DH systems, and identify viable cleaner heating sources—including possible conversion from coal to gas CHPs, but only as a transition fuel and as part of a longer-term decarbonization plan.

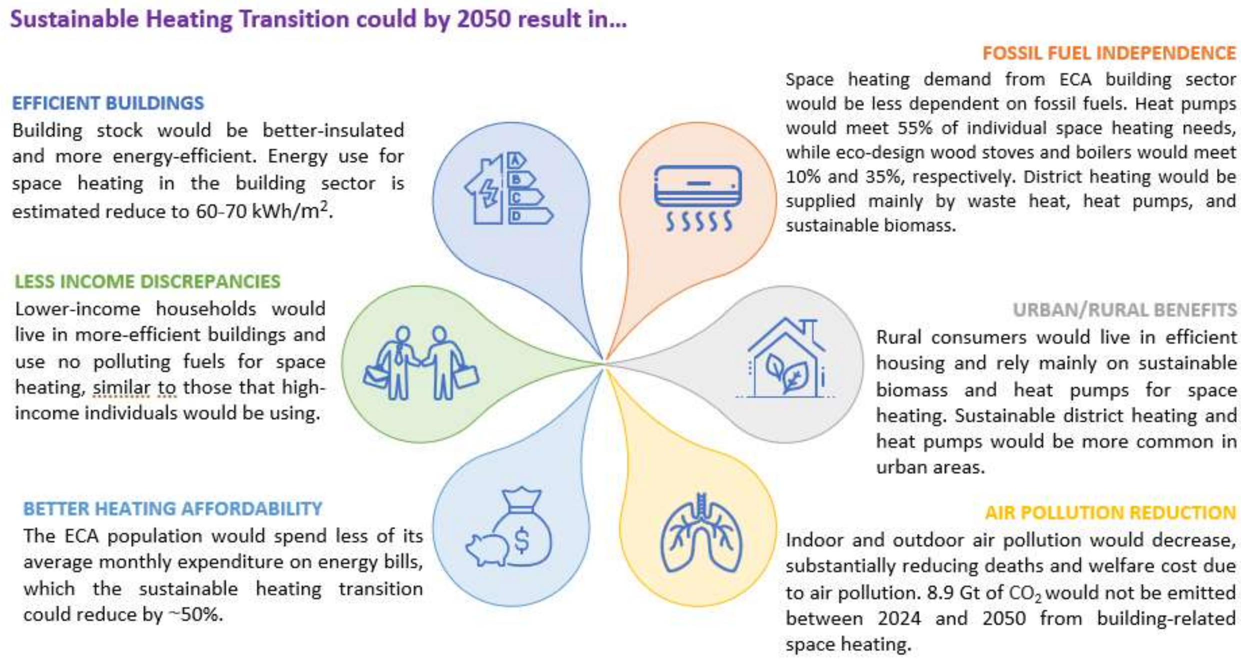
(ii) ***Natural gas will likely continue to have a role in the transition.*** While some clean alternatives may exist in most countries, there are cases where the alternatives are simply too expensive or too difficult to access in sufficiently large quantities (to replace the magnitude of gas-based heating in ECA) or will still take many years to become fully commercial. In countries with ample industrial waste heat, solar resources, geothermal potential, biomass, or sufficient electricity supply (as is the case in Belarus, Bulgaria, and Türkiye), it would likely be difficult to justify new gas installations for DH or individual systems. However, in parts of Central Asia where few of these options exist and there is heavy reliance on coal (e.g., Kyrgyz Republic, Kazakhstan), natural gas may represent a viable transition fuel. While the application of gas will be location-specific and should be used judiciously, some broad guidelines are proposed: (i) gas should be the least-cost economic option (taking into account fuel subsidies, environmental/health, and other impacts); (ii) gas should be used primarily to offset dirtier fuels such as coal; (iii) gas investments will not introduce any new infrastructure or equipment that would lock-in its use for more than a 10-15 year period; and (iv) such investments are consistent with the principles of the Paris Agreement and the country's long-term decarbonization strategy.

(iii) ***The use of hydrogen could also support the heating transition, but there is growing consensus that hydrogen is not the most efficient, economical, or sustainable option.*** Green hydrogen has also been considered as a clean heating fuel, given its potential for a less disruptive transition from traditional, centralized fossil fuel infrastructure. However, many experts believe that the inefficiency and low cost-competitiveness of hydrogen for heating makes it unsuitable—a view that is supported by 32 independent studies, including from the IPCC and IEA. Hydrogen requires significant energy to produce—at least five times more energy than heat pumps today. And hydrogen is associated with major infrastructure investments—from electrolysis plants to compressing stations to distribution networks—which require long-term investment horizons with uncertainties about returns on investment.

While the transition would cost over US$2 trillion, the socioeconomic benefits would be even larger—in terms of energy security, lower energy subsidies, reduced energy poverty, extended building lifetimes, increased property prices, better comfort, lower energy bills, and health and environmental benefits.

These potential benefits are summarized in Figure ES.4. The cost of inaction ore delays would simply maintain the status quo—unsustainable, inefficient, and unaffordable heating, continued energy subsidies, energy insecurity, and environmental degradation which would be devastating for all.

Figure ES.4: Sustainable Heating Transition—Potential Results



Source: Authors.

I. Introduction: What is Sustainable Heating?

Main Messages:

- Sustainable heating solutions are those that are widely affordable, reliable, efficient, low-emission, and consistent with carbon neutrality by mid-century.
- Space heating based on coal, peat, oil and other petroleum products is considered unsustainable. In line with the World Bank Group's Climate Change Action Plan 2021-2025[1], natural gas can have a role in some countries over the medium term as a transition fuel as part of a longer-term decarbonization plan. For biomass to be a sustainable fuel, the management of the underlying biomass resource must be certified and follow a robust regulatory framework.
- Progress towards country transitions to sustainable heating options can be achieved by: (i) reducing energy demand, (ii) decarbonizing district heating, and (iii) promoting clean individual heating.
- Sustainable heating can provide numerous environmental, economic, and social benefits, such as: (i) improving energy security; (ii) lowering fiscal obligations; (iii) decreasing air pollution and greenhouse gas emissions; (iv) reducing energy poverty; (v) stimulating job creation; (vi) enhancing economic activity.

Despite decades of investment, the heating sector in the Europe and Central Asia (ECA) Region remains unsustainable. Heating remains heavily reliant on fossil fuels and highly polluting stoves based on solid fuels (biomass and coal), with often marginal service levels and weak cost recovery ratios. District heating (DH) is often underpriced and lacking consumption-based metering and billing. Individual boilers or stoves rely mostly on underpriced coal and unregulated firewood, which are almost always very inefficient and polluting. Only a small fraction of the building sector has been renovated, leading to massive inefficiencies on the demand side; buildings in ECA[2] often consume 2-3 times more energy per square meter than their counterparts in Western Europe, even though many countries in ECA report substantial underheating and much lower overall per capita energy use. The high energy and carbon intensities have huge socioeconomic implications: high government energy bills and subsidies, high energy insecurity from dependency on imported fossil fuels, high energy bill burdens for the poorest households, and, during the winter months, considerably higher pollution levels—leading to respiratory diseases that impact all citizens, especially the poor.

a. Sustainable heating definition

For this report, sustainable heating solutions are those that are widely affordable, reliable, efficient, low-emission[3], and consistent with plans to reach carbon neutrality by mid-century. The provision of sustainable heating services must be: (i) reliable and adequate given the often-harsh winters throughout the region; (ii) financially sustainable and efficient, both on the supply and demand sides, yet affordable;

[1] https://openknowledge.worldbank.org/bitstream/handle/10986/35799/CCAP-2021-25.pdf.

[2] The World Bank's ECA Region includes several EU Member States (e.g., Bulgaria, Croatia, Poland, Romania), the Western Balkans (Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, Serbia), Türkiye, Eastern Europe (Belarus, Moldova, Ukraine), Russia, the Southern Caucasus (Armenia, Azerbaijan, Georgia) and Central Asia (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan).

[3] Refers to local pollutant emissions, such as particulate matter; PM_{10} = particulate matter (10 µm or less); $PM_{2.5}$ = particulate matter (2.5 µm or less).

and (iii) environmentally sustainable, requiring substantial reductions in air pollution and greenhouse gas (GHG) emissions. Given the complexities in the heating sector, the scope of this report will focus on space heating in buildings, including DH.

In terms of heating resources, space heating based on coal, peat, oil and other petroleum products is considered unsustainable. In line with the World Bank Group's Climate Change Action Plan 2021-2025[4], natural gas can have a role in providing household and business heating solutions in some countries over the medium term as a transition fuel provided it is compatible with a country's goal of long-term decarbonization. For biomass to be a sustainable fuel in line with the definition cited above, the management of the underlying biomass resource must be certified and follow a robust regulatory framework[5].

Space heating can be either centralized or decentralized (i.e., individual or building-level heating). In terms of system configurations, individual heating uses an individual heating appliance (e.g., a small boiler, stove, or electric heater) for a specific room, a single-family home, an apartment building (building-level or apartment-level) or a public/commercial building. Individual building-level boilers rely on an internal piping system and radiator network to distribute hot water throughout the building.

Centralized or district heating, on the other hand, is an infrastructure asset that delivers thermal energy to many dwellings, campuses, or public/commercial buildings from one or more heating (or combined heat and power or CHP) plants. In general, they generate steam and/or hot water and transmit the fluid through underground piping networks to buildings in a given area. Regarding system temperatures, there are (a) low-temperature heating systems, which typically heat the fluids to temperatures of 30-55°C (and are thus more energy-efficient); and (b) high-temperature heating systems, which heat fluids above 70°C (often 70-100°C for DH and individual heating).

In terms of heat sources, progress towards country transitions to sustainable heating options can in principle be achieved through three complementary approaches (Figure I.1). Depending upon local conditions and requirements, each country can deploy these options in different proportions to transition its heating sector:

1. **Reduce demand:** Energy efficiency investments in buildings will help reduce heat-energy demand (and thus the need for costly new heat-supply investments) in two ways: through building codes for new buildings and renovations of existing ones. These can include measures such as building envelope improvements (e.g., wall/roof insulation, windows, doors), improvement in internal heating systems (insulation of pipes, cleaning of radiators, efficient boilers, switch to horizontal or underfloor heating), and improved operations and maintenance (O&M) practices and changes in behavior (e.g., boiler maintenance, cleaning of radiators, reducing thermostats).
2. **Bolster and decarbonize district heating:** Centralized heat supply (typically referred to as "district heating" or DH) should be strengthened and transition to low-carbon or renewable energy (RE) heating solutions, such as large electric heat pumps; heat from solar thermal, geothermal,

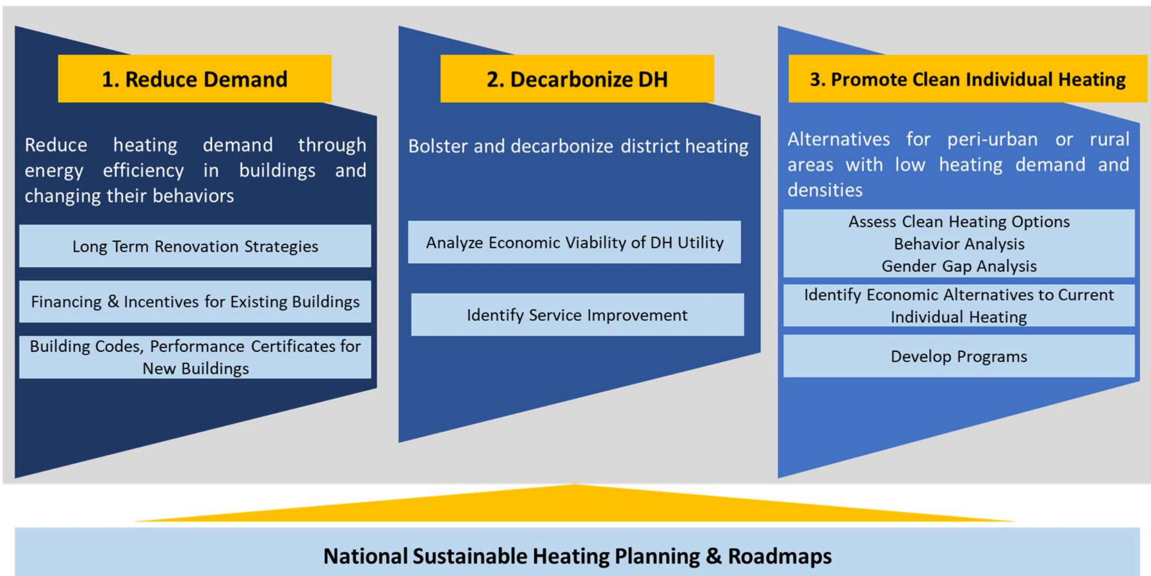
[4] https://openknowledge.worldbank.org/bitstream/handle/10986/35799/CCAP-2021-25.pdf.

[5] On the 14th of September 2022, the European Parliament voted to recognize primary woody biomass as an RE source. It defined primary wood biomass as all roundwood felled, harvested or removed. This includes all wood obtained from removals, such as wood recovered due to natural mortality and from felling/logging. It also includes all wood removed with or without bark. The definition of primary wood biomass does not include woody biomass obtained from sustainable wildfire prevention measures in high-risk fire prone areas, wood biomass obtained from road safety measures, and woody biomass extracted from forests affected by natural disasters, active pests or diseases to prevent their spread, while minimizing wood extraction and protecting biodiversity.

industrial or urban waste heat; or boilers and stoves using biogases from agricultural or municipal waste.

3. **Promote clean individual heating:** In areas where DH is not viable, efficient decentralized-heating use of the least-cost clean options—e.g., heat pumps, sustainable biomass stoves—should be encouraged, along with the development of complementary financing, incentives, information and outreach.

Figure I.1: Proposed framework for sustainable heating



Source: Authors

In contrast to room-level heating equipment (such as electric heaters, stoves, or air-conditioning units that can also switch to heating mode), building-level heating equipment relies on different types of systems to distribute the heat from the source to the various rooms. Figure I.2 presents the main technological options. These distribution systems represent a major share of installation cost and, especially in rural areas and old buildings, are an often-overlooked barrier to switching to high-efficiency heating equipment (e.g., when switching from coal stoves to centralized boilers or DH).

Figure I.2: Types of distribution arrangements for heating systems

	Forced-Air System	Steam Radiant	Radiant Heating	Hot Water Baseboards	Electric Baseboards
Description	A forced-air system distributes heat from a furnace throughout the home using air ducts and vents.	Steam radiant heating uses radiators to distribute heat.	Transfer heat directly from a hot surface to people and objects in the room. Can be installed as floor, ceiling or wall panels.	Use hot water to heat a space via wall-mounted baseboard units. Also called *hydronic heat*.	A type of zone heater that releases heated air out of the top while pulling cooler air to the bottom of the unit.
Pros	Can be used for cooling	Relatively trouble-free	Doesn't distribute allergens	Provide close temperature control	Quiet operation and low maintenance
Cons	Distributes allergens throughout the house	Requires a separate distribution system for cooling	Can be expensive to install and repair if problems arise	Limits furniture placement and slow to increase temperature	Limits furniture placement and easily damaged
Energy-Saving Tip	Clean air filters monthly and replace them regularly	Bleed trapped air from hot water radiator	When installed in a wood-framed floor, consider covering it with ceramic tiles	Install a programmable thermostat to take advantage of zone heating	Clean the heating coils regularly to prolong heater's life
Compatible Heating Source Systems	Furnace, heat pump, active solar heating	Boiler	Boiler, heat pump, active solar heat, electric heating	Boiler, active solar heating	Electric heating

Source: Edited based on US Department of Energy (2013), Energy Saver 101 Infographic: Home Heating, available from: https://www.energy.gov/energysaver/articles/energy-saver-101-infographic-home-heating.

Sustainable heating can provide numerous environmental, economic, and social benefits. Environmentally, the switch from fossil fuels and inefficient, unsustainable use of biomass to cleaner sources can bring major reductions in indoor and outdoor air pollution and GHG emissions. A recent study found that inefficient wood-burning stoves in Skopje, the capital of North Macedonia, are responsible for nearly 90 percent of all primary PM emissions[6], which could be substantially reduced by switching to heat pumps. The development of sustainable heating systems can also help countries to decarbonize their building sectors and reduce their GHG intensities. The International Energy Agency (IEA) estimates that the GHG intensity of residential buildings declined by almost 40 percent (per unit of area, expressed in tonnes of CO_2/m^2) between 2000 and 2021, largely due to energy-efficient building codes, heat pumps and RE heating equipment[7]. Economically, sustainable heating can play an important role in improving countries' energy security and lowering their fiscal obligations. In 2018 Poland launched a major Clean Air Priority Program (CAPP) which seeks to encourage single-family buildings to phase out solid fuels for heating, including coal; the program is projected to reduce coal imports by about 25 percent.[8] Combining sustainable heating with a RE power matrix would allow the ECA region to be independent of international coal/natural gas/oil price fluctuations to meet its energy and heating needs, making the region much more resilient to energy supply shocks. Sustainable heating programs can also lower public expenditures in heating public facilities and help lower energy subsidies.

Socially, sustainable heating can reduce energy poverty, stimulate job creation, and enhance local economic development. Investments in building energy efficiency measures and more efficient heating technologies can reduce energy poverty, while enabling poor households to use the savings for other

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[6] UNDP (2021). *Tackling air pollution in Europe and Central Asia for improved health and greener future.*

[7] IEA (2022). https://www.iea.org/reports/heating

[8] World Bank (2020). https://documents1.worldbank.org/curated/en/773511612341641822/pdf/Poland-Catching-Up-Regions-Towards-Robust-Scalable-and-Inclusive-Clean-Air-Program-for-All.pdf. See also Annex L.

necessary expenses. A previous study by the World Bank estimated that a 10 percent gain in energy efficiency could help lower energy poverty rates by 1-6 percent[9]. Further, the development of sustainable heating markets can spur new industries (e.g., energy auditors and designers, insulation/windows/heating suppliers, installers, etc.), potentially creating thousands of skilled jobs.

Annex A presents global projections and experiences with sustainable heating. The various global heating-decarbonization pathways (from various think tanks, agencies and governments) and scenarios (from academia) described show there are a variety of options for achieving decarbonization of the heating sector, each involving a different combination of heat supply, fuels, and demand reductions. Annex A suggests strategies for transitioning to sustainable heating in advanced economies that combine energy efficiency scale-up with a mix of targets for RE heat sources and regulatory measures to phase out or limit the use of fossil fuels in buildings. The annex also provides examples of countries that have enacted heating fuel bans, such as the oil-fired boilers already banned in countries such as Austria, Norway, and Sweden.

b. Report coverage

This report is designed primarily for policy makers and practitioners in the region who deal with the heating sector. It reviews the status and trends of space heating in ECA, identifies common regional barriers to sustainable heating, assesses heating options (in terms of both cost and technical viability), and proposes a framework, with policies and programs, for planning the transition. Given the broad mix of countries in ECA, alternative pathways are provided for the transition given each country's economic conditions, institutional capacities, dependency on fossil fuels, availability of local resources and other factors.

Where possible, the report includes data and analysis for all 23 ECA countries to illustrate the diversity of contexts and pathways to sustainability. However, since few countries systematically collect and report comparable data on the heating sector, some of the analysis is based on a smaller range of countries from different subregions. Following Chapter II's summary of the status of space heating in ECA, the DH analysis in Chapter III focuses on utilities in four countries: Bulgaria, Kyrgyz Republic, Poland, and Serbia, while the analysis of the levelized cost of heating in Chapter IV focuses on Armenia, Kyrgyz Republic, Poland, Serbia, Türkiye, and Uzbekistan. Chapter V the details the proposed framework for transitioning to sustainable heating; Chapter VI describes government programs designed to accelerate the transition; and in Chapter VII key takeaways are presented, as well as an investment analysis of how much it would cost to implement the transition in the ECA region.

[9] World Bank, 2013. *Balancing Act: Cutting Energy Subsidies While Protecting Affordability*. https://elibrary.worldbank.org/doi/epub/10.1596/978-0-8213-9789-3

II. Current Status of Space Heating in Buildings in Europe and Central Asia

Main Messages:

- Space heating demand from the ECA building sector is heavily reliant on fossil fuels – especially natural gas (23 percent) and coal (10 percent) – and traditional biomass (14 percent). District heating accounts for 43 percent of the demand and is mostly supplied by natural gas (70 percent) and coal (28 percent). It is estimated to be 2,625 TWh for buildings overall, comprising 1,889 TWh for residential buildings and 736 TWh for commercial and public buildings.
- Most of the buildings were constructed over 40 years ago, so the building stock is inefficient; it is also often poorly maintained. Energy use for space heating in the residential sector is estimated at 160 kWh/m^2, which is much higher than EU27 (110 kWh/m^2).
- Rural consumers live in larger and less-efficient housing and rely more on traditional biomass (47 percent) and coal (33 percent) for space heating. District heating (30 percent), electricity (25 percent) and natural gas (17 percent) are the main space-heating sources used by urban consumers.
- Indoor and outdoor air pollution, to which space heating is a major contributor, causes 302,000 deaths and a welfare cost of US$305 billion (7 percent of regional GDP) annually in ECA. The building-related space-heating sector emits 22 percent of total regional CO_2 emissions from fuel combustion.
- Lower-income households are more likely to live in older/leaky buildings and use more-polluting fuels for space heating due to affordability: firewood and charcoal are cheaper and sometimes free.
- Approximately 34 percent of the population in ECA spend 10 percent or more of their average monthly expenditure on energy bills - a threshold for energy poverty.

Because of the ECA region's prolonged and often harsh winters, the supply and further development of heating will play a critical role in the transition. District heating systems typically operate for about six months of the year, from about mid-October to mid-April, and individual heating systems can operate longer. Temperatures can be brutally cold: northern Kazakhstan, northern areas of Russia (Siberia, Sakha), southeast Tajikistan and other areas can experience temperatures of -40° C or below for weeks at a time. Furthermore, the heating sectors (covering both DH and building-level or individual heating systems) have among the highest energy and carbon intensities due to the cold climates and long heating seasons, fossil fuel-dependent systems, chronic under-maintenance, and very old and inefficient building stock. As a result, space heating in ECA today is responsible for about 24 percent of the total energy consumed in the region.

a. Current demand for heating in ECA

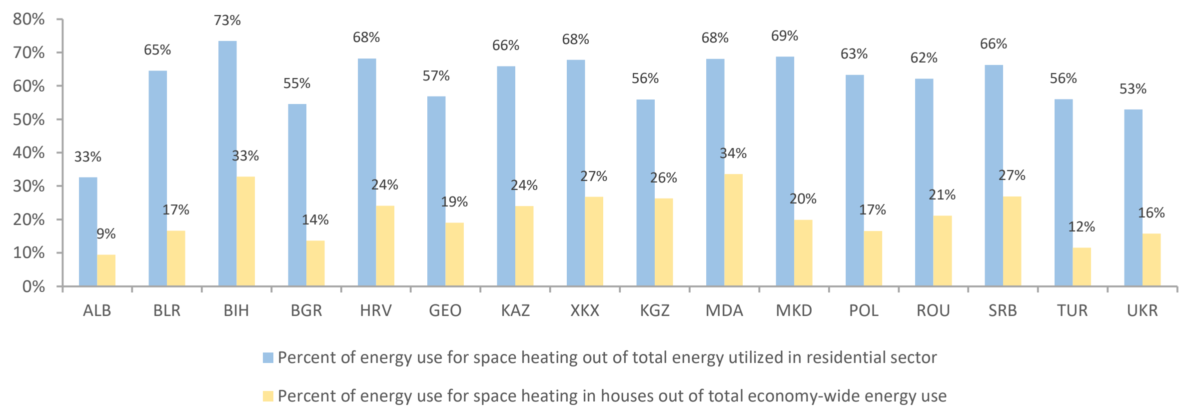
Based on available data, the current annual space heating demand of the buildings sector in the ECA region[10] is estimated to be 2,625 TWh, or around 24 percent of total energy demand. Of this, 1,889 TWh (17 percent of

[10] Space heating demand data were available for Albania (ALB), Belarus (BLR), Bosnia and Herzegovina (BIH), Bulgaria (BGR), Croatia (HRV), Georgia (GEO), Kazakhstan (KAZ), Kosovo (XKX), Kyrgyzstan (KGZ), Moldova (MDA), North Macedonia (MKD), Poland (POL), Romania (ROU), Serbia (SRB), Türkiye (TUR) and Ukraine (UKR). Data were not available for Armenia (ARM), Azerbaijan (AZE), Montenegro (MNE), Russian Federation (RUS), Tajikistan (TJK), Turkmenistan (TKM) and Uzbekistan (UZB). The report estimates space heating consumption using data on residential consumption from IEA (2019) World Energy Statistics and Balances. https://www.iea.org/data-and-statistics/data-product/world-energy-statistics-and-balances .

regional energy demand) is consumed in the residential sector and 736 TWh (7 percent of regional energy demand) in commercial and public buildings[11]. In addition, traditional heating systems were built based on a high-temperature operation (e.g., supply temperature above 80°C) to meet the high heat demand of low-efficiency buildings with poor thermal insulation and envelope. In Central Asia, 60-80 percent of the building stock is built from mud and clay, and constructed without the guidance of proper building codes to prompt energy efficiency improvements. Most of the semi-urban and rural areas are not connected to a DH network, and rural households generally use coal and biomass (wood, cow dung) in traditional heating stoves with a typical thermal efficiency below 40 percent[12]. Overall, despite its cold climate, these factors make ECA the most inefficient region in the world in terms of space heating.

In terms of heated floor area, the average specific energy consumption (SEC) for space heating in the region is estimated to be about 180 kWh/m^2. In the residential sector, approximately 63 percent of the energy used is for space heating. As shown in Figure II.1, space heating is responsible for more than half of total residential energy use in all countries for which data are available (except in Albania, where it is about one-third). The specific energy consumption in the residential sector is estimated to be 160 kWh/m^2, which is much higher than in the EU27[13] (110 kWh/m^2), Canada (114 kWh/m^2), United States (70 kWh/m^2) and Japan (33 kWh/m^2)[14]. Moreover, these figures do not account for different climate conditions and are likely to be low given the prevalence of underheating (see Chapter II Section f).

Figure II.1: Percent of energy used for space heating in the residential sector



Source*: IEA***,** *World Energy Balance, 2019; IEA, Energy Efficiency Indicators, 2019*

The high energy use is in part due to the climate, as ECA is the coldest region in the world. This is based on the heating degree days (HDD), a way to estimate the heating demand for a country, quantify the energy needed to heat a building, and measure the severity and duration of cold weather. The HDD is the sum over the year of the differences between the average temperature of each day and a reference base temperature, which in this case is 16° C. For instance, the average HDD for the ECA-23 region over the past 22 years, from 2000 to 2021, weighted by the population, was 3,001 degree-days. Compared to 2,106 degree-days in the EU-28 and 1,946 degree-days in North America, the ECA region is over 42 percent higher. Figure II.2 compares the ECA region with other

[11] No regional space heating consumption data was found in commercial and public buildings. IEA Energy Consumption Data was used as an estimate. It was assumed 80% for natural gas, coal, oil and biomass, 100% DH, 30% electricity and 10% other RE of the energy consumed in the commercial and public building sector goes towards space heating.

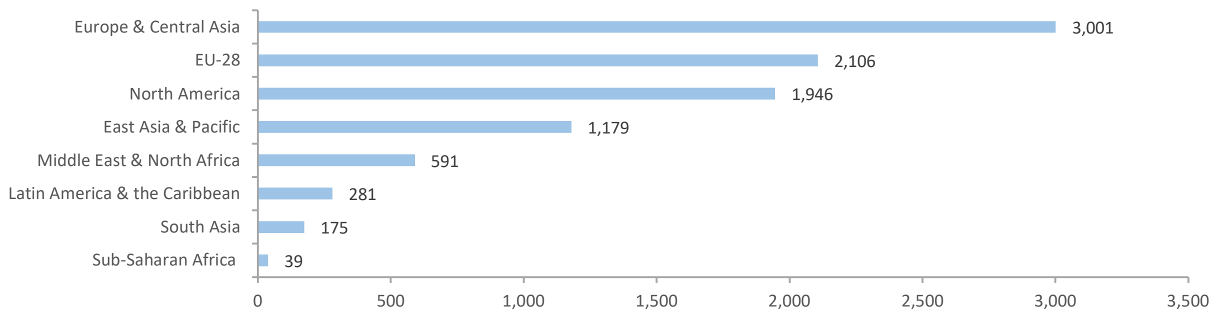
[12] Mehta K, Ehrenwirth M, Trinkl C, Zörner W, Greenough R. The energy situation in central Asia: A comprehensive energy review focusing on rural areas. Energies (Basel) 2021; 14:1–27. https://doi.org/10.3390/en14102805

[13] Odyssee (2019). https://www.odyssee-mure.eu/publications/efficiency-by-sector/households/heating-consumption-per-m2.html

[14] IEA – Energy Efficiency Indicators https://www.iea.org/data-and-statistics/data-product/energy-efficiency-indicators

regions. Many studies project that space heating needs are expected to decline due to the effects of climate change in the long term, though this will be offset to some extent by increased cooling demand.[15]

Figure II.2: Average Heating Degree Days from 2000 to 2021 weighted by population



Source: IEA and CMCC, *Weather for Energy Tracker*, Available at: https://www.iea.org/data-and-statistics/data-tools/weather-for-energy-tracker. Accessed on March 1, 2023.

b. Building stock

The total ECA building stock is estimated to be about 106 million buildings, comprising 15 billion m^2 of floor space, of which 12 billion m^2 are residential buildings (divided into 156 million dwellings[16]) and 3 billion m^2 are commercial and public buildings[17]. The detailed available building-stock data are presented in Annex B. The residential building stock includes single-family homes (SFHs) and multifamily apartment buildings (MFBs). MFBs can consist of very large building complexes with 1,000 or more dwellings (down to small duplexes) and are mainly concentrated in urban and peri-urban areas; SFHs are more prevalent in rural areas and some peri-urban or suburban districts.

The ECA region has an extremely diverse housing stock. For the 22 countries for which data are available[18], it was found that people reside primarily in MFBs in seven countries: Armenia (53 percent), Belarus (69 percent), Bulgaria (53 percent), Kazakhstan (60 percent), Russian Federation (71 percent), Türkiye (75 percent), and Ukraine (51 percent). However, in the remaining 15 countries, more than half of the dwellings are SFHs. In terms of urban-rural division of dwellings, 16 countries have a majority of their residential sector in urban areas. Only six countries—Bosnia and Herzegovina (51 percent), Kosovo (50 percent), Kyrgyzstan (59 percent), Moldova (57 percent), Tajikistan (72 percent), and Uzbekistan (65 percent)—have half or more of their dwellings located in rural areas (Figure II.3).

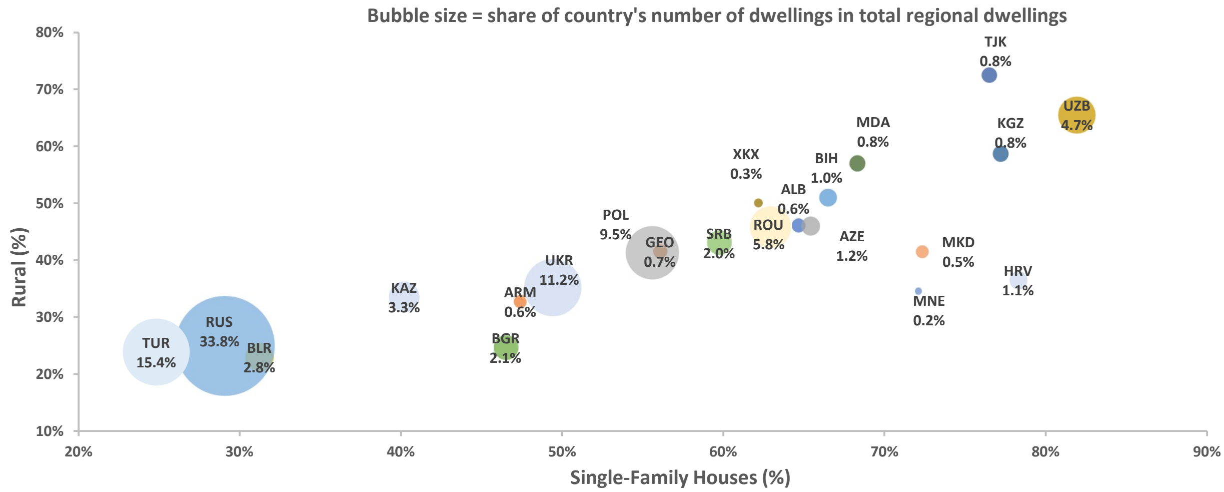
[15] IEA (2022). *The Future of Heat Pumps*. Available from: https://www.iea.org/reports/the-future-of-heat-pumps

[16] For the purposes of this report, a *dwelling* is a place where people live, such as a house or apartment. It is a self-contained unit of accommodation used by one or more households as a home.

[17] In terms of commercial and public buildings, the available data are scarce, and not all countries have commercial and public building data. This estimate is based on available data from 16 countries.

[18] No housing stock data were found for Turkmenistan.

Figure II.3: Housing Stock Characteristics



Source: World Bank Compilation of Country-Specific Housing Characteristics

Data were also analyzed to assess regional demographic shifts affecting the amount and types of housing. In terms of population, while the overall population in ECA grew by 8 percent from 1990 to 2020, subregional differences were substantial (Table II.1). Türkiye and Central Asia saw huge population booms during this period (increases of 50 percent or more), while the EU member states, Western Balkans and Eastern Europe showed population declines of 8.9, 10.5, and 13.7 percent, respectively. In terms of ECA urban and rural populations, there was a net increase of only 4 percent. However, some subregions have seen a stronger trend—both the Western Balkans and Türkiye saw a decline in rural citizens by 10 percent and 17 percent, respectively. In Central Asia, the only predominantly rural subregion, countries are either urbanizing slowly (Kyrgyzstan, Tajikistan) or in some cases even experiencing a slight decline in urbanization (Kazakhstan, Uzbekistan)[19]. Taken as a whole, the Central Asian urban population has marginally increased from 45 to 48 percent.

Table II.1: Europe and Central Asia Population, by Year and Location (1990-2020)

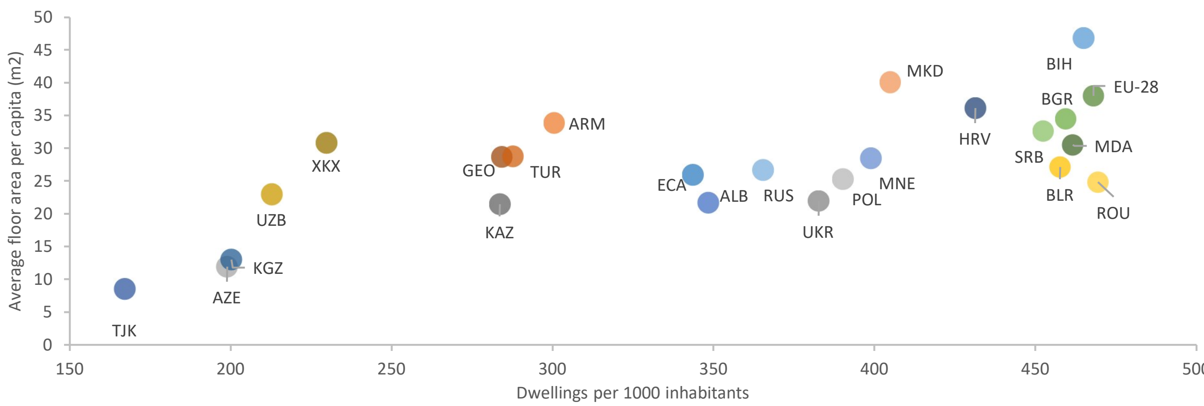
	1990				2020			
	Urban		Rural		Urban		Rural	
	Population	%	Population	%	Population	%	Population	%
EU Members	43,922,961	59%	30,885,313	41%	40,773,989	60%	27,372,026	40%
Western Balkans	8,771,579	45%	10,830,377	55%	9,600,382	55%	7,952,542	45%
Eastern Europe	42,751,127	66%	22,295,599	34%	39,304,031	70%	16,843,100	30%
Southern Caucasus	8,897,377	57%	6,636,362	43%	9,681,798	58%	6,939,647	42%
Central Asia	22,733,293	45%	27,654,045	55%	36,407,533	48%	38,953,728	52%
Russian Federation	108,600,667	73%	39,368,740	27%	107,700,434	75%	36,372,705	25%
Türkiye	32,161,522	59%	22,162,620	41%	64,031,267	76%	20,104,161	24%
ECA	267,838,526	63%	159,833,056	37%	307,499,434	67%	154,537,909	33%

Source: World Bank (2022). *World Population Prospects*. Available at: https://data.worldbank.org/indicator/SP.POP.TOTL

[19] Wahba Tadros, Sameh Naguib, et al., *Demographic Trends and Urbanization*. Washington, D.C.: World Bank Group. Available at: http://documents.worldbank.org/curated/en/260581617988607640/Demographic-Trends-and-Urbanization

There are also variations in the number and size of dwellings per capita. The number of dwellings per 1,000 inhabitants and the average floor space per capita (m^2/person) are presented in Figure II.4. It shows that the countries with the smallest housing stock per capita, Tajikistan and Azerbaijan, have less than half the number of dwellings per 1,000 inhabitants compared with Romania (167 and 198 vs. 469 dwellings). This contrast is even starker when analyzing floor space per capita. On average, residents in Bosnia and Herzegovina have almost four times more floor space than Kyrgyzstan (47 vs. 13), further illustrating the heterogeneity in the housing stock. One of the reasons for this discrepancy is the likely frequent migration in the region. For example, countries such as Romania and Bulgaria have seen steady emigration since joining the EU, reducing their populations by 16.9 and 20.4 percent, respectively, since 1990; both are projected to experience further population declines (by 10.4 and 25.1 percent, respectively) by 2050. By contrast, other countries, such as Türkiye and Uzbekistan, have seen more frequent immigration due to conflicts in neighboring countries, increasing their populations by 55 and 67 percent, respectively, since 1990[20].

Figure II.4: Dwellings per 1,000 Inhabitants and Average floor Area per Capita



Source: World Bank Compilation of Country-Specific Housing Characteristics. Data sources detailed in Annex B.

The region's building stock is also aging, very inefficient and has been poorly maintained. Most of the buildings were constructed over 40 years ago, when energy-efficient building standards were either not enacted or enforced. A summary of housing construction pre- and post-1980 is presented in Figure II.5, showing countries where data were available. As shown, in most countries, half or more of the residential buildings were built before 1980 (except for Albania, Bosnia and Herzegovina, Kosovo, Kyrgyzstan, and Montenegro). In addition, there have been chronic under-maintenance and low levels of capital investments for repairs which, combined with low renovation rates, contribute to a very poor-quality stock. ECA also has substantial moderate or high seismic risk zones. A World Bank study[21] that assessed earthquake risk for seven building types[22] in 27 cities within ECA estimated that roughly half of the cities' populations reside in MFBs constructed before 2000 (when privatized developments introduced varying building typologies with different seismic durability); and of these, about 23 percent resided in one of two building types with high seismic risk, which may be different in each city. With this group, Bucharest has the highest number of people residing in the top two building types—unreinforced masonry (URM) buildings and reinforced concrete frame (RCF) buildings—with 1.1 million people (61 percent of the city's population), followed by Belgrade (550,000 people or 33 percent of the city population

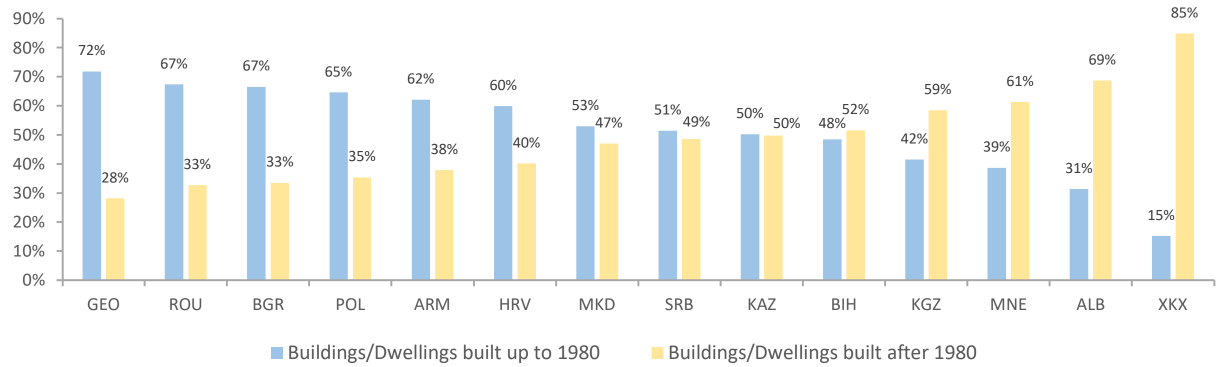
[20] https://data.worldbank.org/indicator/SP.POP.TOTL and https://databank.worldbank.org/source/population-estimates-and-projections#

[21] World Bank Group, Earthquake Risk in Multifamily Residential Buildings Europe Central Asia Region, https://documents1.worldbank.org/curated/en/401931598952181261/pdf/Earthquake-Risk-in-Multifamily-Residential-Buildings-Europe-and-Central-Asia-Region.pdf

[22] Unreinforced masonry buildings, reinforced concrete frame buildings, dual frame-wall system buildings, precast large panel buildings, block buildings, slab-column system buildings, reinforced concrete wall system buildings.

living in URM and RCF), and Tashkent (550,000 people or 22 percent of the city's population living in URM and slab-column system buildings).

Figure II.5: Age of Housing Stock in ECA



Source: World Bank compilation of country-specific age of housing stock.

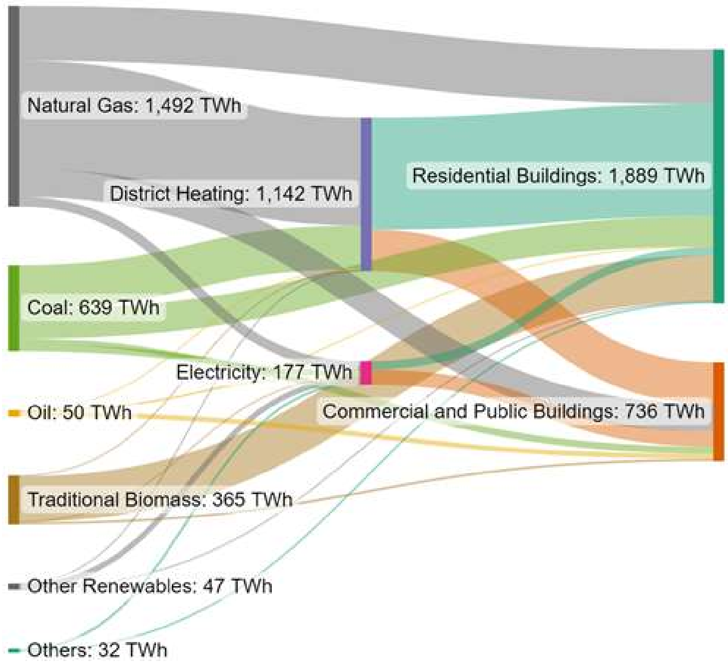
In conclusion, while there are commonalities among countries within the ECA region, there are also important differences in the characteristics of individual country building stocks—in terms of floor area, SFH/MFB split, rural/urban split, demographic trends, and construction period. There is of course a range of other building stock characteristics that were not analyzed due to their limited impact on heating—structural aspects, seismic and fire safety, functionality, vacancy rates, ownership vs. rentals, land tenure, etc.—but would also have to be considered as part of a broader housing strategy.

c. Sources of heating

Space heating in ECA is still heavily reliant on fossil fuels—especially natural gas and coal—and traditional biomass (predominantly firewood). Figure II.6 illustrates the estimated disaggregated space heating supply by fuel in the building sector[23]. It shows that approximately 83 percent of space heating is delivered from fossil fuels. With DH and electricity disaggregated, the regional space heating demand is supplied by natural gas (1492 TWh - 57 percent), coal (639 TWh - 24 percent), traditional biomass (365 TWh - 14 percent), oil (50 TWh - 2 percent), other renewables (47 TWh - 2 percent), and other fuels (32 TWh - 1 percent). Therefore, almost all the demand (approximately 95 percent) is supplied by natural gas, coal, and traditional biomass.

[23] Commercial and public building space heating demand was estimated from the total energy consumption in these buildings. The residential buildings' space heating was calculated from various country-specific sources. The data are largely based on two sources: (i) data from surveys on the share of dwellings relying on different heating fuels (survey data); and (ii) data from energy balances providing the percentage of energy space heating coming from different fuels/sources (energy data).

Figure II.6: Estimated Building Sector Space Heating Supply in ECA, by Fuel (Sankey Diagram)



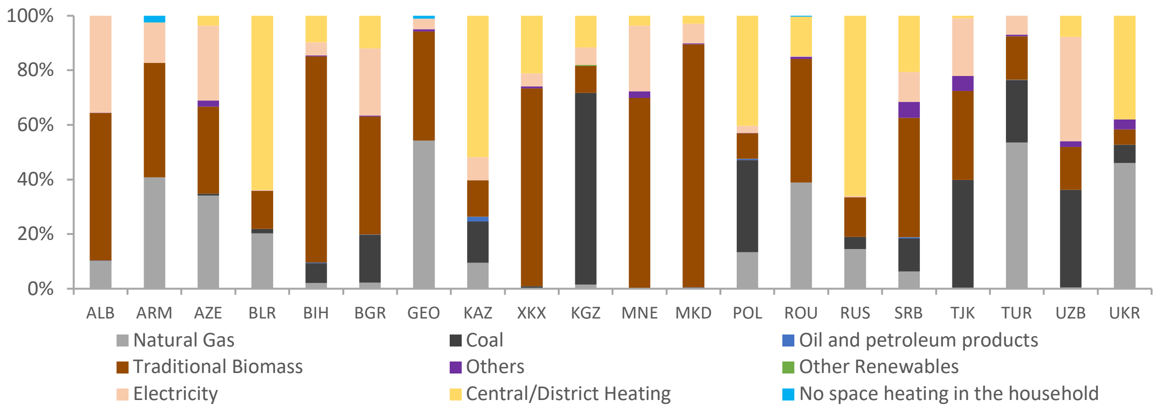
Source: World Bank estimates based on best available data.

Note: "Other Renewables" = waste, hydro, geothermal, solar PV, solar thermal, wind, and tidal. "Others" = nuclear and other sources. "Oil" = oil and petroleum products.

However, the fuel mix for heating differs widely between countries. Figure II.7 shows the main fuels used for residential space heating in each country. The graph was compiled from various household survey data (see Annex C for the main sources utilized here and elsewhere in Chapter II). As presented, natural gas, coal, and traditional biomass remain the main residential heating fuels. In some countries, such as Türkiye and Georgia, over half (54 percent) of households rely on natural gas to heat their homes. For others, such as Kyrgyzstan, Tajikistan, and Poland, coal is the main heating fuel (70 percent, 40 percent and 34 percent, respectively).

However, due to limitations of heating infrastructure (DH and gas networks) and affordability, traditional biomass continues to be a prominent fuel in households across the region. Most of the Western Balkan countries' households depend on traditional biomass for space heating (e.g., Bosnia and Herzegovina at 76 percent, Kosovo at 72 percent, and Montenegro at 70 percent). Central/DH is more common in Russia and Belarus, where such systems serve over 60 percent of their populations; these systems rely mainly on natural gas.

Figure II.7: Distribution of Dwellings, by Type of Fuel Used for Space Heating

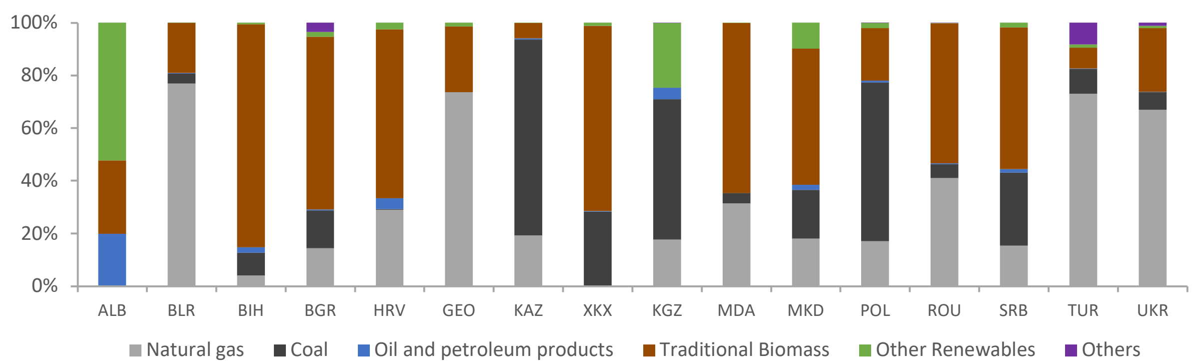


Source: World Bank compilation of country-specific sources (survey data)

Note: Central heating is inclusive of DH and private/building central heating in Belarus, Kazakhstan, Kosovo, Poland, and Ukraine. Only DH in Azerbaijan, Bosnia and Herzegovina, Bulgaria, Kyrgyzstan, North Macedonia, Romania, Russian Federation, Serbia, Tajikistan, and Uzbekistan. Only private/building central heating in Montenegro. For Albania, "Solid fuels" is presented as Traditional Biomass; for Romania, "Wood/Coal/Oil" stove as Traditional Biomass; for Georgia "Central Heating" as Natural Gas and "Charcoal", "Wood", "Animal dung" and "Pellets" as Traditional Biomass; "Coal/Lignite" as Coal; "Solar air heater" as Other Renewables

This dependence on unsustainable fuels is also visible when analyzing energy balance data and disaggregating fuels used for the electricity and DH sectors (Figure II.8). For instance, Ukraine meets 67 percent of its home space heating energy needs from natural gas (as of data before Russia's invasion of Ukraine), and Poland relies on coal for 60 percent of its residential heating. In addition, eight countries out of 16 have more than 50 percent of their heating energy coming from traditional biomass, including Bosnia and Herzegovina and Kosovo (noted above), Bulgaria (66 percent), Croatia (64 percent), Moldova (65 percent), North Macedonia (52 percent), Romania (53 percent), and Serbia (54 percent).

Figure II.8: Share of Energy Sources in Total Energy Used by ECA Households for Space Heating (with Fuels Used for Electricity and District Heating Disaggregated)

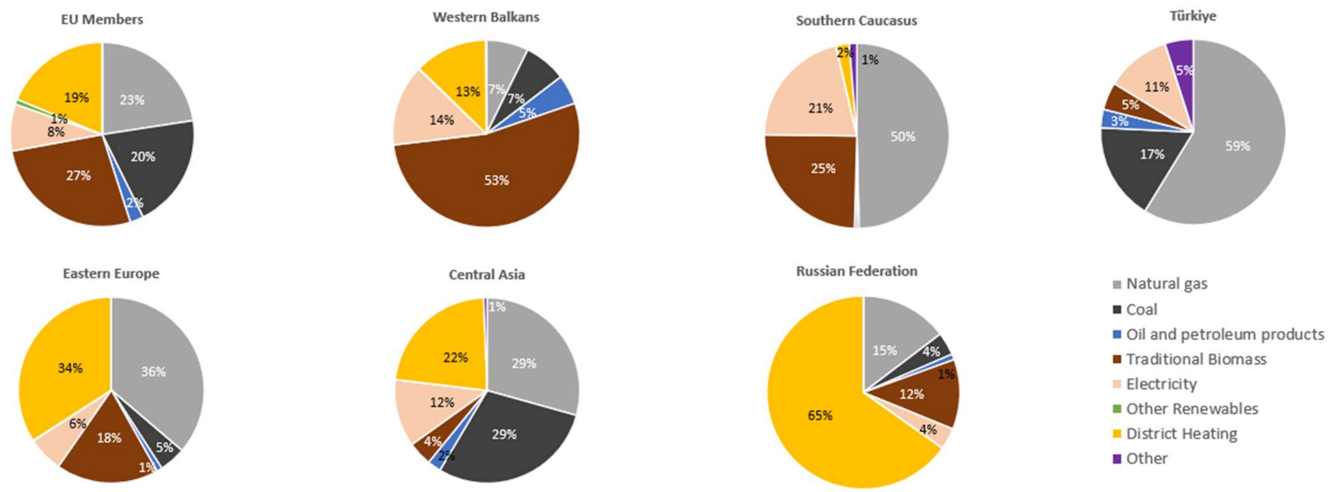


Source: World Bank compilation of country-specific sources (energy data)

Note: Figure shows the fuels consumed to produce electricity and district heating in each country. Solid fossil fuels, peat, peat products, oil shale and oil sands" are considered as Coal; "Primary solid biofuels" and "biofuels and waste" are considered as Traditional Biomass; "Other source" is considered as Others.

When analyzing at the sub-regional[24] level (Figure II.9)—without disaggregation, and incorporating estimates from commercial/public buildings and residential buildings where data was not available[25]—the same trends are evident, such as the high dependence on traditional biomass in the Western Balkans and the high share of natural gas in the Southern Caucasus, Türkiye, and Russia. Coal remains an important heating fuel in parts of Central Asia and some EU member states.

Figure II.9: Estimated Distribution of Heating Fuels Used for Space Heating in the Building Sector, by Sub-Region



Source: World Bank estimation based on a compilation of country-specific sources.

Due to the large populations and high heat-demand densities in cities, natural gas, electricity, and DH are much more common in urban areas; by contrast, rural consumers rely much more on traditional biomass and coal using individual heating systems. Out of 20 surveys analyzed, 14[26] show the split between urban and rural space-heating consumption. In all countries, there is a substantial share decrease in DH and natural gas in rural areas, which is expected given the low housing densities that make such networks less economically viable. 74 percent of urban residents use DH, electricity, or natural gas (32, 25, and 17 percent, respectively) as their main source of heating. In terms of the rural population, 80 percent heat their homes with traditional biomass and coal (46 and 34 percent, respectively).

Some countries have even sharper differences. In Kazakhstan, for example, 75 percent of urban dwellings use DH as their main source of heating, while in rural areas only 3 percent are connected to DH systems. Coal (35 percent) and traditional biomass (31 percent) are the main fuels in rural areas. Similarly, in Romania, natural gas is the main source of heating in urban areas (59 percent), but traditional biomass is the dominant fuel for 80 percent of rural households. Figure II.10 presents data from all countries whose urban and rural data were available.

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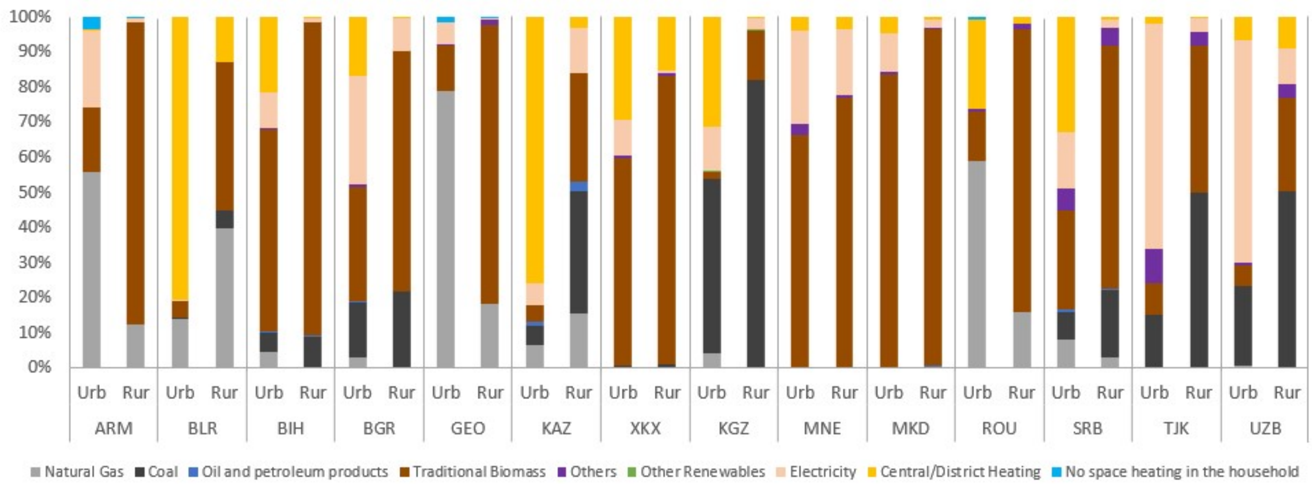
[24] EU Members: Bulgaria, Croatia, Poland and Romania / Western Balkans: Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia and Serbia / Southern Caucasus: Armenia, Azerbaijan and Georgia / Central Asia: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan

[25] Space heating demand from commercial and public buildings was estimated from energy consumption in these buildings. For residential buildings, data was estimated for Armenia, Azerbaijan, Montenegro, Russian Federation, Tajikistan, Turkmenistan and Uzbekistan.

[26] Armenia, Belarus, Bosnia and Herzegovina, Bulgaria, Georgia, Kazakhstan, Kosovo, Kyrgyzstan, Montenegro, North Macedonia, Romania, Serbia, Tajikistan, and Uzbekistan.

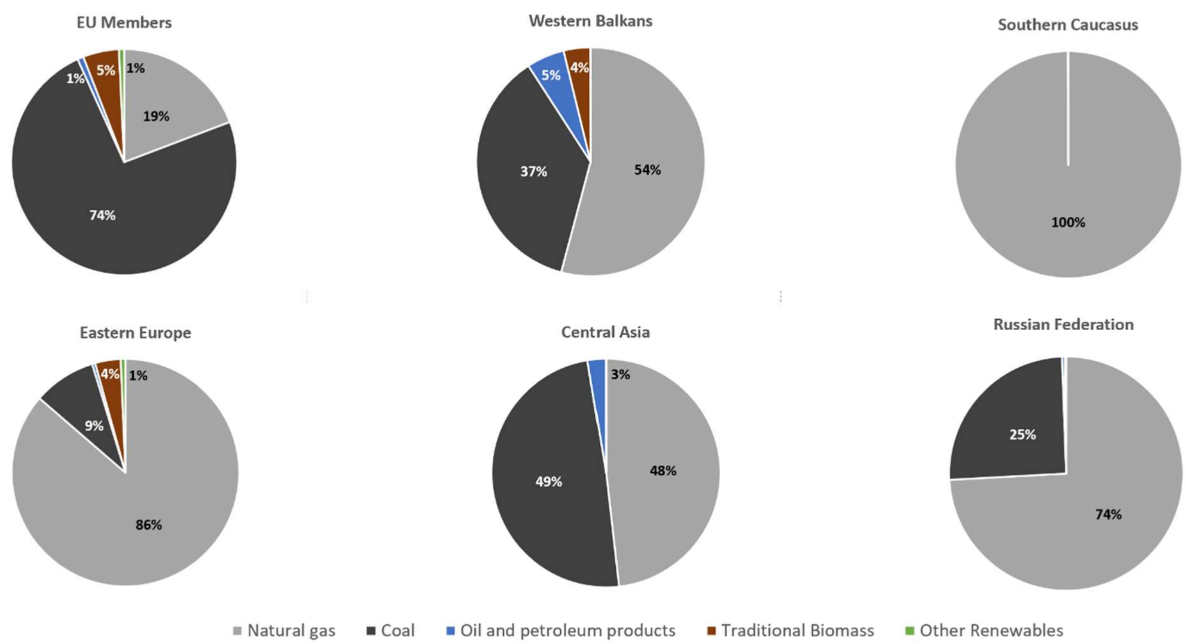
Figure II.10: Distribution of Dwellings, by Type of Fuel Used for Space Heating, with Urban/Rural Split (%)



Source: World Bank compilation of country-specific sources.

District heating networks serve approximately 30 percent of the regional population, but the DH share differs widely among countries, from zero to about 70 percent. Figure II.11 shows that these systems mainly use fossil fuels such as coal and natural gas. Even though some countries have converted from coal to natural gas over the past 20 years (e.g., Bulgaria, Russia, Ukraine), a few (Kyrgyzstan, Kazakhstan, Kosovo, Poland and Tajikistan) still rely heavy on coal for their DH heat supply. Several are also now almost exclusively reliant on natural gas (Azerbaijan, Belarus, Moldova, North Macedonia, Turkmenistan). Albania, Armenia, Georgia, Montenegro, and Türkiye are not presented as they do not (or no longer) have any major DH systems. Some countries (such as Belarus, Bulgaria, and Ukraine) have switched some gas heating boilers/CHP units to biomass, but this has been on a relatively small scale to date. (See Chapter III for an in-depth discussion of DH.)

Figure II.11: Fuels Consumed for District Heating, by ECA Sub-Region (%)

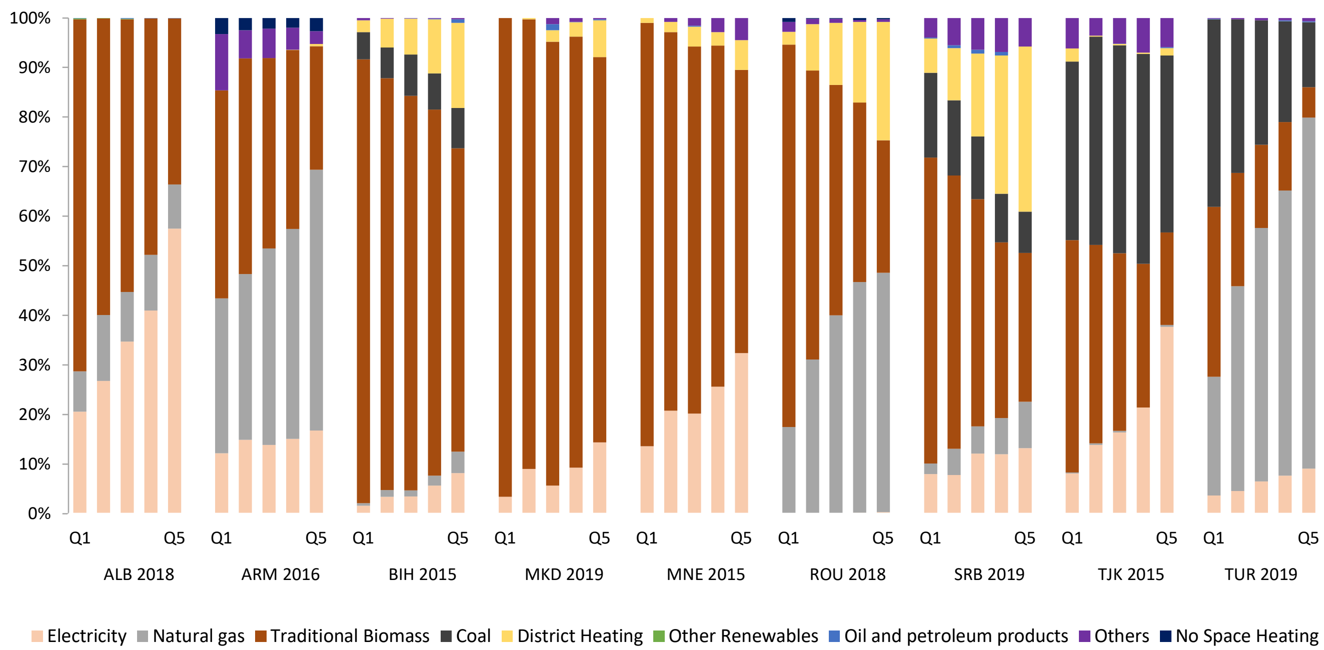


Source: World Bank compilation of country-specific sources.

Note: "Municipal waste (renew)" and "Biogases" are considered as Other Renewables. "Lignite", "Bituminous Coal", "Coal and coal product" are considered as Coal.

In terms of income levels, DH, electricity, and natural gas tend to be more prevalent among higher-income households, whereas biomass and coal are more common among lower-income households. This trend can be seen in most of the countries with available data (Figure II.12). For instance, in Albania, households in the lowest income quintile rely heavily on traditional biomass (71 percent), while for the richest quintile, electricity is the major heating source (58 percent). In Tajikistan, when moving from low-income to high-income individuals, electric-based heating shifts from 8 percent to 38 percent. In Türkiye, natural gas increases substantially from 24 percent for the lower income to 71 percent for the wealthier households, while traditional biomass usage declines from 34 to 6 percent.

Figure II.12: Income Distribution of Fuel Mix for Heating, by Quintile



Source: World Bank compilation of country-specific surveys.

d. Impacts of current service delivery: air quality and GHG emissions

The heavy reliance on fossil fuels and traditional biomass for space heating has led to a significant level of emissions[27]. In ECA, air pollution is a serious threat that causes 302,000 deaths[28] and a welfare cost of US$305 billion (7 percent of GDP) annually[29]. The main cause of fine particulate matter (PM) emissions is individual space heating, which accounts for almost 50 percent of all fine PM emissions in the region[30]. The impacts are even worse in urban and peri-urban areas. In Skopje, for example, the burning of solid fuels for residential space heating is responsible for nearly 90 percent of all $PM_{2.5}$ and PM_{10} emissions[31], while in Poland, it is over 80 percent in many of the more polluted cities. During the winter, Belgrade has been frequently elected the most

[27] $PM_{2.5}$ is the air pollutant that poses the greatest risk to health globally, affecting more people than any other pollutant. Chronic exposure to $PM_{2.5}$ considerably increases the risk of respiratory and cardiovascular diseases in particular.

[28] OECD (2019), *Air pollution exposure*. https://data.oecd.org/air/air-pollution-effects.htm#indicator-chart

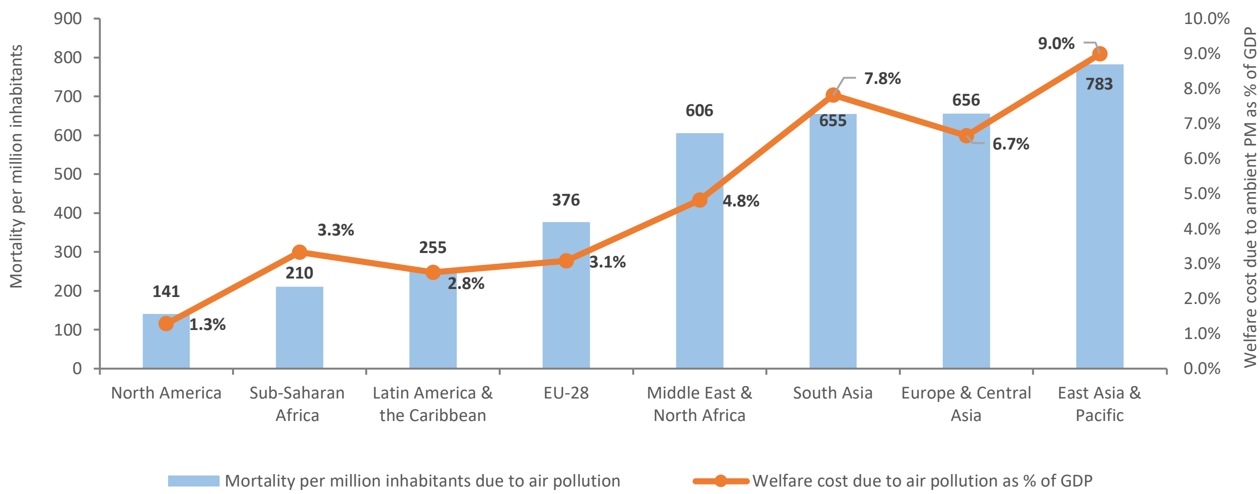
[29] OECD (2019), *Mortality and Welfare Cost from exposure to air pollution.* https://www.oecd-ilibrary.org/environment/data/air-quality-and-health/mortality-and-welfare-cost-from-exposure-to-air-pollution_c14fb169-en.

[30] UNEP (2021). *European and Central Asian Actions on Air Quality*. Available at: https://europa.eu/capacity4dev/file/113149/download?token=a_HHoRFb.

[31] UNDP (2021). *Tackling air pollution in Europe and Central Asia for improved health and greener future*.

polluted city in the world[32]. This occurs because the emissions factor of heating fuels is generally high, and the efficiency of the appliances is low. For instance, a typical residential firewood boiler releases 470 g/GJ of $PM_{2.5}$[33], compared with a coal boiler which emits 303 g/GJ[34]; similarly, while a firewood stove produces 740g/GJ of $PM_{2.5}$, a wood eco-stove emits 150g/GJ[35]. NO_x, a poisonous gas, is also a cause for concern; it can cause respiratory problems and lead to smog and acid rain. NO_x emissions are also a product of fuel combustion—a coal boiler can emit up to 160 g/GJ, a firewood boiler 90 g/GJ and a natural gas boiler 73g/GJ[36]. As heat pumps operate from electricity from the grid, there are no direct emissions of such pollutants[37]. Apart from directly burning fuels, space heating also contributes to air pollution indirectly via deforestation from unmanaged use of biomass fuel in some ECA countries. In Western Balkans, for example, where biomass meets approximately 55 percent of its space heating demand, over 58 percent consumed in the region comes from unregistered sources[38]. Figure II.13 compares the ECA region with other regions in terms of mortality due to air pollution (per million inhabitants) and the welfare cost due to ambient particulate matter (as a percent of GDP).

Figure II.13: Mortality and Welfare Cost due to Air Pollution (% of GDP)

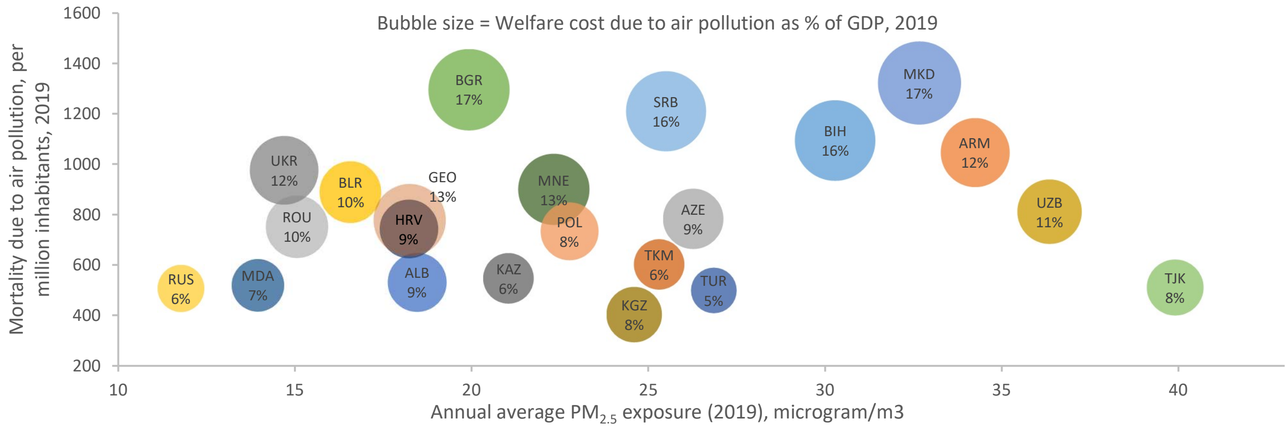


Source: OECD (2019), *Air pollution effects (indicator).* Available at: https://data.oecd.org/air/air-pollution-effects.htm; OECD (2019), *Welfare cost due to ambient particulate matter as % GDP*. Available at: https://stats.oecd.org/Index.aspx?DataSetCode=EXP_MORSC.
Note: In addition to space heating, power generation, DH, industry processes, and transport also contribute to mortality and welfare lost.

To analyze in more detail how air pollution negatively impacts countries within the ECA region, Figure II.14 presents the annual average $PM_{2.5}$ exposure, the mortality due to air pollution, and the welfare costs of air pollution for each country. In general, countries with low $PM_{2.5}$ exposure and mortality (such as Albania, Moldova, and the Russian Federation) tend to have a smaller welfare cost due to air pollution. By contrast, countries with high figures in these two variables (such as Bosnia and Herzegovina, Bulgaria, North Macedonia, and Serbia) tend to have significant welfare costs.

[32] https://n1info.rs/english/news/a582617-air-visual-belgrade-most-polluted-world-city.
[33] Stanytsina, V., et al. (2022). "Fossil Fuel and Biofuel Boilers in Ukraine: Trends of Changes in Levelized Cost of Heat". *Energies* 2022, 15, 7215. .
[34] Mitchell, E.J.S., et al. (2019). *A review of the impact of domestic combustion on UK air quality. Independent report commissioned for HETAS.* Leeds, UK.
[35] European Environmental Bureau (2021). *Where there's fire, there's smoke: Emissions from domestic heating with wood.*
[36] Department of Environmental, Food and Rural Affairs (2022). *Emission Factors for Small Combustion Appliances*. https://laqm.defra.gov.uk/air-quality/air-quality-assessment/combustion-emission-factors.
[37] No explicit indoor air pollution data was found. However, indoor air pollution problem related to use of coal and biomass for space heating and cooking, especially in rural areas, is an important issue that is hard to measure. In terms of space heating, because some heating systems have chimneys, indoor air pollution tends to be less problematic than for cooking.
[38] https://www.energy-community.org/dam/jcr:730c81e6-f570-496d-aa22-1e354eafb67e/best_burn_ENG.pdf.

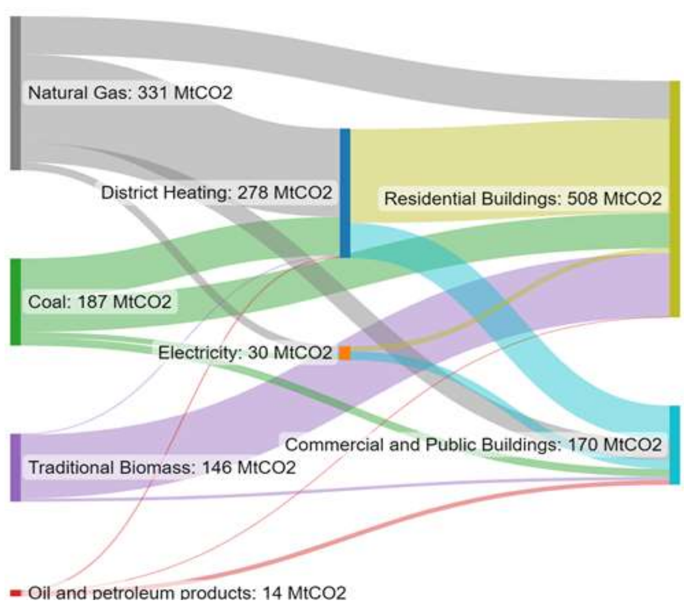
Figure II.14: Annual average $PM_{2.5}$ Exposure, Mortality due to Air Pollution, and Welfare Cost due to Air Pollution



Source: OECD (2019), *Air pollution exposure*. Available at: https://data.oecd.org/air/air-pollution-exposure.htm#indicator-chart; OECD (2019*), Mortality due to air pollution: air pollution effects (indicator)*. Available at: https://data.oecd.org/air/air-pollution-effects.htm; OECD (2019), *Welfare cost due to ambient particulate matter as % GDP*. Available at: https://stats.oecd.org/Index.aspx?DataSetCode=EXP_MORSC.

High fossil fuel use also leads to high GHG emissions. The annual ECA buildings-related space heating gross CO_2 emissions were estimated to be about 22 percent of the total regional emissions from fuel combustion, or 678 million tonnes of carbon dioxide ($MtCO_2$), of which 75 percent (508 $MtCO_2$) is attributed to the residential sector and the remaining 25 percent (170 $MtCO_2$) to commercial and public buildings. These emissions include burning solid and liquid fuels on-site and from electricity or heat production due to space heating[39]. While fossil fuel use for space heating in all cases leads to high emissions, electricity use for heating is more varied, with some countries (e.g., Albania, Georgia and Tajikistan) having very low grid-emissions factors due to a high share of hydropower, while others (e.g., Kazakhstan, Poland) show high grid-emissions factors due to the high share of coal use for power generation.

Figure II.15: ECA Buildings-Related Space Heating: Gross Co_2 Emissions per Year

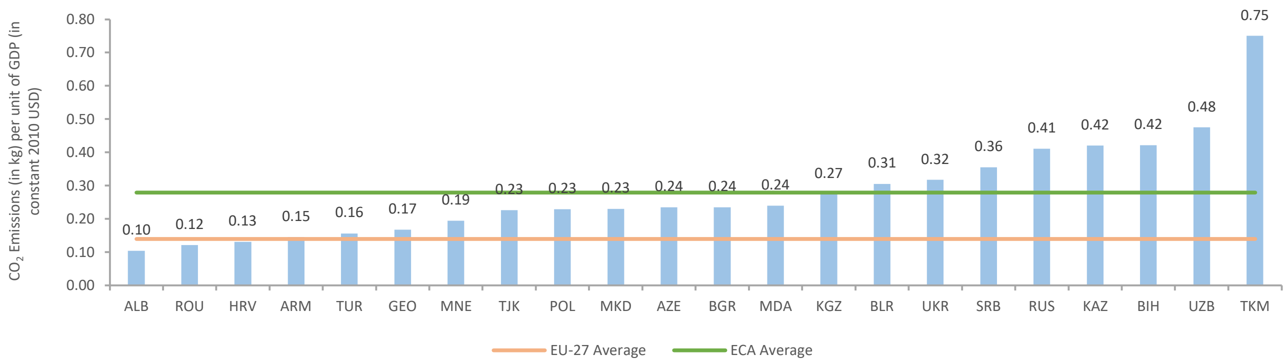


Source: World Bank estimation based on best available data.

[39] The emission factors for natural gas, coal, oil and traditional biomass are 56, 95, 73 and 112 t/TJ, respectively. Source: GHG Protocol (2017), https://ghgprotocol.org/sites/default/files/Emission_Factors_from_Cross_Sector_Tools_March_2017.xlsx. These estimates do not account for the CO_2 extracted from the air and soil during the production of biomass.

The ECA region is also carbon intensive. Although it accounts for 12 percent of global GHG emissions[40], it contributes to only 5 percent of the global GDP. Figure II.16 shows this in more detail by comparing CO_2 emissions per unit of GDP in the ECA countries with the EU-27 average. On average, CO_2 emissions per unit of GDP in the ECA region are double those of the EU-27. And out of 23 countries, only 3 are below the EU-27 average.

Figure II.16: CO_2 Emissions per unit of GDP: ECA Countries vs. EU-27 Average



Source: United Nations Global SDG Database (2019). Available at: https://w3.unece.org/SDG/en/Indicator?id=28.

e. Impacts of current service delivery: fiscal/economic

The heating sector also represents severe economic and fiscal costs for the region. Its dependency on fossil fuels makes ECA one of the most vulnerable regions to energy insecurity, energy supply disruptions, and price fluctuations—all exacerbated by the war in Ukraine. In 2021, ECA had an average consumer price inflation (CPI) of 3.2 percent, while regions such as EU-27, East Asia and Pacific, and South Asia had 2.9, 1.3 and 2.0 percent[41], respectively, with high energy costs being a major contributor.

Moreover, higher energy prices tend to be regressive as they typically hurt poorer households more than richer ones. This is because poorer households spend a larger portion of their incomes on energy, and are often plagued with less-efficient heating systems and homes. In a region with extremely cold weather and relatively high rates of energy poverty, inefficient energy use and higher prices severely impact the quality of life.

Rising energy prices have also led to increasing costs of energy imports and widening energy trade deficits. The energy-importing countries in ECA have a fuel trade deficit of between 0.9 percent of GDP (Türkiye) and 7.3 percent (Ukraine)[42].

In addition, high energy costs for public facilities and large subsidies provided for the production and use of fossil fuels for heating represent a huge fiscal burden. The International Monetary Fund (IMF) estimates that the combined ECA direct fossil-fuel subsidies in 2020 were US$115 billion, representing 2.5 percent of regional GDP. In countries such as Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Russia, Tajikistan, and Ukraine, this value exceeded 4 percent of GDP[43]. More than 45 percent of regional direct subsidies went toward natural gas and 4 percent to coal, which are the main DH fuels in ECA. Including explicit and implicit costs (e.g., climate change, local air pollution, vehicle externalities, and foregone revenue), the IMF estimated the total subsidies in ECA in 2020 were US$850 billion, or about 18.5 percent of regional GDP. In terms of financial support for

[40] World Bank (2021). *Energy Efficiency in Europe and Central Asia.* https://www.worldbank.org/en/region/eca/brief/ee-in-eca.
[41] World Bank (2022). Inflation, consumer prices. https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG
[42] Comtrade (2021). https://comtrade.un.org/
[43] IMF (2022). https://www.imf.org/-/media/Files/Topics/Environment/energy-subsidies/fuel-subsidies-template-2022.ashx

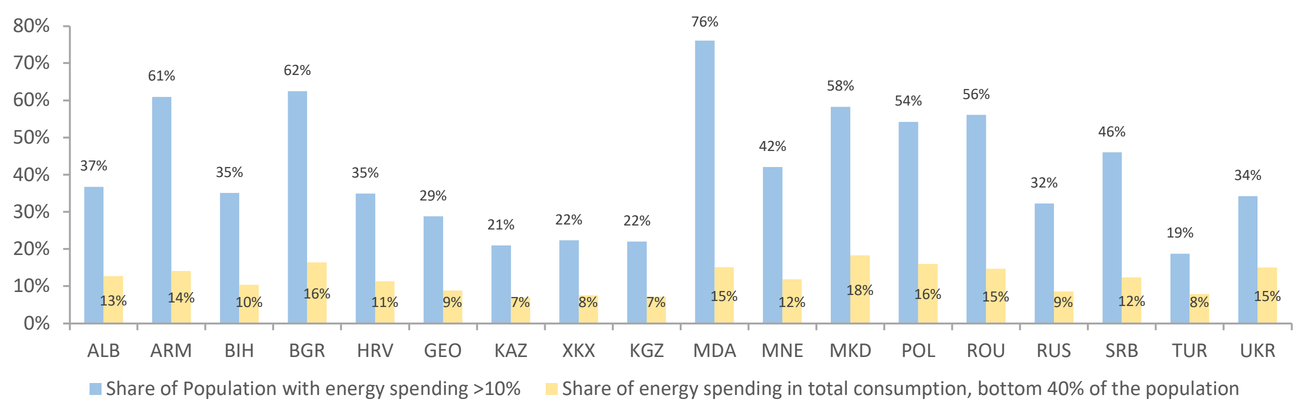
households, including budgetary transfers and tax exemptions, Armenia, Azerbaijan, Georgia, Moldova, and Ukraine provided US$210 million in natural gas subsidies, which are mainly used for household space heating[44]. Government subsidies are also very prevalent in the DH sector, but data are often not available.

f. Energy poverty

As noted previously, high exposure to fluctuating energy prices affects ECA countries given the cold climate, inefficiencies, and high rates of energy poverty—and often leads to challenges of heating affordability and underheating. Because of the substantial heating demand, ECA households tend to spend a higher share of their income on energy than households in other regions.[45] Surging gas and power prices resulting from reduced Russian supplies and the COVID-19 pandemic (supply chain disruptions) have led to inflation, hindering commercial activity and imposing record-high bills on consumers[46]. This creates a major challenge for governments, as households already pay a high share of their monthly spending on heating and other energy costs despite substantial fuel and service subsidies. As the need for price reforms on fuels, DH, and electricity and the transition to cleaner heating fuels becomes more urgent, this would likely exacerbate affordability concerns and compromise households' quality of life as well as limit their ability to meet other necessary expenses.

In terms of energy poverty, the poor tend to spend a larger share of their household budgets on heating. Approximately 34 percent of the population in ECA spend 10 percent or more of their average monthly expenditure on energy bills, a typical threshold for energy poverty. In 12 countries out of 18, the poorest 40 percent spend more than 10 percent of their household budgets on energy bills (see Figure II.17). This is exacerbated by the less-efficient homes and equipment that most poorer households often have. Box II.1 shows this implicit energy inefficiency tax on the poor based on a World Bank analysis conducted for Poland.

Figure II.17: Household Energy Spending as a Share of Total Expenditure, and Percentage of Energy-Poor Households



Source: World Bank staff estimates, and imputation based on the latest available household budget survey for each country. The survey data were harmonized to have fuel and total consumption aggregates comparable across countries. The survey years range from 2017 to 2020, with some estimates relying on the 2015 surveys as the only available year.

[44] OECD (2021). Fossil fuel support dataset. https://www.oecd.org/fossil-fuels/data/

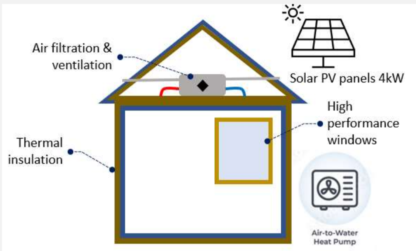
[45] Of the 19 surveyed ECA countries, 8 exhibit average household expenditure on domestic energy use above 10 percent of total household expenditure, with some reaching as much as 14-15 percent. The last global comparison of energy spending in household surveys by the World Bank, covering 17 countries in the Middle East and North Africa (MNA), Africa (AFR), East Asia and Pacific (EAP), and South Asia (SAR) regions in 2010, found only one country with expenditure on domestic energy use above 10 percent (India, with 11.2 percent).

[46] https://www.brookings.edu/blog/future-development/2022/10/18/how-to-help-people-in-europe-and-central-asia-pay-their-energy-bills.

Box II.1. The Implicit Energy Inefficiency Tax on the Poor

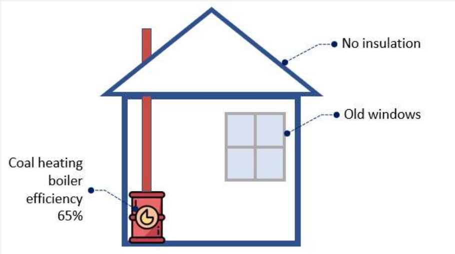
Consider two homes, one that has undergone a full renovation and one that has not been upgraded:

Full renovated single-family home



Annual energy bill: US$0-461.5/year

Unrenovated single-family home



Annual energy bill: US$2,501.3 per year

The home on the left has been fully thermally renovated (including wall and roof insulation, and window replacement) and has installed air filtration and ventilation systems, an air-water heat pump, and rooftop solar photovoltaic (PV) panels. The house would meet all requirements for thermal comfort and indoor air quality. The cost of the investment is US$35,398, with a simple payback period of about 14.2 years. Depending on the net metering or net billing system in place, which would allow the homeowner to sell the unused solar electricity to the grid to offset their bill, the monthly energy cost would be US$0-38.5 (US$0-461.5 per year).

In the second case, there would be no investment cost. The house uses coal for heating but would typically be unable to keep the home sufficiently warm. There would likely be some concerns about indoor air quality, and the home would likely be in violation of emissions standards, contributing to poor outdoor air quality. The monthly energy bill to heat the home using coal would average US$208.4 (US$2,501.3 per year).

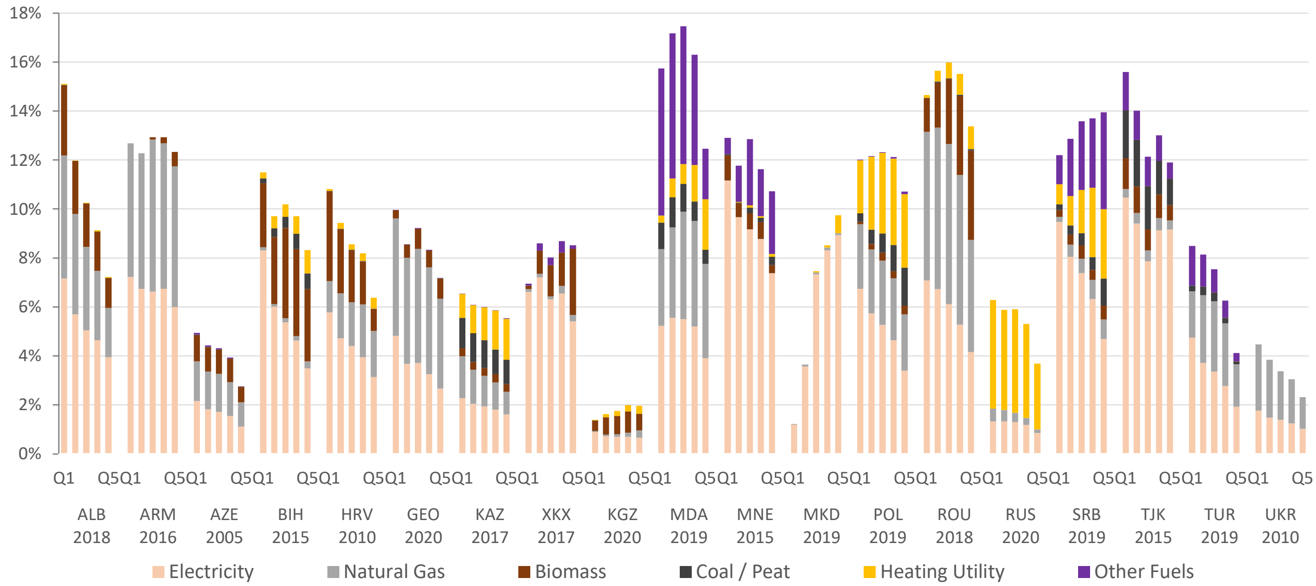
Because lower-income families cannot afford simple energy-efficiency investments or more-efficient heating systems, they are burdened with chronic heat losses in their homes. This leads to higher energy bills and lower quality of heating, creating a vicious cycle. However, when allowed to invest in energy efficiency with affordable options, many do opt to invest.

Source: World Bank analysis based on a 130 m^2 single-family home in Poland. This assumes US$434.8/ton coal and $0.15/kWh.

When comparing quintiles, lower-income households tend to spend more of their budget on energy than higher-income ones. When moving from lower to highest income levels, household expenditure on energy as a share of total expenditure decreases by 8 percent in Albania and 4 percent in Croatia, Tajikistan, and Türkiye (Figure II.18). Even before the recent energy crisis, the poorest households allocated as much as 60 percent of their budget on essentials such as food, housing and energy, which left little discretionary spending for better heating and insulation. The low elasticity of energy consumption illustrates the difficulties households face in adjusting their consumption in times of high prices, due to the imperative for heating, which means that many households are at risk of falling into absolute poverty when energy prices rise. Further price increases may push many ECA citizens into extreme poverty and most likely increase the percentage of the population unable to keep their homes adequately warm.

Many countries address the affordability of heating through heating allowances or other support programs, but coverage and targeting, as well as the level of support, are often inefficient. Annex D: Summary of Existing Allowances Schemes for Energy Expenditure in ECA Countries provides an overview of existing allowance schemes for energy expenditures in ECA that specifically target poor and/or socially vulnerable households. Out of 20 countries, only 9 explicitly mention or focus on space heating. Electricity subsidies are the most common type of allowance, followed by natural gas. This economic support varies from approximately €5/month in Albania to almost €200 per month in the Brčko District (Bosnia and Herzegovina).

Figure II.18: Household Expenditure on Energy as a Share of Total Expenditure, by Country and Income Quintile (%)



Source: World Bank estimates based on ECAPOV (a World Bank data repository that harmonizes nationally representative household surveys). Sources detailed in Annex C.

If heating prices do become unaffordable, households are often left with two unappealing choices: reduce the heating levels in the home or revert to more-affordable fuels which often have higher emissions. Households struggling to pay for heating in rural areas may start to switch back to more-polluting sources of heating fuels, such as firewood and coal. There have even been reports in Poland of homes burning garbage to stay warm when confronted with high energy prices.[47] Many households also limit their heating demand below typical norms. Kosovo reported over 40 percent of its population could not keep their homes adequately warm in 2018; Bulgaria, North Macedonia and Albania reported underheating figures of 23, 24 and 36 percent, respectively, in 2020-22[48] (Figure II.19). When analyzing the population receiving less than 60 percent of median equivalized income, Kosovo and Albania report 53 and 58 percent of underheating, respectively. While the unaffordability of heating fuels is a factor, underheating can also be a symptom of (a) uninsulated homes that cannot get warm enough despite good heat supply, (b) buildings with DH networks that cannot regulate their heat (sometimes even leading to overheating) or are at the end of the network and receive less heat, and (c) unavailability of fuels (seasonal shortages of coal, wood, electricity, gas). As noted previously, the effects can be severe—several reports document the excess winter death rates among those living at low indoor temperatures[49]. There are also health costs related to the additional burden on health systems. These risks are often most severe for young children and the elderly.

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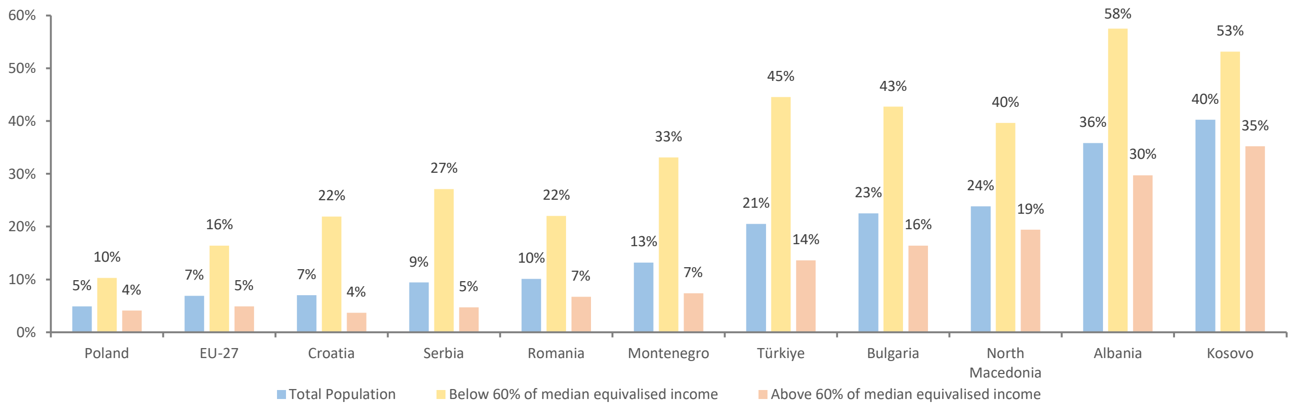
[47] https://www.bloomberg.com/news/articles/2022-10-06/energy-crisis-people-in-poland-burn-trash-to-keep-warm-in-coal-shortage.

[48] Eurostat-SILC, Statistics of Income and Living Conditions (SILC). Inability to keep home adequately warm. Available at: https://ec.europa.eu/eurostat/databrowser/view/ILC_MDES01/default/table?lang=en.

[49] Martin Recalde et. al. (2019), "Structural energy poverty vulnerability and excess winter mortality in the European Union: Exploring the association between structural determinants and health." *Energy Policy*, Vol. 133, 110869, ISSN 0301-4215. Available at: https://doi.org/10.1016/j.enpol.2019.07.005.

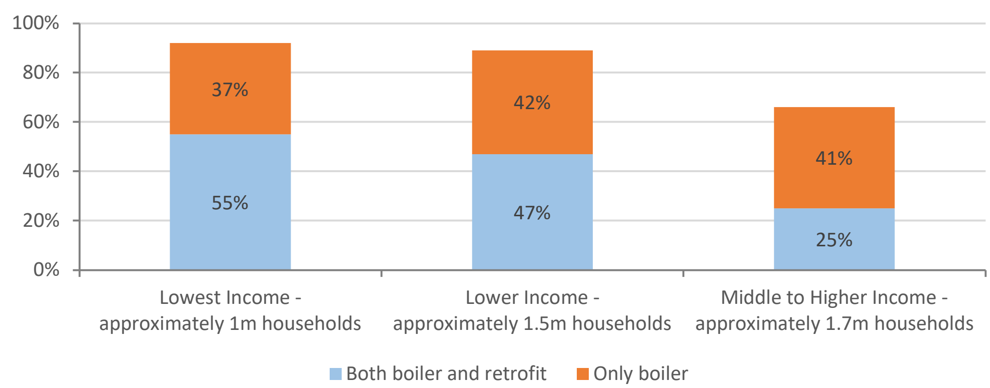
Figure II.19: Percentage of the Population Unable to Keep their Homes Adequately Warm



Source: Eurostat – Statistics of Income and Living Conditions (SILC). Most recent data year: 2018 – Kosovo; 2020 – Albania, Montenegro, North Macedonia; 2021 – EU-27, Romania, Serbia, Türkiye; 2022 – Bulgaria, Croatia, Poland.

Analyses of heating fuels/technologies show that households using solid fuels are more likely to be energy-deprived[50]. A recent World Bank study of Poland's Clean Air Priority Program[51] used the low-income-high-cost (LIHC) concept of energy poverty and concluded that energy poverty rates are particularly high among households using solid fuels to heat their dwellings. Poorer households were more likely to require comprehensive support for thermal modernization as well as upgrades to cleaner fuels and more efficient heating systems. It estimated that over 90 percent of the lowest-income households living in SFHs required a heating upgrade, compared to 66 percent of higher-income SFHs (Figure II.20).

Figure II.20: Share of Single-Family Homes in Need of a Boiler Upgrade and/or Thermal Modernization (%)



Source: World Bank (2019). *Technical Assessment Report: Poland's Clean Air Priority Program*.
Note: *Lowest Income*: Household that receives social assistance programs and has an income under approximately 800/1000 PLN per month. *Lower income*: Income under 1400 PLN per person per month. *Middle to Higher Income*: Income between 1400 and 2000 PLN.

Energy poverty is often a combination of factors that cause a household to have above-average energy needs and costs—high energy losses in the home, costly fuels, and low-income levels[52]. Such cases are broader than

[50] For a household to be classified as "energy deprived", it must meet two criteria simultaneously: high required energy costs and low income. "Required energy costs" mean the expenses that the household would incur, taking into account its housing situation, if it were able to fully meet standard energy needs. Rutkowski et al. (2018), *How to reduce energy poverty in Poland?*, IBS Policy Paper 01/2018, Instytut Badan Strukturalnych.
[51] World Bank (2019). *Technical Assessment Report: Poland's Clean Air Priority Program*.
[52] A. Kiełczewska, P. Lewandowski and J. Sokołowski (2018), *Defining and measuring energy poverty in Poland,* Institute for Structural Research, policy note no. 01/2019.

many discussions about energy poverty which focus on the affordability of fuels. Low-income households also tend to live in older, uninsulated houses with poor windows and doors, use lower-efficiency heating technologies, and purchase dirtier fuels (e.g., coal, firewood) and, therefore, may require larger investments to transition to sustainable heating alternatives. To improve this scenario, governments need coordinated policies that tackle both the affordability and technology of energy poverty. Unfortunately, poorly targeted and designed social support measures—such as those introduced in response to the recent energy-cost shock due to the post-COVID recovery period and Russia's invasion of Ukraine—could mute the role of market prices or even subsidize the consumption of cheaper, dirtier fuels and inefficient heating equipment by low-income households.

III. District Heating Systems

Main Messages:

- District heating (DH) serves 30 percent of ECA's population—mainly in dense, urban areas, where it remains the most economic approach to heating. Although there are estimated to be more than 52,000 DH utilities in the region, only about 2,300 exist outside of Russia. Over 97 percent rely on fossil fuels, mainly natural gas (66 percent) and coal (28.5 percent).
- Despite their advantages, most systems are very inefficient and outdated, with decades of few or no upgrades and little regular maintenance. Heat supply is often based on floor area and underpriced. Low service levels have led to customer disconnections, which has eroded revenue bases and further limited new investments.
- A survey was conducted to assess the financial and operational performance of 18 DH utilities in Bulgaria, Kyrgyz Republic, Poland, and Serbia over a five-year period (2017-21). There was a wide range in performance: 3 out of 18 had good financial and operational performance; 8 had poor performance in either financial or operational performance; and 7 had poor performance in both categories. Critical reforms are thus necessary to turn around incumbent providers prior to large-scale investments in sustainable heating.
- Cleaner technologies and fuels could help DH systems transition to a more sustainable future. This includes RE sources (e.g., geothermal, solar, biomass), electricity (large heat pumps), waste heat, biogas, and hydrogen. DH networks could also transition to lower temperature systems, building-level substations, adding domestic hot water, district cooling and heat storage. By coupling electricity and heating, excess RE-based electricity could store heat.

a. Overview of district heating in ECA

District heating (DH) systems have evolved substantially since their introduction in the United States in the nineteenth century. These early systems were intended to replace individual boilers in apartment buildings, reducing the risk of boiler explosions and improving thermal comfort. Steam was distributed through pipes and the heat was delivered to consumers through steam condensation radiators.

The second generation of DH systems, from approximately the 1930s to the 1980s, used pressurized hot water with high supply temperatures (more than 100°C). In the Soviet Union, these systems were inefficient, and consumers lacked control over their heat demand. With an abundance of energy, consumer bills were set well below the cost of supply and often based on floor area rather than consumption. The goal of many second-generation DH systems was to achieve fuel savings through the use of combined heat and power (CHP) plants.

The third generation of DH systems, beginning in the 1980s, introduced pressurized water at temperatures below 100°C and prefabricated, pre-insulated pipes—the goal being energy efficiency, fuel cost savings, and energy security. The future development of DH could be focused on high-efficiency, low-temperature production, and RE to mitigate the effects of climate change; it could operate as an integrated part of a smart energy system.[53] Table III.1 briefly summarizes the general characteristics of each generation.

[53] Henrik Lund, et al. (2014), "4th Generation District Heating (4GDH): Integrating Smart Energy Grids into Future Sustainable Energy Systems," *Energy* 68: 1–11.

Table III.1: Characteristics of District Heating Systems, by Generation

	1st Generation (1880–1930)	2nd Generation (1930–1980)	3rd Generation (1980–2020)	4th Generation (2020–)
Heat carrier	Steam	Pressurized hot water (>100°C)	Pressurized hot water (<100°C)	Low-temperature water (30–70°C)
Pipes	Insulated steel pipes	Insulated steel pipes	Pre-insulated steel pipes	Pre-insulated flexible pipes
Circulation systems	Steam pressure	Central pumps	Central pumps	Central and individual pumps
Metering	Condensate meters to measure the amount of steam used	Heat meters with annual or monthly readings; sometimes allocation meters on radiators	Heat meters; sometimes metering of flow to compensate for high return temperatures; wireless, more frequent readings	Continuous meter reading
Radiators	High-temperature radiators (>90 °C) using steam or water	High-temperature radiators (>90 °C) using DH water	Medium-temperature radiators (70°C) using DH water	Low-temperature radiators (50°C)
Hot water	Tank heated directly with steam or from a secondary water circuit	Tank heated to 60°C and circulated at 55°C when needed	Heat exchanger heats water to 50°C; domestic water tank heated to 60°C and circulated at 55°C when needed	Efficient local heat exchanger heating water to 50°C
Heat production	Coal steam boilers and some CHP plants	Coal- and oil-based CHP and some heat-only boilers	Large-scale CHP, distributed CHP, biomass and waste, or fossil-fuel boilers	Low-temperature heat recycling and RE sources
Integration with electricity supply	CHP as heat source	CHP as heat source	CHP as heat source; some large electric boilers and heat pumps	CHP systems integrated with heat pumps and operated on regulating and reserve power markets as well as spot markets
Primary motivation	Comfort and reduced risk	Fuel savings and reduced costs	Security of supply	Transformation to sustainable energy system
Infrastructure planning	Governing competing DH infrastructures	Developing and expanding DH suitable for cost-efficient use of CHP	Identifying and implementing suitable DH infrastructures in fossil-based energy systems	Identifying and implementing suitable DH infrastructures in fossil-free energy systems
Cost principles	Minimizing per unit supply costs; few concerns about savings because space is more important	Minimizing per unit supply costs; few concerns about savings because CHP is inexpensive and plentiful	Dilemma between short- and long-term marginal costs, with short-term marginal costs, winning based on existing investments (sunk costs)	Dilemma between short- and long-term marginal costs, with a need to integrate better long-term marginal costs (future investments)

Source: Lund, et al., "4th Generation District Heating (4GDH): Integrating smart thermal grids into future sustainable energy systems," *Energy*, vol. 68, no. 0, pp. 1–11, Jan. 2014.

In areas with sufficiently dense heat demand, DH can provide several benefits over individual heating systems:[54]

- DH systems use different heat sources in parallel on the same integrated heating grid, allowing system operation to be optimized to minimize costs depending on the prices of various fuels.
- The use of different heat sources in parallel also allows sources to back each other up.
- Industrial waste heat can be distributed to customers as hot water through the network.

[54] Arlene Haas, *The Overlooked Benefits of District Energy Systems*, Burnham International, April 12, 2018, https://www.burnhamnationwide.com/final-review-blog/-benefits-of-district-energy-systems.

- DH enables quick implementation of new technologies and fuels because it is easier to apply new technologies in one integrated system than in hundreds of separate buildings.
- DH provides better control over load to accommodate peak demand on the electrical system.
- DH's economy of scale allows for lower costs for heat generation, distribution, maintenance (e.g., flue gas cleaning with electric precipitators) and environmental controls (e.g., desulphurization, nitrogen oxide (NO_x) reduction) that would be uneconomic in smaller-scale applications.
- DH reduces indoor and outdoor air pollution because of greater efficiencies and pollution control equipment.
- DH can use biomass economically and ecologically because of its scale and high combustion efficiency, and can better integrate other clean and RE heat sources (e.g., geothermal, solar, waste heat).
- DH allows for heat storage to be utilized for backup (e.g., when RE-based heat supply is limited, or for peak shaving).
- The possibility of integrating district cooling offers an option to integrate DH and CHP plants to reduce the consumption of both electricity and primary energy.

However, DH may not be the best heating solution in all cases. It requires substantial public sector intervention—including centralized, long-term planning; obligations for most customers to connect; and large upfront investments. DH works best with stable heat supply and fuels, consistent and predictable demand, high heat demand density (often corresponding to population density), a relatively efficient building stock, horizontal piping (within MFBs), temperature controls, and individual metering—many of which can be lacking or suboptimal in many ECA countries.

District heating is common throughout the ECA region. Table III.2 shows the characteristics of the DH sectors in the region, although it should be noted these are from different sources in different years. Based on the available data, an estimated 139.3 million people in the region are served by DH (approximately 30.1 percent of the population). There are more than 52,000 DH utilities in the region, but most of these are in Russia; excluding Russia, there are about 2,300 utilities serving about 14.8 percent of the population. Most DH in the region is generated from fossil fuels; of the 19 countries where data was available, more than half generate 100 percent of heat from fossil fuels, with four more generating at least 95 percent of heat from fossil fuels. Only Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, and Poland generate 70-90 percent of heat from fossil fuels.

Table III.2: District Heating in the ECA Region

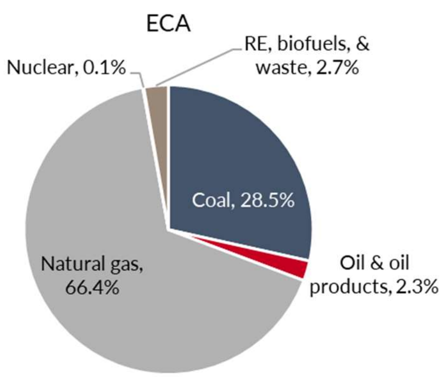
Country	DH customers	% of the population served by DH	DH utilities	% fossil fuels	Sources
Armenia	450	<1%	1	100%	UNDP
Azerbaijan	3,568 residential buildings	No data available	1	100%	Govt. of Azerbaijan
Belarus	6.6 million	70%	No data available	70%	Euroheat & Power
Bosnia and Herzegovina	262,000	8%	32	80%	IRENA; Euroheat & Power
Bulgaria*	605,000	22%	14	75%	Govt. of Bulgaria
Croatia	436,000	11%	19	85%	Euroheat & Power; KeepWarm Europe
Kazakhstan	13.1 million	70%	52	100%	KazNIPI Energoprom; IEA
Kosovo	11,000	3–5%	4	95%	Kabashi et al.; Euroheat & Power; ERO

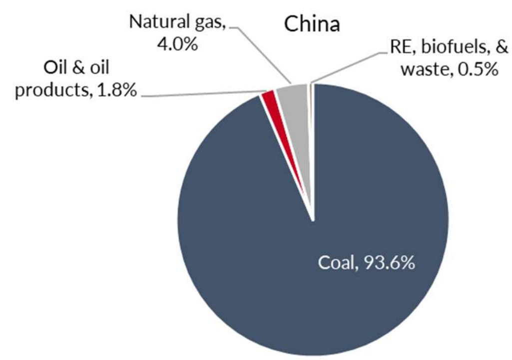
Country	DH customers	% of the population served by DH	DH utilities	% fossil fuels	Sources
Kyrgyz Republic*	205,000	19%	16	100%	World Bank; Min. of Energy
Moldova	500,000	19%	3	100%	World Bank
North Macedonia	48,000	2%	3	100%	Euroheat & Power
Poland*	16.5 million	43%	412	87%	Euroheat & Power
Romania	1.3 million	21%	61	97%	Govt. of Romania; Euroheat & Power
Russia	92 million (est.)	64%	50,000	>99%	Aqua-Therm
Serbia*	572,000	19%	59	100%	RES Foundation; Euroheat & Power
Tajikistan	86,000	<1%	12	100%	World Bank
Türkiye	600	<1%	1	100%	Danfoss
Ukraine	5.5 million	40%	1,600	98%	KeepWarm Europe; USAID
Uzbekistan	1.3 million	14%	41	100%	Inogate, World Bank

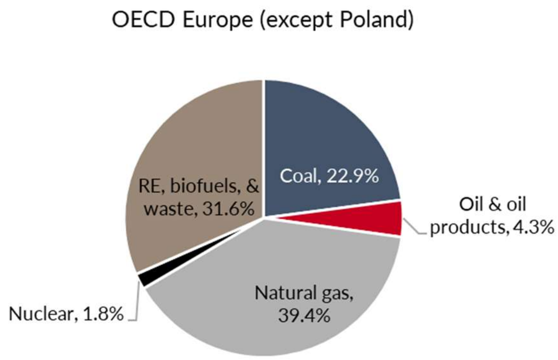
Sources: See links in table.
Notes: An asterisk indicates the country has utilities included in this study. There is no DH in Albania, Georgia or Montenegro; data were not available for Turkmenistan. Numbers for DH customers are approximate. Estimates for Russia are included but there are widely different figures in different reports, partially due to the fact that some smaller-scale heat-only boiler operators that sell heat are also classified as DH companies.

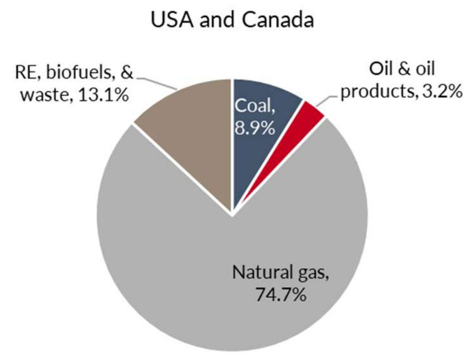
While over 97 percent of the region's CHP and heat-only plants rely on fossil fuels, over 66 percent is from natural gas. However, 28.5 percent is from coal that is often burned in very old plants, which makes the systems very inefficient and polluting. Other regions show similar dependence on fossil fuels for heating: China relies on fossil fuels for over 99.4 percent (93.6 percent coal) of its heating plants, Europe about 66.6 percent (22.9 percent coal), and US/Canada 86.8 percent (8.9 percent coal) (see Figure III.1).

Figure III.1: Combined Heat and Power and Heat-Only Plants: Fuel Mix by Region, 2019









Source: IEA Energy Balances.

Outside of ECA, DH is a prominent part of sustainable heating strategies in the EU (especially the Nordic countries, but also elsewhere—see Box III.1), Japan, and Chile, while playing a smaller role in North America. Denmark, for example, plans to switch approximately 50 percent of households that are currently heated by oil/natural gas to DH by 2028.

Box III.1: District Heating in the EU

To meet ambitious EU energy and climate goals, a complete transformation of the EU's energy sector will be necessary. This includes the heating and cooling sectors, which account for about 50 percent of energy demand, of which two-thirds is based on fossil fuels. Gas is the predominant fuel, followed by coal. Biomass accounts for about 12 percent of heating use, but much of it is not certified and burned in older, less-efficient stoves and boilers. District heating accounts for about 12 percent of heat supply. The EU does provide indicative targets and encourages incentives to increase DH coverage in urban areas, but generally does not specify requirements for network heating fuels.

The *Heat Roadmap Europe* set of studies and analyses (https://heatroadmap.eu) shows that investments of about €68 billion each year could transform the heating sector—through a 30 percent reduction in heat demand (through energy efficiency), expansion of DH to cover about 50 percent of demand, a shift from fossil fuels to waste heat and RE sources, and introduction of "smart" energy systems—and reduce emissions by about 85 percent. The latter would allow DH networks to be integrated into power and other systems to allow for flexible CHP plant production and larger heat pumps and electric boilers (when RE-based power generation is high) and additional elements, including thermal storage and heat-demand response and metering to help curb heat demand. The Roadmap even calls for EU member states with little or no DH (e.g., the United Kingdom, the Netherlands, and Spain) to introduce it. Some developments in the EU include:

- Sweden (52 percent), Denmark (50 percent), Finland (42 percent) and Lithuania (42 percent) have the highest share of DH. Denmark has worked to increase DH from about 50 percent of dwellings (mid-1990s) to about 67 percent (2022), with about 600 heat-producing companies and 354 DH (58 municipal-owned, 286 customer-owned coops, and 10 private).
- Most countries (about 70 percent) rely on CHPs for heat production in DH systems. While some are very coal-dependent (e.g., Czech Republic, Poland, Slovakia), others use very limited fossil fuels (e.g., Sweden has a high share of large heat pumps, while France relies on geothermal and waste incineration).
- Most systems are relatively old but still efficient, with higher DH distribution losses in Denmark (21 percent), the Netherlands (14 percent), Finland (13 percent) and Italy (13 percent), and lower losses elsewhere (e.g., Austria and Estonia, at around 5 percent each).
- Gradual shifts to more-sustainable DH are becoming more common in the EU. Austria, Croatia, Estonia, Finland, France, and Sweden have all built CHP plants that use agricultural waste, wood, or peat to fuel biomass CHPs; Finland has been operating a waste incineration CHP since 2014 and a waste gasification plant since 2012; Denmark commissioned a new solar collector plant in 2019 and now has over 70 percent of DH heat supply from geothermal, biomass, waste, and RE-based waste heat; Austria has several thermal storage units (thermal energy storage towers, pit storage); and several European DH utilities are expanding to include district cooling in the summer months.
- Germany received funding in late 2022 to provide incentives for the development of heat supply based on RE and waste heat to achieve 75 percent of the DH network from green energy by 2028.

The EU is also proposing a range of schemes and mandates to support decarbonization plans for DH with national-level targets, carbon taxes on fossil fuels used for heating, incentives for using waste heat, improved urban planning, incentives for customers to connect to DH, and other measures. The EU's Renewable Energy Directive also calls for an annual increase in RE for heating and cooling by 1.3 percent each year. More efforts are now underway to better define efficient DH, and new minimum requirements will be gradually changed to ensure a fully decarbonized DH supply by 2050. Support for new DH high-efficiency cogeneration using natural gas will likely not be allowed after 2030.

Sources: B. V. Mathiesen et al. (2019), *Towards a Decarbonised Heating and Cooling Sector in Europe: Unlocking the Potential of Energy Efficiency and District Energy*, Aalborg Universitet; K. Johansen and S. Werner (2022), "Something is Sustainable in the State of Denmark: A Review of the Danish District Heating Sector," *Renewable and Sustainable Energy Review*, Vol. 158; Alexander Richter, "German green district heating scheme approved by EU Commission," *Think GeoEnergy*, 8 August 2022, available at https://www.thinkgeoenergy.com/52545-2; European Commission, *Overview of District Heating and Cooling Markets and Regulatory Frameworks under the Revised Renewable Energy Directive,* Publications Office of the European Union, 2022, available https://data.europa.eu/doi/10.2833/962525; March 2023 press release "*EU agrees stronger rules to boost energy efficiency*," available at Revisions to the EED (https://ec.europa.eu/commission/presscorner/detail/en/IP_23_1581), which includes a timeline for a revised definition.

b. District heating survey

As part of the analysis of DH systems in ECA, a rapid assessment methodology was developed to assess their operational and financial performance. This was deemed necessary to determine when and how DH could be strengthened before identifying major investments in switching to cleaner heating fuels and systems. This section briefly describes the methodology for selecting the countries to be included in the study, identifying and selecting financial and operational indicators for the rapid assessment, collecting data, and conducting the rapid assessment. (Further details on methodology, indicators and utilities surveyed are included in Annex E.)

Financial performance findings

Table III.3 summarizes the financial indicators and regional benchmark comparisons used in the assessment. Some identified results and trends include:

- For the surveyed utilities, there was a huge variation in the cost recovery indicator, with a gradual decline (with and without subsidies) from 2017 through 2020 followed by a large increase in 2021, likely associated with the beginning of the post-COVID-19 recovery period. As would be expected, subsidies—where it was possible to identify them in the accounts—helped, especially for those utilities with the lowest cost-recovery scores.
- Average tariffs increased slightly over the 2017-21 period (5.0 percent), and average costs rose at nearly the same rate (4.4 percent). This may have been driven by roughly comparable increases in mean spending on operating and maintenance costs and some increases in fuel prices in late 2021.
- Collections varied considerably from year to year. This pattern is common for many utilities given their invoicing cycles and the use of accruals accounting. They may under-recover in some years and over-recover in others.
- Average profitability declined during this period, except for one Bulgarian utility that showed a substantial turnaround from massive losses to profitability between 2017 and 2020.

Table III.3: Summary Statistics for Key Financial Indicators

Indicator	Statistic	2017	2021	Regional Benchmark
Cost-recovery (%)	# utilities reporting	18	13	
	Minimum	48.57	93.93	
	Maximum	130.77	142.60	
	Mean	101.73	111.63	100
Average Tariff (US$/kWh)	# utilities reporting	16	14	
	Minimum	0.029	0.028	
	Maximum	0.108	0.135	
	Mean	0.054	0.068	--
Average Cost (US$/kWh)	# utilities reporting	18	15	
	Minimum	0.010	0.012	
	Maximum	0.126	0.139	
	Mean	0.049	0.059	Average Tariff > Average Cost

Indicator	Statistic	2017	2021	Regional Benchmark
Collections (%)	# utilities reporting	18	13	
	Minimum	74.09	90.20	
	Maximum	201.33	147.95	
	Mean	105.26	102.86	95
Profit Margin (%)	# utilities reporting	18	13	
	Minimum	-65.04	-5.52	
	Maximum	17.12	11.71	
	Mean	0.23	2.49	5

Sources: Benchmark data are from select EU countries, World Bank reports and expert estimates.

Operational performance findings

Table III.4 shows summary statistics for the operational indicators and regional benchmarks. Some observable trends include:[55]

- Production and distribution efficiencies showed a modest decline, which suggests that assets continued to age during this period without being renewed or replaced. Surveyed utilities performed below the regional benchmark for production efficiency but reasonably well in the area of distribution efficiency.
- The mean specific heat consumption decreased slightly during the 5-year period. In looking at some of the input data, this appears to have been driven more by non-residential heat consumption improvements, which decreased by about 10 percent (i.e., likely due to building renovations or increased home-based work), than by residential, which was largely constant.
- The mean heat demand density, substation and building metering remained relatively constant during the 5-year period.
- The prevalence of building-level metering decreased slightly during the 2017-21 period and remains about 20 percent below the regional benchmark. Substation metering and mean demand density remained relatively constant. Consumption-based billing (a long-list indicator) remains very high (near or at 100 percent) in all of the utilities reporting except one.
- The fossil fuel share (also a long-list indicator) also remained constant, with a mean of about 99.5 percent, indicating substantial investment needs for expanding the use of sustainable heating fuels. The exception is a utility in Bulgaria which introduced some biomass fuel use in recent years but still relies heavily on fossil fuels (over 93 percent).

Table III.4: Summary Statistics for Key Operational Indicators

Indicator	Statistic	2017	2021	Regional benchmark
Production Efficiency (%)	# utilities reporting	9	9	
	Minimum	59.65	54.12	
	Maximum	90.96	99.65	

[55] The statistics shown in the table are for utilities that reported each of the five years 2017-2021. If a utility did not report for any given year, it was dropped from the analysis.

	Mean	74.08	67.70	89
Distribution Efficiency (%)	# utilities reporting	6	6	
	Min	85.86	80.80	
	Max	95.36	95.95	
	Mean	90.09	88.22	90
Specific Heat Consumption (kWh/m2)	# utilities reporting	8	8	
	Minimum	96.68	76.34	
	Maximum	208.49	219.77	
	Mean	152.32	142.91	120
Water Replacement (Ratio)	# utilities reporting	10	10	
	Minimum	0.08	0.08	
	Maximum	3.63	4.86	
	Mean	2.04	1.86	1.9
Heat Demand Density (MWh/m)	# utilities reporting	11	11	
	Minimum	1.67	1.58	
	Maximum	9.28	9.65	
	Mean	3.07	3.01	2.0
Substation Metering (%)	# utilities reporting	7.00	7.00	
	Minimum	78.54	65.73	
	Maximum	100.00	100.00	
	Mean	96.93	95.10	100
Building Metering (%)	# utilities reporting	8	8	
	Minimum	9.08	8.62	
	Maximum	112.29	125.11	
	Mean	80.09	77.05	100

Sources: Benchmark data are from EU countries, World Bank reports and expert estimates.
Note: Table shows utilities that reported each of the five years 2017-2021. If a utility did not report for any given year, it was dropped from the analysis.

Combined performance findings

Figure III.2 shows the total financial and operational scores for each utility[56]. Utilities are placed into groups based on their financial and operational performance scores, and recommendations are provided for each group. The four utility groupings based on these scores are as follows:

- **Group 1 (3 utilities): Good financial and operational performance** (both scores greater than or equal to 70): Utilities D, E, and J. All three utilities are located in Poland.

[56] For the presentation of results, utilities are kept anonymous due to concerns from some utilities surveyed about sharing their performance data.

- **Group 2 (5 utilities): Good financial performance only:** Utilities A, G, K, L, and M. Four of these utilities are in Poland, and one is in Serbia.
- **Group 3 (3 utilities): Good operational performance only:** Utilities P, R and S. Two of these utilities are in Poland, and one is in Serbia.
- **Group 4 (7 utilities): Poor financial and operational performance** (both scores less than or equal to 70): Utilities B, C, F, H, N, O and Q. Five of these utilities are in Bulgaria; one each in Serbia and Poland.

Figure III.2: Summary of Final Financial and Operational Scores

Source: Authors.

This assessment is merely a tool to allow a quick assessment to inform governments, regulators, and utility managers about the areas in which a utility's performance is meeting regional benchmarks and areas where further study is needed. Thus, the results of this rapid assessment should be viewed more as indicative, and any results considered as part of a broader discussion with governments and stakeholders. For low scores, a more detailed assessment should be conducted, to drill down on each parameter to determine whether the problem relates to recent performance concerns, declining performance over time, or volatile performance over time—or some combination of these parameters—and to determine the main reasons for the poor performance, which could be a result of low tariffs, aging system assets, poor customer payments, or other factors.

Recommendations for improvement

The results of the rapid assessment reveal a wide variation in utility performance across the region and within countries. In some cases, past performance assessments and improvement plans have led to substantial progress in operations, cost recovery, and other parameters. Unfortunately, in many other cases, the very old assets—combined with an inefficient building stock, high costs, low tariffs (and consumers with limited ability to pay), and a lack of political will for reforms—have led to limited performance improvements.

Further, some smaller DH systems are likely to be uneconomic going forward or would require levels of subsidies that the national or local governments are unwilling or unable to mobilize, as has been the case in some DH systems in Romania and Bulgaria (see next section). Now that issues of decarbonization and sustainability are at the forefront, the impetus for addressing these systemic issues has become more urgent. Large investments in cleaner heating cannot be made without addressing these systemic performance issues; otherwise, these investments are unlikely to be sustainable. (Annex F presents World Bank and other multilateral development bank support for DH and sustainable heating, and Annex G offers some case studies from the region including an example of how comprehensive reforms improved DH in Ukraine and how some DH utilities failed in Bulgaria and Romania.)

The sections below contain broad suggestions and recommendations, largely based on other reports and good practices, for how governments and utilities in each of the groups could develop a set of reforms to address performance gaps and better prepare for a transition to more sustainable heating services. But regional experience suggests that there is no uniform pathway or simple fix to address major performance deficiencies, and solutions need to be developed based on the local context.

Group 1 utilities: good financial and operational performance

Group 1 utilities show signs of good operational and financial performance. These utilities will have the highest level of readiness for developing a transition plan to sustainable heating. Alternative heat sources and technologies that can further enhance the sustainability of these DH systems are described in the next section. A mapping of cleaner heating sources with heat demand will be needed to help define how the DH system could make this transition where it remains economic to do so.

Many countries in ECA and Europe are also developing aggressive building renovation programs as part of their energy and climate plans and long-term renovation strategies (LTRSs). While such programs are important for energy efficiency and affordability, these programs are likely to lead to large reductions in heating loads, which could impact the operational and financial viability of these existing DH systems, even ones with good performance. Some counties are also projected to experience declines in populations, which may further affect heat demand. Thus, medium-term planning is critical to ensure their continued viability and, where necessary, properly calibrate the capacities, quantities of heat supply, new customer recruitment/expansion, and other parameters to maintain strong performance metrics.

These utilities may also be ready for more advanced reform options that include the adoption of more market-based approaches in the DH sector, the potential unbundling of heat generation and distribution, the introduction of private sector participation, demand-side management services, and fully reflective heating tariffs. Care will need to be taken, however, to ensure that the more market-based approaches are designed to further improve efficiencies and service quality, including the gradual transition toward sustainable heating sources, and do not compromise affordability or adversely impact the most vulnerable consumers.

Group 2 and 3 utilities: good financial or operational performance

Group 2 and 3 utilities score well in either operational or financial performance, but not both. If the operational performance is good but the financial performance is lagging, it could mean the issues are more related to low tariff levels, collection issues, or the high cost or levels of debt; conversely, if financial performance is good and operational performance is poor, it may signal very low fuel or heat supply costs or imply past or present subsidies in the sector. Reforms for these utilities will likely require a mix of utility-specific and sector-wide legal and regulatory reforms; improved governance, transparency, and institutional strengthening cut across both dimensions. However, for these utilities, it is important to investigate more deeply where they are falling short and why. In most cases, a more detailed diagnostic will be necessary.

Where the challenges faced by a utility are principally financial, reforms are more likely to include changes to tariff levels and structures, strategies to improve collections, efforts to reduce fuel supply costs and—where debt service is a large component of costs—financial restructuring. The design and adoption of methodologies for revenue requirements and tariffs (including incentives linked to quality and reliability performance standards) and improvements in commercial operations (such as better metering, billing and collections) are also important. In implementing financial reforms, regulatory or other measures may be needed to ensure that such reforms (in particular, higher tariffs) do not induce customers to disconnect and switch to dirtier or less-efficient heating, or unduly impact the poor. Tariff reforms should be accompanied by strong communication efforts to explain the rationale for the needed changes and expected benefits. Annex G describes the case of Shumen, Bulgaria, where low service levels gradually led to disconnections and a downward spiral in operational and financial performance, and ultimately the collapse of the DH company.

Where the challenges faced by a utility are principally operational, needed reforms are likely to focus on utility management and operational changes, along with a sizeable investment program to significantly improve supply (e.g., improve boiler efficiencies/convert heat-only boilers to CHP, reduce distribution heat losses, expand and densify the network, building level substations).[57] Sound heat demand assessments and expansion plans integrated into urban planning models, along with investment plans with monitoring indicators, will help ensure more-efficient system designs and coordinated strategies.

In launching ambitious investment programs, however, care must be taken to ensure that such programs are financially sustainable and that the full costs of the capital expenditure can be fully passed through to end-users or supported by government subsidies. Institutional reforms are also likely to be needed—to ensure improved management and maintenance practices, suitable tariffs (to help finance the investment programs), effective customer services, and tighter regulatory operational benchmarks. Development of data platforms allowing utilities, regulators, and municipal owners to monitor operational data and assess achievement of targets and benchmarks are also important, as are customer surveys. Care must be taken to ensure that any tariff increases result in clear service-quality and reliability improvements to build customer acceptance and willingness to pay higher fees, and that protection measures are in place for the poorest consumers.

There are of course many synergies between operational and financial improvements, as many operational improvements (e.g., consumption-based billing, loss-reduction measures, network densification) would lead to better financial performance, and better financial performance can enable access to more financing to further increase operational upgrades. The establishment of performance indicators and monitoring systems by the regulator or municipality is critical, along with the development and implementation of a performance improvement plan (PIP) by the utility. However, given the initial conditions of the DH utility, it is recommended to adopt a gradual approach, taking into consideration actions to improve service levels and efficiency while developing a path to cost recovery. The PIP should recognize the quality of service and allowable technical losses in the tariff methodologies that determine the “allowable” level of losses recognized as cost pass-through to regulated heating tariffs[58]. And improved governance—from adopting codes of corporate governance to competitive appointments of key management staff, staff training and rationalization, etc.—are all

[57] World Bank/ESMAP, 2012, *Modernization of the District Heating System in Ukraine: Heat Metering and Consumption-Based Billing*.
[58] World Bank, 2023. *Improving Electricity Distribution Utility Performance through World Bank Engagements* (internal guidance note).

recommended. Proper communication of such gains to the public will be important: explaining how the additional revenues were used to improve performance will help justify some of the customer-facing reforms and foster public acceptance.

Group 4 utilities: poor financial and operational performance

Group 4 utilities score poorly against both the financial and operational indicators. The utilities in this group suffer the most from the vicious cycle in which the financial and operational challenges reinforce one another—poor service quality leads to more customer disconnections that further erode revenues. If parallel building-renovation programs are expected to lead to large reductions in heating loads, the economic viability of these DH systems may deteriorate further. In a sector with high fixed costs, weak service levels often lead to reduced demand (through disconnections), which is ultimately what has caused so many past DH utilities in the region to fail (see also case study for Romania in Annex G).

Therefore, significant reforms for these utilities are needed, with a stronger push for increased political independence and improved utility governance and management—as well as overarching reforms in the national legal and regulatory frameworks. In such cases, further investments in the system should ideally be provided only once a set of reforms are agreed upon to turn around the overall performance. Therefore, a critical assessment will be needed, assessing reforms and likely performance gains, potential load increases or reductions, cost profiles of cleaner heating sources, cost of service studies, etc. before any further investment decisions are made. If it is determined that economic viability conditions are no longer met, a managed phaseout of DH may have to be considered.

The scope and depth of financial and operational reforms are therefore most important for Group 4 utilities. For these utilities, improving the regulatory regime is most important. Cost recovery measures, such as increases in tariffs or improved metering, should be gradual and accompanied by (i) visible improvements in service quality and efficiency; (ii) clear communications to customers about the turnaround plans of the utility and public consultations on medium- and long-term utility PIPs and how to share costs and risks among the utility, municipality, consumers, etc.; (iii) parallel programs to support energy efficiency (to help customers offset potentially higher heating bills); and (iv) expanded social protection measures for the poorest customers. Utilities with low network configuration scores may be able to help improve their performance through better customer-level and building-level metering, and perhaps some new-customer recruitment to help improve the heat demand density in some areas. Regulatory solutions are also possible (for example, requiring new apartment complexes to connect), but heat demand density also depends on demographics—and in some areas, changing demographics may require adjustments to the longer-term DH expansion plans. Defining performance indicators and targets, as set by the regulator, along with the development and implementation of PIPs by the utilities should be a precondition for any new investments and tariff increases. And improved governance, management, staffing, and training will also likely be necessary, including an assessment of the effectiveness of the regulator with regard to overseeing economic efficiencies and quality of service.

c. Sustainable district heating

While fossil fuels remain the dominant heating fuels in the DH sector in the region, there is an emerging range of possible fuels, technologies, and technological improvements to consider, as well as a range of policy options for incentivizing decarbonization and improving the environmental sustainability of DH systems across ECA. Table III.5 includes a summary of alternative fuels that could offset fossil fuels and help DH systems transition to a more sustainable future, Table III.6 includes information on cleaner technologies that could facilitate the transition of the sector, and Table III.7 includes other measures to help strengthen and decarbonize the sector.

Many of the incentives for cleaner DH have historically focused on supporting large CHP plants, which are more efficient and less polluting than heat-only boilers. Thus, throughout Europe, there are many financial incentives for DH CHPs (e.g., with premia for more efficient CHPs, or guaranteed offtake for co-generators). Annex H summarizes the support schemes provided by various EU countries to CHPs, many of which could also be applied to sustainable DH.

Although EU targets for climate neutrality have not yet been widely translated into policies and regulations supporting the decarbonization of the DH sector, there have been positive developments. The EU's revised Renewable Energy Directive (RED II)[59] includes provisions for RE for heating and cooling, including: (i) a national objective to increase the annual RE for heating and cooling by 1.3 percent each year; (ii) the inclusion of RE-based heating and cooling in local and regional city infrastructure planning; and (iii) information for consumers on RE-based heating and cooling options.[60] A 2022 European Commission report also made a number of recommendations to better quantify, mainstream, and incentivize sustainable heating and cooling at the national level.[61] Similar efforts are underway in a number of other EU countries as well.

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[59] See https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en.

[60] While clean sources such as waste heat and heat pumps can count as RE-based heating under RED II, there are limits. For waste heat, member states: (i) may count waste heat and cold, subject to a limit of 40 percent of the average annual increase; (ii) where its share of RE in the heating and cooling sector is above 60 percent, may count any such share as fulfilling the average annual increase; and (iii) where its share of RE in the heating and cooling sector is above 50 percent and up to 60 percent, may count any such share as fulfilling half of the average annual increase. For heat pumps, only heat pumps with a seasonal performance factor above 1.15 count towards the RE-based heating target.

[61] European Commission, *Overview of District Heating and Cooling Markets and Regulatory Frameworks under the Revised Renewable Energy Directive*, Publications Office of the European Union, 2022, available at https://data.europa.eu/doi/10.2833/962525.

Table III.5: Cleaner Fuels for District Heating

Fuel	Description	Status	Examples
Waste Heat	Industrial waste heat in nearby communities can be captured and fed into DH systems to offset fossil fuels. Can also include water treatment plants, power plants, supermarkets, data centers, etc.	Common in northern and western Europe	Szlachęcin (Poland) installed CHP based on waste heat from a sewage treatment plan for DH; China has several projects using industrial waste heat (e.g., Chifeng in Inner Mongolia, Qianxi City in Hebei)
Biomass/Biogas	Biomass can be collected from agriculture (straw, manure) and forests (wood chips) for use in CHP and heat plants. Biogas, from landfill gas and wastewater treatment plants, can also be used to support heat generation.	Common	Austria, Belarus, Croatia, Estonia, Finland, France, and Sweden all have CHPs that use agricultural waste, wood, and pellets to provide heat
Hydrogen	Most hydrogen is produced through steam reacting with a hydrocarbon fuel (usually natural gas). However, green hydrogen may also be produced through RE-powered electrolytic and biological processes. While not economic today, it could replace natural gas for CHPs	Emerging	As of yet, no commercial applications

Source: Authors.

Table III.6: Cleaner Technologies and Practices for District Heating

Technology	Description	Status	Examples
Heat Pumps	Heat pumps have been deployed in DH for more than 15 years. The most developed systems utilize various heat sources for heat pumps (ambient air; ground soil; sewage; sea, river, and lake water; and various types of industrial, commercial, and residential waste heat).	In use	In use across Europe. Examples include a 105 MW heat pump to support DH and cooling in Helsinki, Finland; a 500 MW heat pump plant in Stockholm using wastewater treatment with water temperatures of 7-22°C; and an 8 MW heat pump installed in Berlin's DH system.
High-Tech Solar Collectors	Allows customers to benefit from solar heat from early morning until late evening, even during early spring and late autumn days due to their enhanced off-center incident radiation performance.	Emerging	In 2019 in Jelling Gronnegade, Denmark, the solar heating system produced ~10,000 MWh, which led to the wood boilers being shut down from April to September when solar production was highest. Solar collector projects are also being considered for several countries in the Western Balkans, with one in Kosovo recently approved[62].
Waste Incineration Based Cogeneration	Waste incineration can produce heat and power in a CHP. Thus, unrecyclable waste can be incinerated for energy production, replacing fossil fuels and reducing carbon emissions.	In use	In Vantaa, Finland, a €300 million waste incineration CHP plant was built in 2014 that now generates 920 GWh of heat and 600 GWh of electricity annually. The plant incinerates 340,000 tons/year of mixed waste in an under-pressure bunker at 1,000°C.[63]
Waste Gasification-Based Cogeneration	Gasification technologies involve a circulating fluidized bed gasification process to partially burn biomass or waste at high temperatures using a controlled amount of air.	Emerging	The CHP plant *Kymijärvi II*, launched in 2012 in Lahti, Finland, gasifies recycled household and industrial waste with advanced gas-purifying technology. The Kymijärvi II plant produces 90 MW_{th} and 50 MW_{e} for Lahti and surrounding cities[64].

[62] https://solarthermalworld.org/news/big-solar-in-kosovo-replaces-coal-based-electric-heating/
[63] Vantaan Energia, "Vantaa Energy progressing towards carbon negativity in 2030," November 2021, available https://www.vantaanenergia.fi/en/vantaa-energy-progressing-towards-carbon-negativity-in-2030/
[64] https://makron.com/en/references/lahti-energia-s-unique-gasification-plant.

Biomass Gasification	Gasifying biomass to biogas to substitute for coal in an existing CHP plant would not require any retrofits to the existing CHP plant, as the biogas would be mixed with the inlet combustion air.	Not widely used	One of the largest gasifiers with a capacity of 140 MW integrated into an existing power plant was commissioned in 2012 in the city of Vaasa, Finland. The capacity of the existing coal boiler is 560 MW, and the plant generates 230 MW_e and 170 MW_{th}.
Low-temperature DH	Low-temperature DH reduces energy needs by taking an integrated approach to rely on more localized, often RE sources to provide space and water heating—minimizing the need for higher, centralized DH temperatures.	In use	A number of (mostly experimental) systems have been developed in Denmark, the UK, Canada and Germany

Source: Authors.

Table III.7: Other Decarbonization Options for District Heating Systems

Option	Description	Status	Examples
Heat Storage	Heat storage (e.g., a hot water tank) can reduce the need for fossil-fuel boiler use by shaving peak loads and operating when clean heat options are not available. It also smooths the daily heat load variation caused by the domestic hot water and air conditioning systems and can be replenished at night when loads are low. It can also act as a water emergency source in case of a network burst to maintain the static pressure. Storage can also allow coupling with electricity systems, so excess RE electricity supply can be converted to stored heat.	In use	Several of Austria's DH companies use heat storage in the form of thermal energy storage towers. Hamburg is using excess wind energy to run electric boilers for DH. They are also piloting an aquifer thermal storage system which will pump hot water 1.3 km underground to deploy as needed for DH heat supply.
Building-level substations	Moving centralized substations and heat exchangers to the building (BLS) can convert DH to a more modern demand-driven mode. The demand-driven mode, combined with consumption-based billing, provides tools and incentives to customers to save heat energy.	In use	In Finland, each building has its own substation separating the responsibility of the DH company and the building owner. The BLS is owned by the customer and provides both space heating and DHW.
District cooling	District cooling can offer a more economical and environmentally sound option than individual cooling. The advantages include lower operating costs and competitive capital investments; environmental sustainability (because of the ability to use existing low-temperature sources); and high operational safety, flexibility, and availability.	Emerging	More than a dozen DH companies in Finland and Sweden were providing district cooling in 2021.

Source: Authors.

Box III.2 describes how DH in Finland is becoming more sustainable.

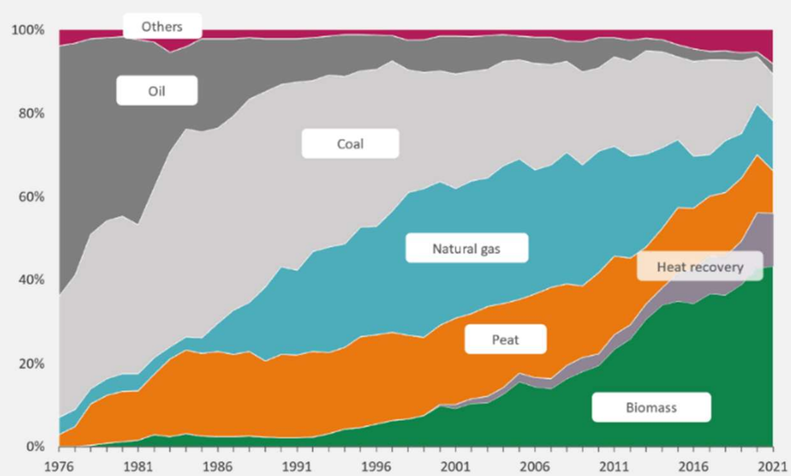
Box III.2: Sustainable District Heating in Finland

Finland, the coldest country in the EU, has had DH services since the 1950s. There are more than 200 DH systems in Finland, served by 112 utilities (mostly municipal limited stock companies) and 68 industrial companies. In cities where there is sufficient population density to support it, DH covers more than 90 percent of the heat demand; nationwide, it meets about 45 percent of the overall heat demand. Finland's DH and cooling with CHP has been recognized as global best practice by the United Nations, the Euroheat & Power network, the International Energy Agency, and the International District Energy Association.

District heating in Finland relies heavily on CHP plants, where cogeneration of electricity and heat is about 30 percent more efficient than generating them separately. Between 2010 and 2019, CHP production rose from 71.3 percent to 74.4 percent.

Finland has ambitious climate targets. It is on track to be carbon neutral by 2035 and to gradually become carbon negative thereafter. Power generation is already 80 percent carbon neutral (with generation from nuclear, hydropower, and wind); DH is also making progress toward becoming carbon neutral, as shown in Figure III.3. Fossil fuels have increasingly been replaced by biomass and recovered heat: biomass use has more than doubled in the last decade, while the amount of recovered heat has more than tripled over the same period.

Figure III.3: District Heating and CHP Fuel Mix in Finland, 1976–2021



Finland's DH companies also have exceptional technical and financial performance. Less than one percent of pipeline length needs to be replaced annually because of a long history of preventive maintenance, including the use of well-treated water and pre-insulated pipes to prevent corrosion. Network heat losses are low (less than 9 percent, compared with 15–40 percent in transition economies) and heat generation is highly efficient (93 percent compared with 60–90 percent in transition economies). Profitability is high (10–20 percent, whereas DH profitability in transition economies is usually either quite low or negative), even though Finland's heat tariffs are among the lowest in Europe relative to purchasing power. The government provides no operational subsidies.

Heating companies in Finland are also becoming more sustainable by exploring new business lines and practices. More than a dozen DH companies provided district cooling in 2021; cooling supplements the existing heating business because it serves the same customers using the same technology. Moreover, cooling demand is likely to increase while heating demand decreases because of climate change and improved energy efficiency in buildings. Some companies engage in heat trading with neighboring companies through heating networks that are interconnected with heat exchange systems; the direction of trade depends on the prevailing marginal prices.

Some smaller (and usually more rural) systems operate remotely, with heat generation and distribution happening automatically. Local entrepreneurs are contracted, on a competitive basis, to ensure sufficient biomass is available in the boiler plant's fuel bunker, and there is 24-hour online monitoring of these remote systems.

Sources: Carolyn Gochenour, *Regulation of Heat and Electricity Produced in Combined-Heat-and-Power Plants* (Washington, D.C.: The World Bank, 2003); Finnish Energy Association, *District Heating in Finland*, 2010–2019 editions (Helsinki: Finnish Energy Association, 2011–2020).

IV. Economics of Individual Sustainable Heating Options

Main Messages:

- In each country, for areas where DH is not available or viable, an economic analysis should be done for specific locations to determine the lowest levelized cost of heating (LCOH) for a range of heating fuels and technologies. The government should then develop policies and programs around promoting these fuels and technologies.
- For this report, indicative LCOH analyses were conducted for a sample of MFBs and SFHs in urban and rural areas in six countries: Armenia, Kyrgyz Republic, Poland, Serbia, Türkiye, and Uzbekistan. Where available, DH represents the lowest cost in both financial and economic terms. For urban SFHs and MFBs, air-to-air heat pumps generally have the lowest LCOH for homes without internal heat distribution systems; condensing gas boilers often have the lowest LCOH (both economic and financial) for homes with internal piping. In rural SFHs, air-to-air heat pumps and eco-design biomass (wood) stoves generally have the lowest economic LCOH.
- Distortions in fuel pricing remain the biggest barrier to selection of the most economically viable options for households. Combining the replacement of heating systems with thermal renovations does increase the upfront costs but can substantially lower recurring heating costs. Some systems, such as DH and heat pumps, can also help meet cooling loads, which have grown in recent years.

This chapter assesses options for individual or building-level heating solutions in ECA where DH is not available or viable. Analyses were conducted to include the levelized cost of heating (LCOH), in both financial and economic terms, in six countries chosen in consideration of geographical spread, income levels, and data availability. While heating technologies are constantly evolving, those assessed in this chapter include those that are both commercially viable and readily available. The analyses identify which individual heating solutions may be technically, economically, and financially viable low-emission alternatives to traditional options (e.g., solid fuels such as coal and firewood), which are highly polluting, both in terms of GHG emissions and local air pollution. The financial analyses determine which heating options are most cost-effective from an individual consumer's cashflow perspective, while the economic analyses[65] determine the most viable technologies for the country as a whole by including externality costs such as GHG emissions and health impacts due to air pollution.

a. Heating options evaluation

The study evaluated heating options for a sample of residential buildings in urban and rural locations (selected based on the availability of data) in six countries in the ECA region: Armenia, Kyrgyz Republic, Poland, Serbia, Türkiye, and Uzbekistan. Table IV.1 provides information on the locations included in the study and a breakdown of the residential building stock, including SFHs, MFBs, and other residential buildings (which typically include townhouses)[66]. The study included an assessment of an urban and rural location for each selected country. The full methodology is included in Annex I.

[65] The key challenge for the economic analysis was the lack of available data, including the level of implicit and explicit subsidies. Evaluating the level of subsidies would require a separate study of the fuel sources in each country. Some of the fuel pricing is also difficult to assess (e.g., for firewood), while DH and electricity tariffs would require sector-wide assessments.

[66] Building types that did not represent at least 20 percent of the residential building stock in each location were not included in the analyses.

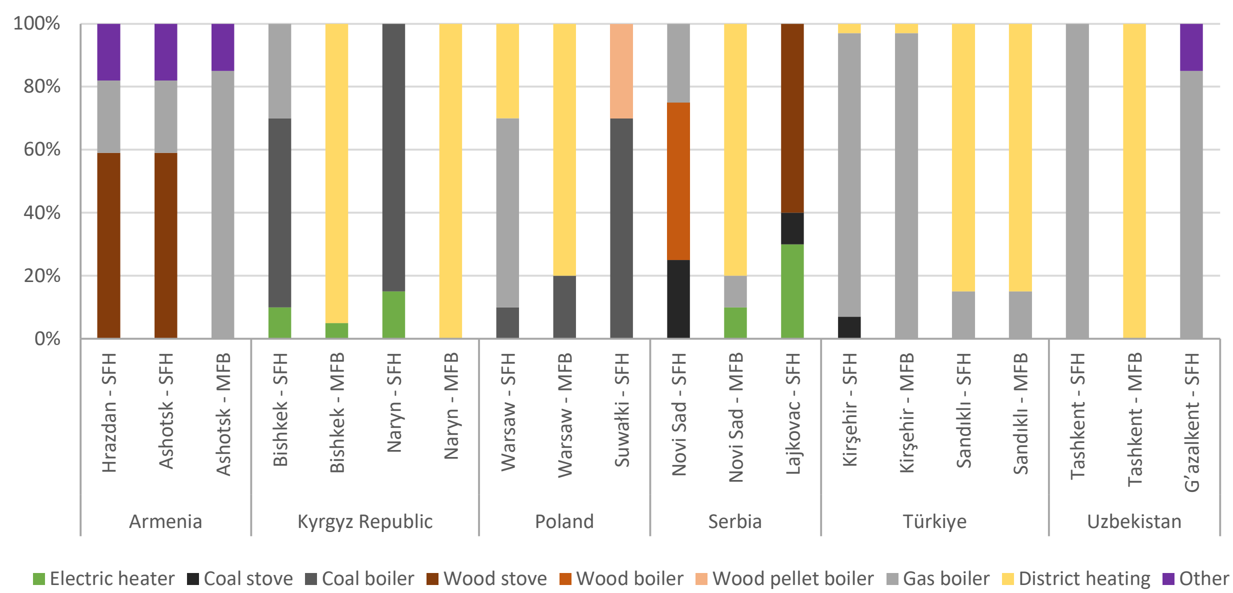
Table IV.1: Locations and Building Stock Included in the Study

Country	Location	Location Population	Avg. Jan. Temperature	Heating Degree Days*	Residential Building Stock		
					SFH (%)	MFB	Other
Armenia	Hrazdan (urban)	39,900	-5.9 °C	3,410	93%	7%	n/a
	Ashotsk (rural)	9,300	-6.8 °C	3,916	**57%**	**43%**	n/a
Kyrgyz Republic	Bishkek (urban)	1,059,075	-3.9 °C	2,573	**60%**	**35%**	5%
	Naryn (rural)	41,178	-14.8 °C	4,575	**60%**	**40%**	n/a
Poland	Warsaw (urban)	1,795,569	-1.9 °C	2,678	**79%**	**20%**	1%
	Suwałki (rural)	7,867	-3.9 °C	3,116	97%	3%	n/a
Serbia	Novi Sad (urban)	363,789	0.8 °C	2058	**40%**	**60%**	n/a
	Lajkovac (rural)	14,407	-0.3 °C	2,047	96%	4%	n/a
Türkiye	Kirşehir	115,078	-0.2 °C	2,057	**20%**	**75%**	5%
	Sandıklı	37,804	0.4 °C	2095	**35%**	**65%**	n/a
Uzbekistan	Tashkent (urban)	2,934,137	0.3 °C	1711	**42%**	**56%**	2%
	G'azalkent (rural)	21,600	-4.7 °C	2,836	95%	5%	n/a

Sources: World Bank reports and expert estimates.
Note: Percentages in bold indicate that building type is included in the assessment for that location.
* *Heating degree days* compare the average outdoor temperature recorded at a location with a standard base temperature; the base temperature indicates the temperature below which buildings are generally heated. Heating degree days are therefore a proxy for the energy needed to heat a building. A high number of degree days usually results in higher energy use for space heating.

The study also analyzed heating technologies utilized in the sample buildings. Figure IV.1 shows space heating systems' prevalence in each building type and location.

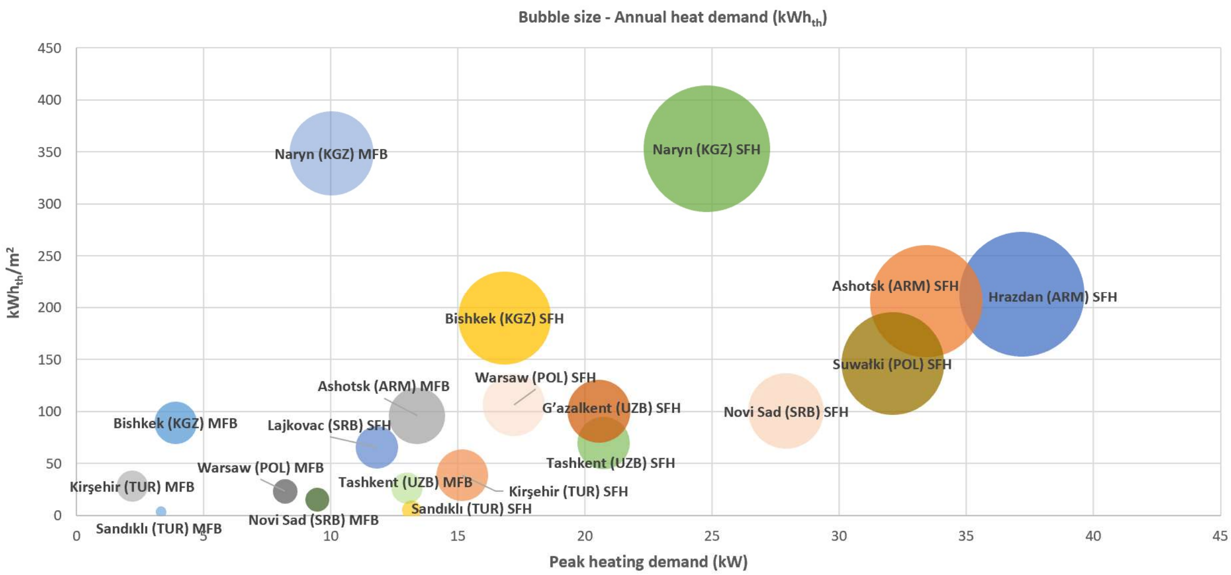
Figure IV.1: Prevalence of Heating Technologies



Source: World Bank reports and expert estimates.
Note: MFB = multifamily building; SFH = single-family house.

After analyzing the buildings sector and the heating technologies utilized, a heating demand assessment was performed. The DesignBuilder software tool was used to run the required building energy modeling. Results included annual heat demand, peak heating demand, and specific energy consumption for each building type (Figure IV.2). The range of building types and locations was helpful to understand the impact of various demand scenarios on the LCOH results.

Figure IV.2: Annual Heat Demand (kWh_{th}), Peak Heating Demand (kW) and Specific Energy Consumption (kWh_{th}/m^2) by Building Type and Location



Sources: World Bank reports and expert estimates.

To evaluate the heating options, alternatives to conventional heating systems were assessed. Figure IV.3 provides an overview of individual space heating technologies and sustainable alternatives that are available in the selected countries.

Figure IV.3: Summary of Space Heating Technologies

Conventional Heaters

Technology	Types of Heater	Fuel	Efficiency
Solid fuel stoves	Wood stove	Firewood, wood pellets	50%
	Coal stove	Coal	50%
Solid fuel boilers	Wood boiler	Firewood	50%
	Wood pellet boiler	Wood pellets	74%
	Coal boiler	Coal	50%
Electric resistance heaters	Electric heater	Electricity	100%
Natural gas boilers	Conventional gas boiler	Natural Gas	79%
DH	n/a	Mostly fossil fuels (natural gas, coal)	Varies by system

Sustainable Heaters

Technology	Types of Heater	Fuel	Efficiency
Solid fuel stoves	Eco-design wood stove	Firewood, wood pellets	73%
Solid fuel boilers	Eco-design wood boiler	Firewood, wood pellets	75%
Natural gas boilers	Condensing gas boiler	Natural Gas	90%
Heat pumps	Air-to-air heat pump	Electricity	300%
	Air-to-water heat pump	Electricity	250%
	Ground-source heat pump	Electricity	350%

Sources: World Bank reports and expert estimates.

Even though a number of alternatives were present, local aspects were crucial for evaluating heating options. The study selected feasible sustainable alternative technologies (with and without requiring internal distribution systems) to replace conventional equipment in the selected locations. This is important because an apartment using an electric heater could install an air-to-air heat pump[67], but may not be able to switch to an efficient wood stove or air-water heat pump due to the lack of associated infrastructure (e.g., chimney, radiator systems, internal piping).

Therefore, for this assessment, sustainable alternatives that do not require building-level internal distribution systems, such as air-air heat pumps and eco-design wood stoves, would be considered feasible options for existing wood and coal stoves. For homes with electric heaters, only air-air heat pumps were considered. For sustainable alternatives in buildings with internal distribution systems, such as condensing gas boilers and air-water heat pumps, all conventional technologies—existing wood, coal and gas boilers, and district heating—were considered. Eco-design wood boilers and wood pellet boilers were considered to be viable alternatives only for existing wood and coal boilers. Box IV.1 discusses the sustainability of biomass in the energy sector.

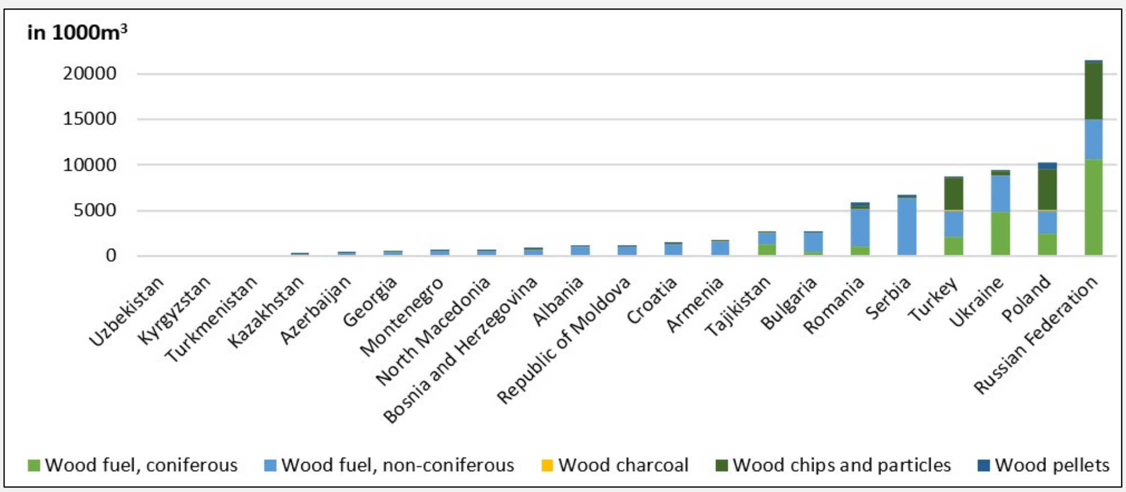
Box IV.1: Is Biomass Use for Energy Sustainable?

Biomass is defined as a solid, plant-based material used as fuel to produce heat or electricity. Examples are wood and wood residues, energy crops, agricultural residues, and waste from industry, farms and households. The EU's Joint Research Centre uses the concept of *solid biofuel,* which is defined as raw or processed organic matter of biological origin used for energy—for instance, firewood, wood chips, and wood pellets (EU 2019).

Modern biomass provided 5.1 percent of total global final energy demand in 2019, accounting for around half of all RE in final energy consumption. Biomass-based heat demand in buildings grew by 7 percent per year from 2009 to 2019. One third of the global forest area is used for wood production or other commercial purposes, and forests provide 85 percent of all biomass used for energy globally. In the EU, forests provide 60 percent of all biomass used, mostly in the form of wood residues and waste.

The principal source of biomass energy in the ECA region is wood. While Africa and Asia are the biggest producers of wood fuels at the global level, the EU and North America are the biggest producers of pellets. However, the availability of biomass in the ECA region varies significantly between countries. Figure IV.4 shows the results of the analysis of the domestic availability of biomass energy—defined as the domestic production plus imports minus exports. It provides a snapshot of the average domestic availability of biomass products. However, this chart does not show the absolute potential for producing biomass products or the potential for future trade within and with ECA.

Figure IV.4: Average Domestic Availability of Wood Energy Products in the ECA Region



Source: EU (2019)

Technical potential. The IEA considers bioenergy an important source of RE and has concluded that current use is well below the levels required in future low-carbon scenarios. The IEA estimates that 9.5 exajoules (EJ) of heat energy for industrial applications was consumed, and 5 EJ of heat

[67] Carbon emissions for electricity-based heating technologies (electric heater and heat pumps) are based on the country's grid emissions factor and adjusted by the efficiency of the technology. A linear reduction was applied to grid emissions factors in each country to reach net zero by 2050.

for buildings in 2020; most of the global bioenergy is produced from forest resources. In IEA's "Net Zero by 2050" scenario analysis, traditional bioenergy would be phased out by 2030, and modern bioenergy's share of the total energy supply would increase from 6.6 percent (2020) to 13.1 percent (2030) and 18.7 percent (2050). A similar analysis by the International Renewable Energy Agency (IRENA) from 2014 projected a doubling of energy produced from biomass in 2030. The Intergovernmental Panel on Climate Change (IPCC) also concluded that most of its mitigation pathway scenarios include substantial contributions from bioenergy.

All these projections are subject to a complex set of parameters that determine competitive land uses—and determine how much land could be used to produce bioenergy. Following analyses by the Food and Agriculture Organization (FAO) and the International Institute for Applied Systems Analysis (IIASA) in 2000 and by the FAO in 2012, IRENA stated in their 2014 report that about 1.4 billion hectares of additional land is suitable but unused to date and thus could be allocated for bioenergy supply. Similar analyses have been executed by the IPCC and EU, although similar limitations apply regarding the future development of competitive land-uses.

***Source**: "*Background note on Sustainable Biomass for Energy Supply" (unpublished), World Bank, 2022; REN21 (2021): RENEWABLES 2021 – Global Status Report. A comprehensive annual overview of the state of renewable energy (https://www.ren21.net/gsr-2021/); European Commission (2019): Brief on biomass for energy in the European Union. The European Commission's Knowledge Center for Bioeconomy, European Union 2019; IRENA (2014): Global bioenergy supply and demand projections. A working paper for Remap 2030, IRENA, Bonn 2014.

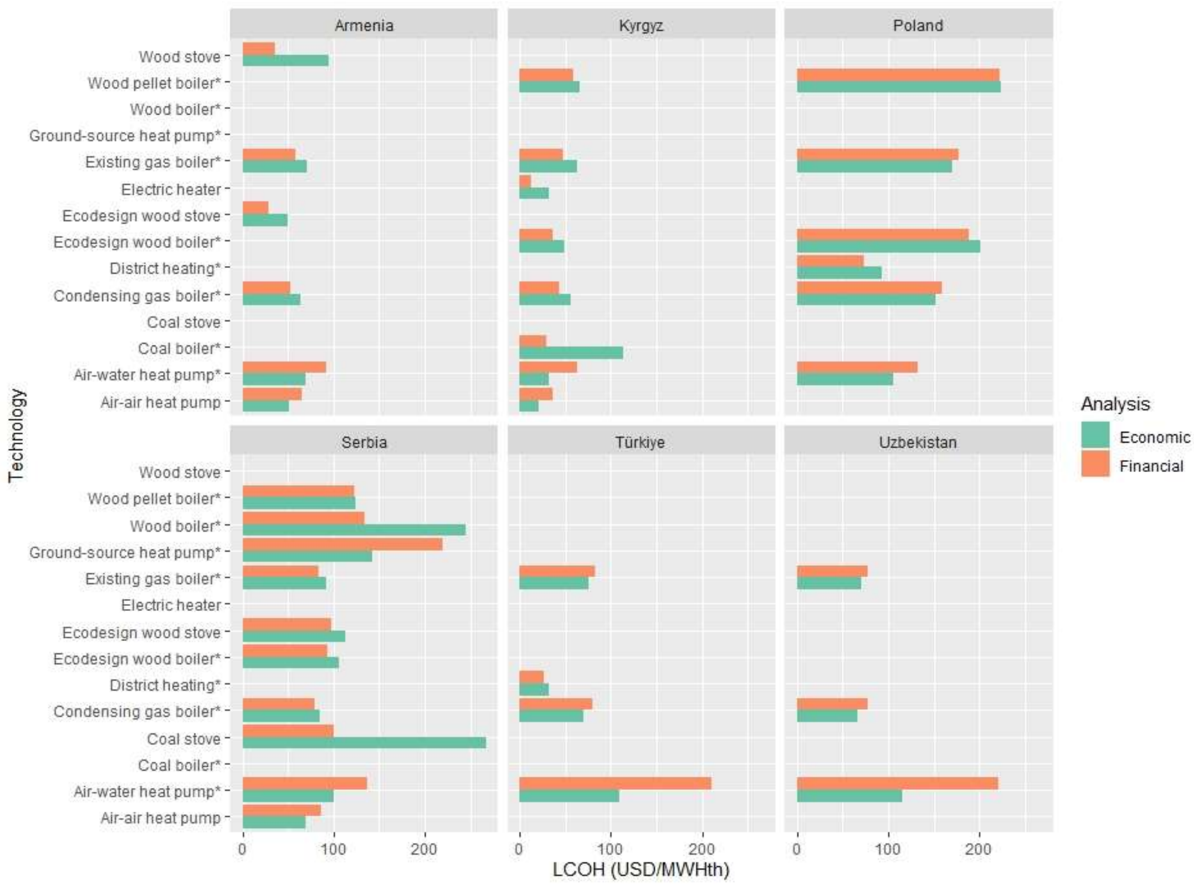
b. Summary of results

The results are here presented in three categories: urban SFHs, urban MFBs, and rural SFHs.

1. Urban SFHs

In urban SFHs, where available, DH was always found to have the lowest cost in both the financial and economic analyses. Among technologies that did not require internal distribution systems, air-to-air heat pumps were usually lowest-cost (except in Armenia, where firewood prices are very low). For technologies that do require internal distribution systems, condensing gas boilers were usually the lowest-cost in both the financial and economic analyses because of their low capital expenditure (CAPEX) costs when compared with air-to-water heat pumps and, in most countries, considerably lower fuel prices for natural gas than for electricity. The only exceptions are the Kyrgyz Republic (where air-to-water heat pumps are lowest-cost because of low electricity prices and a clean electricity grid) and Poland (where air-to-water heat pumps are lowest-cost because electricity prices, combined with the heat pump's greater efficiency, result in much lower levelized fuel costs than for condensing gas boilers). In Türkiye and Uzbekistan, the high LCOH for air-water heat pumps is due to the high CAPEX and lower demand, which reduces some of the efficiency advantages of the heat pumps. Figure IV.5 summarizes the LCOH results for urban SFHs.

Figure IV.5: Summary of Levelized Cost of Heating Results in Urban Single-Family Houses



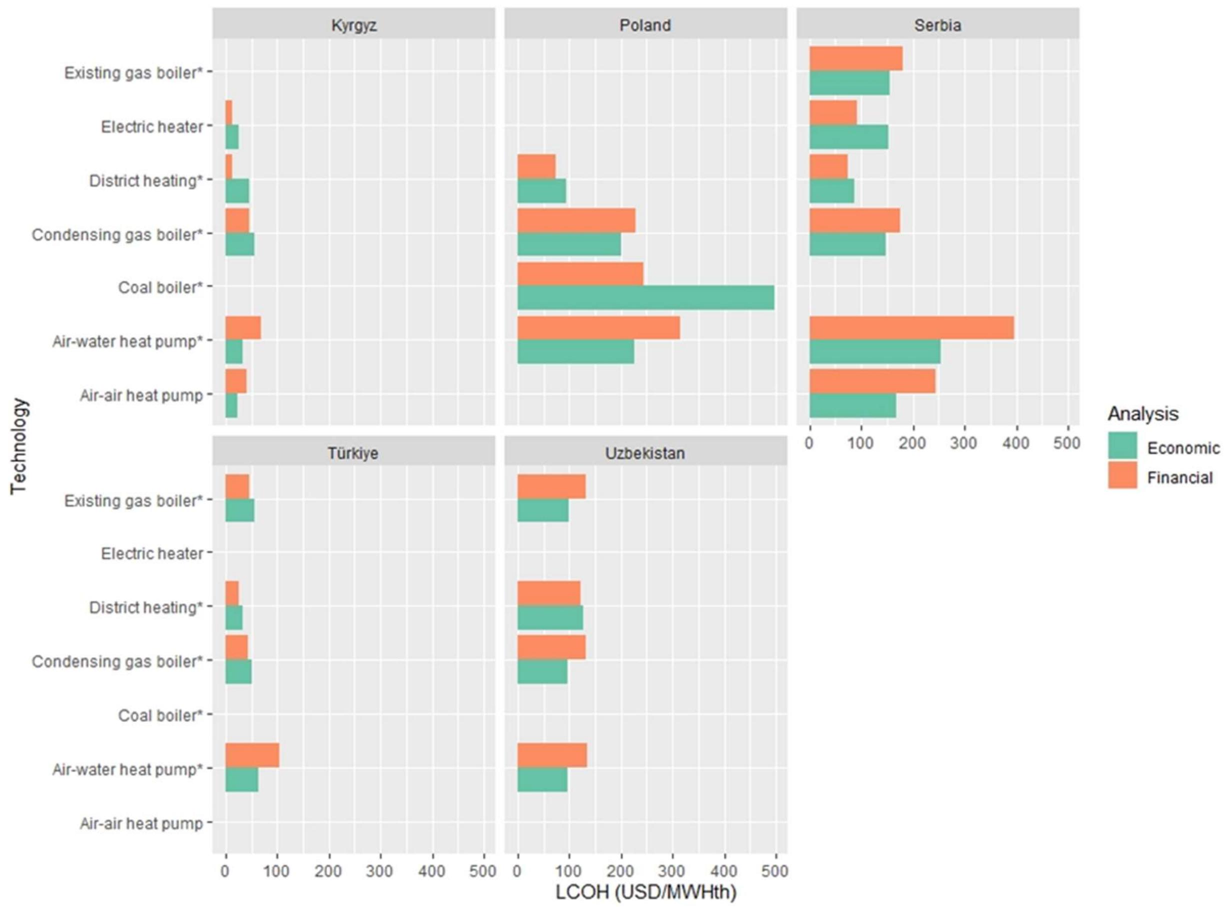
Sources: World Bank reports and expert estimates.

***** Technologies marked with an asterisk have internal distribution systems.

2. Urban MFBs

For Urban MFBs, DH offered the lowest cost in the financial analysis among technologies with internal heat distribution systems. In the economic analysis, DH was usually the lowest-cost, except in the Kyrgyz Republic (where it was electric heating and air-to-air heat pumps) and Uzbekistan (where it was gas boilers). In the case of Uzbekistan, DH could be the lowest-cost option in some scenarios if the DH customers had universal consumption-based billing. Among technologies without distribution systems in the Kyrgyz Republic and Serbia, electric heaters were lower-cost in the financial analysis, but heat pumps were lower-cost in the economic analysis because they are more efficient and therefore result in lower carbon emissions. In Poland and Serbia, condensing gas boilers had the lowest cost in the economic analysis because the countries' coal-dependent electricity grids made heat pumps less economic. Figure IV.6 summarizes the LCOH results for urban MFBs.

Figure IV.6: Summary of Levelized Cost of Heating Results in Urban Multi-Family Buildings



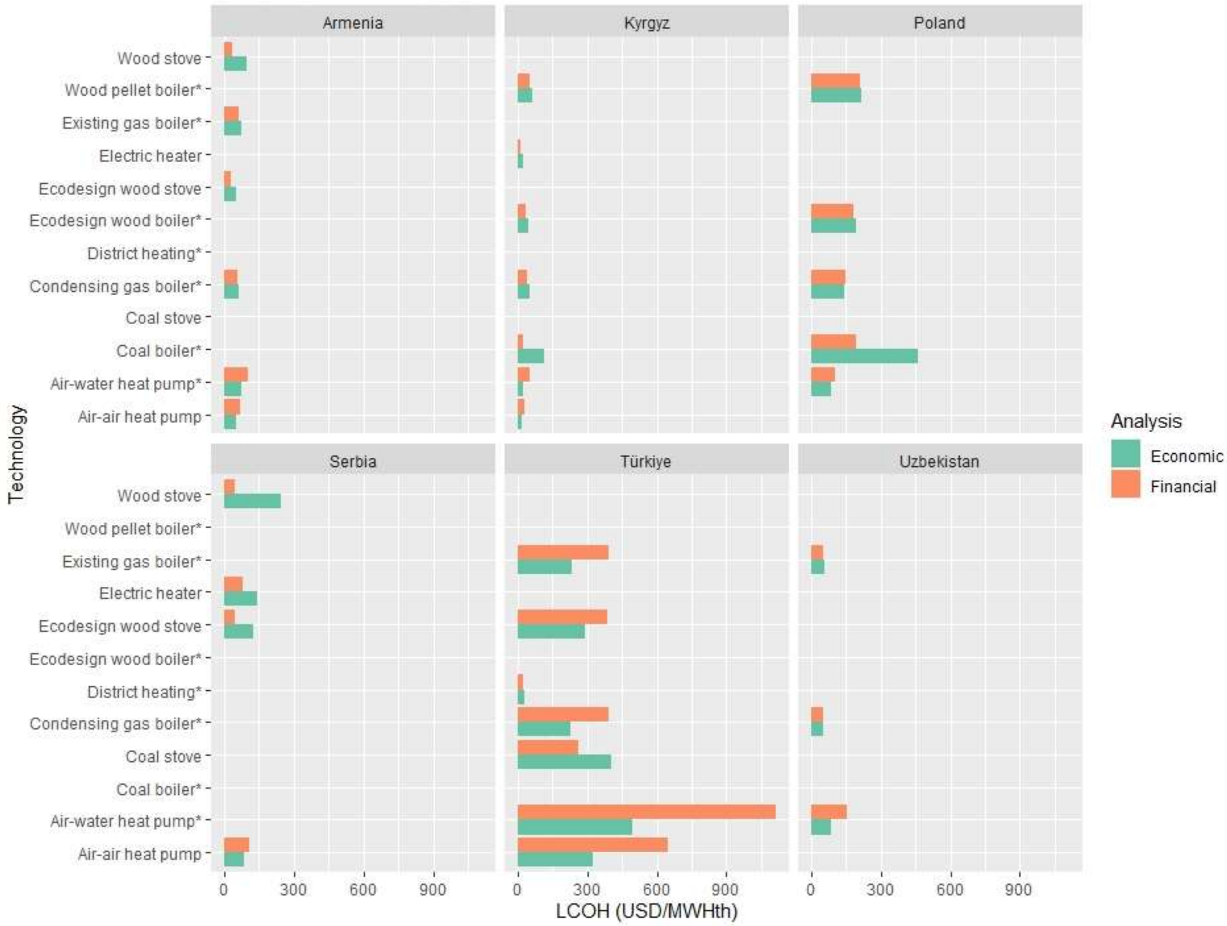
Sources: World Bank reports and expert estimates.

* Technologies marked with an asterisk have internal distribution systems. The city included for Armenia only had about 7% MFBs, so they were excluded from this analysis.

3. Rural SFHs

In rural SFHs, conventional wood, coal, and gas heating systems generally had the lowest cost in the financial analysis because they have lower CAPEX, fuel, and maintenance costs than the more-sustainable alternatives. However, in the economic analysis, eco-design wood stoves and air-to-air heat pumps were generally lower-cost because of their environmental benefits. Note that LCOH values in Türkiye were all higher because of lower demand, while LCOH values in Poland were higher because of high peak demand combined with comparatively high energy prices. Figure IV.7 summarizes the LCOH results for rural SFHs.

Figure IV.7: Summary of Levelized Cost of Heating Results in Rural Single-Family Houses



Sources: World Bank reports and expert estimates.
* Technologies marked with an asterisk have internal distribution systems.

c. Sensitivity analysis: energy efficiency

A sensitivity analysis was also conduced to assess how payback periods were impacted when energy efficiency investments were incorporated. Buildings in four countries (Kyrgyzstan, Poland, Serbia, and Uzbekistan) were modeled to include energy efficiency investments—with insulated walls and efficient windows—alongside the heating upgrades. (Annex I presents detailed results from the sensitivity analyses.)

The sensitivity analysis concluded that while energy efficiency investments (thermal renovations) do allow for lower-capacity heating systems to be installed and can substantially reduce overall energy use (and thus energy bills), the high investment cost for energy efficiency measures can have an adverse impact on the overall payback period. In the case of a Bishkek SFHs, for example, the payback period improved when energy efficiency was combined with switching from a coal boiler to a more sustainable option (e.g., biomass, air-to-air heat pump). The very low price of coal resulted in almost all the sustainable alternatives (except air-to-water heat pumps) being unable to pay back the investment cost; so, combining the sustainable heating investment with energy efficiency improved the payback period. However, when assessing the replacement of a gas boiler with a more sustainable option, the payback period of the heating replacement combined with energy efficiency measures increased considerably, due to the high investment cost for energy efficiency and low electricity prices.

Payback periods also differ substantially by country, type of building, and technology. Poland and Serbia have the lowest average payback periods—when measured on a financial basis—after investments in energy efficiency, while the Kyrgyz Republic has the highest repayment periods, pointing to energy pricing as a key factor.[68]

Overall, investments in energy efficiency had positive impacts, with the median payback period being reduced by nearly 60 years.[69] Another noticeable difference was between MFBs and SFBs: MFBs showed the lowest payback periods when combining heating replacements with energy efficiency investments, while SFH had the highest payback periods. This analysis concludes that reforms to better reflect actual fuel costs are crucial to improve the payback periods of investments combining energy efficiency with sustainable heating replacements, while helping the transition to be affordable to households. It also shows, however, that government incentives may be needed in areas where the energy efficiency investment costs may be much higher, such as SFBs.

d. Conclusions and policy implications

The LCOH analyses revealed some commonalities among countries and building types in the region. Based on that, six conclusions have emerged:

1) ***Efficiency matters, but so does pricing.*** Efficient heating technologies may not always be least-cost on a financial basis, but they are almost always least-cost on an economic basis. Even with the most efficient technologies, customers will be deterred from switching to more sustainable heating options if the conventional fuel prices are low. In addition, the analysis shows that, depending on the current fuel used, energy efficiency investments can increase payback periods given their high upfront investment cost and longer payback periods. Distorted pricing can also substantially skew the ranking of heating technologies and fuels and can incentivize some fuels over others, regardless of which is cleaner or more economic. Thus, the elimination or phasing out of fossil fuel, electricity, and DH subsidies remains important.
2) ***Parallel investments in energy efficiency need to be encouraged.*** Energy efficiency investments can reduce the peak heat demand, heating system size, and monthly heating bills—while improving indoor comfort levels and making the transition more affordable for households. Therefore, combining heating systems and energy efficiency should be encouraged. Governments should also consider incentives to ensure the most economic fuels and technologies are selected for promotion.
3) ***Recognize externalities.*** Governments should consider economic least-cost heating options in their sustainable heating plans based on LCOH or similar analyses. In addition, the introduction of pricing reforms (along with a mechanism to account for environmental externalities, such as a carbon tax) should be considered to encourage the adoption of cleaner technologies and fuels. For firewood or wood pellets, proper certification and pricing is needed to build in mechanisms

[68] Negative payback periods (in which there is no savings from switching) were ignored.
[69] On a financial basis, considering only those investments in which payback periods are reduced when combined with investments in energy efficiency.

to allow for sustainable biomass production and to avoid unsustainable consumption or overuse, as well as excess air pollution.

4) ***DH remains economically least-cost.*** Where available, DH is nearly always the lowest-cost option in both the financial and economic analysis. The exceptions are in countries such as the Kyrgyz Republic and Uzbekistan, where pricing distortions or more polluting DH fuels incentivize other heating alternatives. In the Kyrgyz Republic, DH has a higher economic cost than heat pumps because the fuel used to generate heating in the DH system (predominantly coal) is so much dirtier than the hydropower-dominated electric grid. In Uzbekistan, gas-burning technologies and DH have similar LCOH in urban MFBs; thus, even a slight increase in DH tariffs (8 percent) would make condensing gas boilers least-cost on a financial basis. One reason could be the fact that norm-based billing is still used for DH in MFBs and, thus, bills do not reflect actual consumption.
5) ***Cooling will become more important.*** Technologies that also offer cooling capabilities, such as air-to-air and air-to-water heat pumps, can operate during more months in a year and therefore be more competitive than heating-only options. In fact, the effects of climate change are already showing major heat waves across Europe and much of ECA, pointing to the growing cooling demand in the region. Therefore, a more in-depth analysis should consider future cooling loads. It is also the case that thermal renovations of buildings would be more financially attractive if the impacts of reduced cooling loads were considered in the analysis.
6) ***Consider consumer preferences.*** There are examples of cleaner technologies that, despite having the lowest financial LCOH and better heating services, are ultimately not selected by households due to consumer preferences and other nonfinancial considerations. Households generally do not evaluate investments on a levelized-cost basis. They are unlikely to view the costs of their existing heating system as a sunk cost; they will want to "recover" the cost of that investment by using the equipment for as long as they can. Alternatively, they may simply not have the cash available to pay the upfront cost of the more sustainable heating technology and be unable, or unwilling, to borrow. This points to the importance of government incentives, access to affordable local financing, good information, and after-sales service (e.g., access to spare parts, repairs). Other criteria often used by households to evaluate heating investments include[70]:
   - *Predictability of monthly or annual energy expenditure, fuel supplies.* Predictability often has an inherent value as it helps households to manage monthly cash outlays and ensure access to fuels locally.
   - *Social acceptability and familiarity.* Some technologies may be more attractive to consumers in certain circumstances (for example, more-efficient woodstoves in rural areas), and hence may be better positioned for quicker uptake than other, less familiar technologies.
   - *Sustainability.* Some heating options may be attractive with the availability of grants and other incentives, but may be less attractive if they cannot be implemented through existing distribution channels or business models that allow for proper maintenance and repairs (including access to spare parts), operation, and replacement of equipment over time.

[70] These are some of the consumer criteria that policy makers should keep in mind as they evaluate cleaner heating options and look for ways to encourage the use of such options.

V. Framework for Transitioning to Sustainable Heating

Main Messages:

- The proposed framework for sustainable heating is based on three sequential pillars: (i) reduce heating demand through promoting energy efficiency in buildings and changing user behaviors; (ii) bolster and decarbonize centralized DH where viable; and (iii) promote clean building-level heating systems where DH is not economically feasible.
- The use of geospatial tools, integrated resource mapping, and long-term data-driven planning can help governments make more-informed decisions about sustainable heating options in a more systematic way. Collectively referred to as a *sustainable heating roadmap* (SHR), this approach can help policy makers analyze a complex set of technical, economic, environmental, and social considerations through one integrated platform as they work to optimize a country's or region's economic resource potential. An SHR can be a powerful tool for incorporating national and local objectives and plans to be integrated—looking across building strategies, energy efficiency potential, areas that can be supplied with central and individual heating, the potential of RE and other heat sources, heat and population demand trends, and other factors.

ECA policy makers planning the transition to sustainable heating must seek to address the current heating situation in their countries (as described in Chapter II) while considering options for both district-level and building-level heating (Chapters III and IV). Based on this report's analysis, a framework for transitioning to sustainable heating has been developed and is presented in this chapter.

a. Reduce demand, decarbonize district heating, promote clean individual heating

As shown in Figure V.1, the proposed framework for sustainable heating is based on three pillars: reduce heating demand through energy efficiency in buildings and changing behaviors, bolster and decarbonize centralized DH where viable, and promote clean building-level heating systems where centralized heating is not economic. Each of these will be discussed in turn.

Pillar 1: Reduce demand through building renovations

Energy efficiency in the building sector remains one of the lowest-cost options for helping meet the sustainable heating challenge by substantially reducing heat demand. With a reduction in heat demand, substantially less investment will be needed for new, cleaner heating systems (both for DH and individual). This means lower heating capacity on the DH network and smaller heating units in the individual buildings. Investments in energy efficiency also provide a variety of complementary benefits—such as more comfortable indoor temperatures (fewer leaks and less heat loss), lower heating bills, higher property value, increased operating life of the building, lower subsidy needs (lower social assistance requirements), enhanced energy security, and better overall health.

Figure V.1: Proposed Framework for Sustainable Heating

Source: Authors.

The renovation of existing buildings includes building envelope measures (roof/wall insulation, windows, doors), DH-related building and systems upgrades (building-level substations, horizontal piping, thermostatic radiator valves, heat cost allocators), water heating, pumps/fans, lighting, and rooftop solar PV. These building renovations can also include necessary non-energy-efficiency measures such as rewiring, minor structural repairs, painting, seismic strengthening, or ventilation. For public buildings, these investments generally have payback periods of under 15-20 years, so they can often pay from energy savings with longer loan tenors (Table V.21). The cost of energy savings is generally low (1.7-9.4 US¢/kWh), which compares favorably to the cost of heat supply (about 1-14 US¢/kWh for DH supply and about 5-15 US¢/kWh for individual heating options), although it should be noted that some of the heat supply costs do not reflect full cost-recovery levels.

Table V.1: Energy Efficiency Public Building Renovation Investment Costs and Impacts from World Bank Portfolio

Project name	No. of buildings renovated	Total investment (USD millions)	Lifetime energy savings (MWh)	Investment cost (USD/m2)	Energy savings cost (USD/kWh saved)
Montenegro Energy Efficiency (2009-18)	49	11.77	147,139	99.8	0.094
Armenia Energy Efficiency (2012-16)	124	9.58	540,200	24.4	0.019
Kazakhstan Energy Efficiency (2013-2022)	81	12.42	227,452	37.12	0.055
Kosovo Energy Efficiency and Renewable Energy (2014-present)	87	12.77	752,347	43.85	0.0167
Bosnia and Herzegovina Energy Efficiency (2014-present)	154	36.3	1,327,462	82.9	0.027
Serbia Enhancing Infrastructure Efficiency and Sustainability (2017-present)	149	75.67	483,333	180.85	0.156

Source*:* World Bank project ICRs, ISRs and project data.

Energy audits should be done to identify potential energy efficiency measures and determine the most optimal investment packages in order to maximize the energy savings for a given payback period threshold or discount rate. Noninvestment costs—such as energy audits, technical designs, energy savings monitoring, metering, and measurement and verification (M&V)—should also be considered. When economic costs and benefits are considered (which would include benefits from improved air quality, CO_2 reductions, improved service levels, increased building operating life, etc.) the economic viability improves substantially. For residential buildings, including MFBs and SFBs, payback periods can be longer (20-30 years), especially if the buildings are older and require additional structural measures, so some investment subsidies are often required. Nodal agencies (see below), dedicated funds, public energy service companies (ESCOs), and other institutional setups are often used to help finance and scale-up the pace of building renovations.

Building codes and building energy performance certificates (e.g., Class A, B, C in the EU) are critically important in terms of setting standards and norms, particularly for new buildings. Because countries with growing populations (e.g., Türkiye, Uzbekistan) will likely see substantial new construction, very high energy performance standards and strong enforcement will be important. Building performance labels and certificates can also help buyers identify high-performance buildings and estimate monthly energy bills, which can help influence their purchasing decisions.

Building renovation programs also require a stronger institutional support structure. Many governments have established so-called "nodal" agencies, such as EE agencies or departments, to provide an overall framework for government programs, advise on policies and provide information, develop model tender documents, implement awareness campaigns, and assist public agencies in reducing their energy use. Others have developed financing schemes (using public financing, energy efficiency revolving funds, credit lines through commercial and development banks, etc.) to support such programs. These are discussed in Chapter VI.

Many ECA countries have a package of policy documents to promote energy efficiency in buildings. These can include energy efficiency strategies and action plans, national energy and climate plans (NECPs), long-term renovation strategies (LTRSs), nationally determined contributions (NDCs), etc., which generally call for the entire building stock to be renovated by 2050 with some level buildings reaching net-zero-energy buildings (NZEBs). All of these policy documents recognize that it is less expensive to save 1 kWh of heat than to produce 1 kWh of low-carbon heat.

An LTRS is one of the best mechanisms for assessing the energy efficiency potential in a country's building sector and articulating an investment and implementation plan to realize it. It involves developing a full building stock database, typologies of buildings, cost-optimal investment packages for each building type, and a prioritized list (including pace, sequencing and financing modalities) of building renovations. For now, only EU member states are required to have prepared and submitted them; however, many of the pre-accession and Energy Community countries (e.g., Bosnia & Herzegovina and Serbia) are now preparing them.

As shown in Table V.2, energy savings vary in these plans from about 30 percent to 71 percent by 2050, indicating that a substantial decrease in heating demand is likely to be achieved through the building renovation programs—a decrease that would need to be factored into any sustainable heating plans. A heating assessment conducted by Aalborg University for 14 EU member states (accounting for 80 percent of Europe's heating and cooling demand) found a similar range of heat-demand reduction (30-50 percent) that could cost-effectively be realized through building renovations.[71] Since the building stock in ECA countries is considerably more energy inefficient, demand reductions are likely to be higher (likely in the 50-75 percent range), so significantly less heating supply will be needed. Using space heating demand calculations from the building sector in Chapter II, it was estimated that the space heating load demand in the ECA region could drop from 2,625 TWh to 1,194 TWh (about 55 percent), of which 855 TWh would come from the residential sector and 339 TWh from commercial and public buildings[72].

Table V.2: Targets for Long-term Building Renovation Strategies in Selected ECA Countries

Country	Baseline renovations (2020)	2030 (%, million m2)	2040 (%, million m2)	2050 (%, million m2)	demand reduction by 2050 (%)
Romania (scenario 1)	6.0% 38.66 m m2	10.0% 67.65 m m2	43.3% 279.0 m m2	100.0% 644.3 m m2	65.0%
Poland	5.0%** 0.335 m buildings	35.8%* 2.4 m buildings	77.0%* 5.1 m buildings	114.1%* 7.5 m buildings	71.0%**
Bulgaria**	4.7%	12.7%	30.7%	49.7%	30%

[71] Aalborg University (2019), *Towards a decarbonized heating and cooling sector in Europe: Unlocking the potential of energy efficiency and district heating*, available at: https://vbn.aau.dk/ws/portalfiles/portal/316535596/Towards_a_decarbonised_H_C_sector_in_EU_Final_Report.pdf.

[72] The report assumed 50% average energy savings for renovation of building envelope, 40% for district heating energy efficiency measures and 10% heating loads increase due to underheating in the region.

	13.0 m m2	35.2 m m2	85.2 m m2	118.8 m m2	
Croatia	4.2% 2.95 m m2	25% 36.53 m m2	60% 77.59 m m2	100% 168.8 m m2	n.a.
Serbia (scenario 3)	n.a.	7.0% 28.6 m m2**	14.0% 57.3 m m2**	20.9% 85.5 m m2**	n.a.

* This is the percentage of buildings in 2020 that will be renovated.
** These figures have been estimated based on the data in the LTRS reports.
Note: n.a. = Not available
Source: LTRS reports for Bulgaria, Croatia, Poland, Romania, Serbia.

Pillar 2: Bolster and decarbonize district heating

Once plans are in place to reduce the heating demand through building codes and renovations programs, efforts will need to be made to update centralized-heating plans. As noted in Chapter III, for most dense urban areas, DH remains the most economically viable option, and is the most affordable option for urban residents. However, since most DH is fully dependent on fossil fuels, the continued viability of DH will have to be assessed and will depend on several factors, including the operational and financial performance of the incumbent service provider(s), current and projected customer and heat demand densities (which in turn depend on the potential for reduction in heating demand due to energy efficiency measures, demographic trends, etc.), availability of concentrated and economic clean heating sources, and potential for further efficiency gains in the DH networks. Table V.3 from *Heat Roadmap Europe* includes typical heat density ranges which include both space heating and other urban heat demand (e.g., hot water, gardens/greenhouses), with higher densities better suited for DH. Although there is no uniform threshold at which DH can be deemed to be viable, some experts feel a that heat demand density of around 100 MJ/m^2 could be an indicative level (i.e., classes 3-5 in the table). However, this would vary based on heat supply costs and other local conditions.[73]

Table V.3: Physical Suitability for District Heating of Five Heat Density Classes

Heat density class	Heat density intervals (q) [MJ/m^2]	Concentration of heat demand
0	0	No modelled heat demand
1	$0 < q < 20$	Very sparse
2	$20 \leq q < 50$	Sparse
3	$50 \leq q < 120$	Moderate
4	$120 \leq q < 300$	Dense
5	$q \geq 300$	Very dense

Source: U. Persson et al., "Heat Roadmap Europe: Heat distribution costs," *Energy*, Vol. 176, June 2019, p. 604-22, ISSN 0360-5442, https://www.sciencedirect.com/science/article/pii/S0360544219306097.

Feasibility studies should account for the potentially large reduction in heating demand due to energy efficiency measures and other factors (e.g., population and migration trends). Institutional legacy issues that may have prevented some DH utilities from achieving adequate operational and financial performance should also be addressed to ensure further investments are sustainable. As noted in Chapter

[73] Another common industry benchmark relates to the specific annual energy consumption per meter of DH network pipeline (e.g., 2.5-3 MWh/m).

III, this could require a time-bound action plan with a set of reforms agreed with the government and various stakeholders. If some systems are either found to be uneconomic or would become no longer economically viable based on demand reductions or other factors, alternative arrangements may be needed (e.g., possible reduction in DH service area, break up of system to smaller networks, possible phaseout of DH in unviable areas).

For those DH systems that would remain economically viable, additional analyses would be needed to:

- Determine how best to bolster the DH systems and provision of services (e.g., improve cost recovery ratios, improve service quality, increase consumption-based metering and billing, improve management and operational performance and efficiency, expand and densify networks, transition to building level substations, expand delivery of domestic hot water and/or district cooling, lower heating temperature), as discussed in Chapter III;
- Identify alternative, clean and affordable heating sources that could be tapped to offset the existing heating production; and
- Conduct feasibility studies to transition to these cleaner options and develop and implement a long-term transition plan.

Of course, continued population growth and urbanization may create new opportunities for new DH systems to be considered if there are clean sources of heating available. Türkiye, for example, is exploring new DH systems using its vast supply of geothermal resources. Such studies should seek to coordinate spatial planning with LTRSs, heat systems planning, and national and local development plans. As noted in the next section, geospatial platforms offer one tool to support such assessments.

As discussed in Chapter III, alternative, clean heating sources could include a variety of options, such as geothermal, solar heating, waste heat (typically from industry or waste incineration), sustainable biomass, biogases (e.g., methane from landfills), large heat pumps (based on RE-based electricity) or hydrogen. In some areas, these may not be economic or available at the scale necessary to support DH networks; in other cases, smaller CHPs and/or DH systems may be the most optimal solution. The previously mentioned heating assessment conducted by Aalborg University for 14 EU member states also found that DH in these EU countries could be expanded from about 12 percent today to almost 50 percent (based on clean heating sources) more cost-effectively than building-level or individual heating systems (e.g., heat pumps). Therefore, DH is likely to remain a very important source for heating in Europe overall. In ECA, the situation is less clear given the poorer overall performance, low efficiencies, and low cost-recovery ratios.

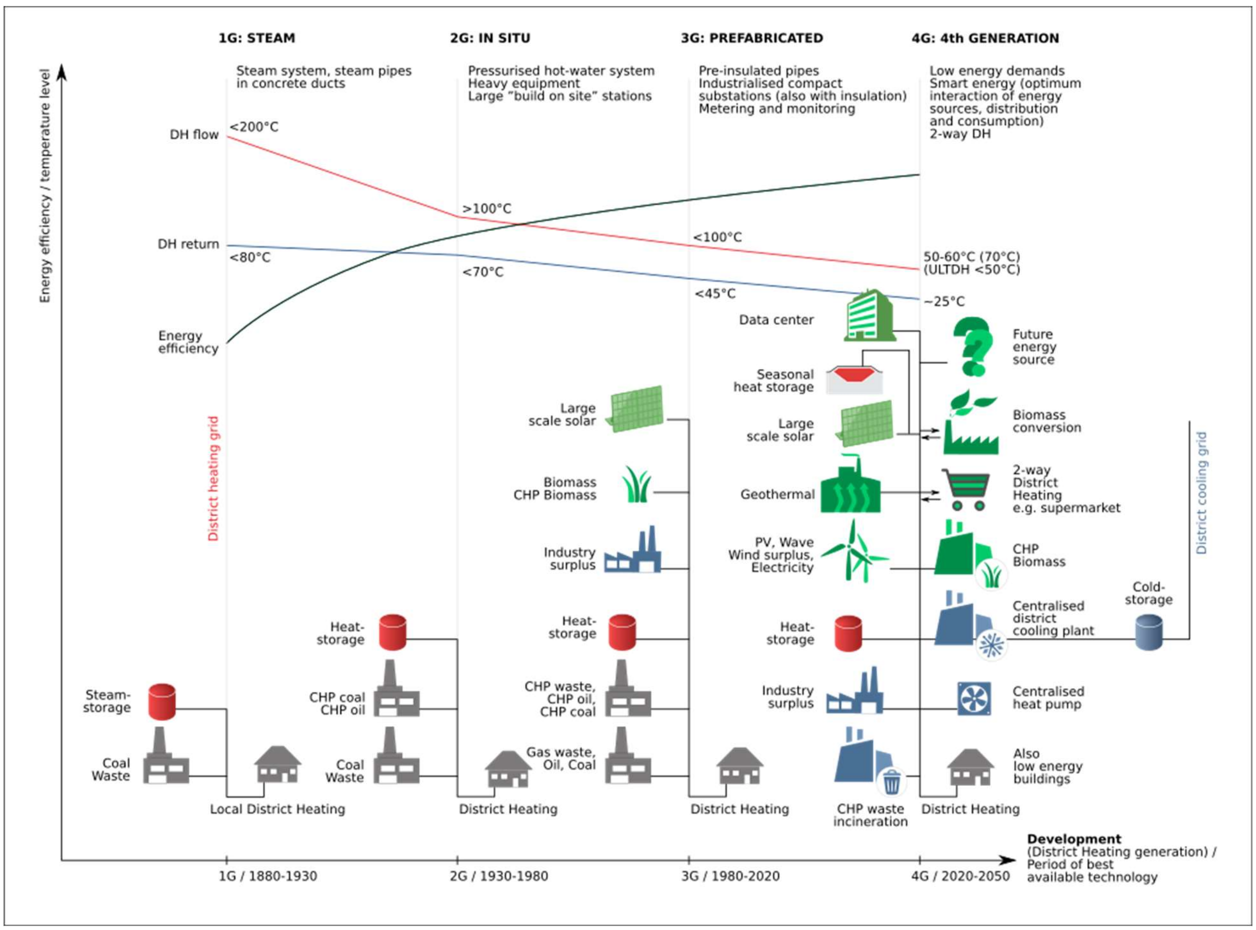
In the event that some parts of an existing DH network would no longer be economically viable, or if there are no identified economic, clean alternative sources, then an assessment of alternatives to the existing DH network may have to be considered. It may be the case that a managed phaseout is the most viable option, perhaps in the form of a 3-5-year phasedown—combined with aggressive financing and incentives for building renovations; promotion of alternative building-level heating systems (such as heat pumps); good information about thermal renovations and heating alternatives, available equipment, contractors, etc.; and parallel investments in supporting infrastructure (i.e., the electricity grid in the case of heat pumps, to accommodate the increased electric load).

Incentives should be targeted based on need (i.e., income level) and/or limited to more efficient and environmentally friendly heating options, such as sustainable biomass stoves/boilers and heat pumps. However, if it is found that DH, while not economic, remains the most affordable and politically desirable option, then agreeing on a suitable package of DH reforms, coupled with shifting to cleaner heating sources where available (e.g., from heat-only coal boilers to gas CHP plants), may be the best near-term option until lower-cost heating technologies and systems become more commercially available. This would likely be the case in Central Asia, for example, where DH utilities may not perform well and are largely based on coal, but electricity is in short supply during the winter months and few clean heat sources (other than natural gas) exist.

To support the identification of alternative heating sources, Aalborg University in Denmark has developed a geospatial heating demand and resource assessment methodology and applied it in the development of sustainable heat roadmaps (SHRs) for 14 EU member states, the United Kingdom, Chile, Romania, and elsewhere. The methodology and guidance underlying these assessments is presented in Section b of this chapter.

Figure V.2 shows the evolution of DH technology over the past century and its possible path to sustainability through 2050.

Figure V.2: Evolution of Heating Systems and Possible Trajectory



Source: H. Lund et al., "4th Generation District Heating (4GDH): Integrating smart thermal grids into future sustainable energy systems," *Energy*, Vol. 68, pp. 1–11, Jan. 2014.

Pillar 3: Promote clean, building-level or individual heating

In areas where DH is not economically least-cost or viable, such as peri-urban or rural areas with low heating demand and densities, governments will need to identify least-cost alternatives to current unsustainable heating fuels and technologies and develop policies and programs to support their adoption. As discussed in Chapter IV, alternative, clean heating sources could include heat pumps (air-to-air, air-to-water, geothermal), sustainable biomass or other. Chapter IV includes an assessment of these options and includes some representative LCOH costs in various locations and for various building types. According to the analysis, while there are a variety of options, heat pumps and eco-wood or pellet stoves/boilers appear to be among the more economic options.

To inform context-specific analyses of these cleaner heating options, market studies will need to be carried out to understand current heating technologies and costs, heating demand, availability and costs of local fuels, information on the building stock, income levels (i.e., ability to afford both the investment cost and the new energy bills from the alternative heating fuels/systems), and consumer preferences. Based on the results of these studies, governments should design programs with a mix of policy and regulatory measures, financing, incentives, information, and training to promote the most economic options. To support public and behavior change campaigns, information should also be collected to determine which media outlets households typically receive information from, priorities for selecting a heating system, and knowledge base for assessing these options. Chapter VI presents detailed considerations for designing programs to promote clean, building-level or individual heating.

b. Sustainable heating roadmaps using geospatial planning tools and data

A recently developed analytical approach to the geospatial prioritization of energy efficiency, DH, and individual heating solutions is to undertake a detailed analysis of heat demand in a country or region and overlay that with mapping of sustainable-heat resources in order to match demand and supply. Researchers at Aalborg University have developed a "sustainable heating roadmap" (SHR), an analytical framework that allows governments to use modern analytical tools to assess sustainable heating options in a more systematic and data-driven way. An SHR provides inputs for policy- and decision-makers on appropriate pathways to follow towards such a transition, helping them to address concerns regarding current heating supply resources and to formulate long-term strategies and plans for sustainable heating solutions. It includes a screening of potential development options, allowing users to identify one or more scenarios that meet local technical, environmental, regulatory, and economic conditions and needs.

The first step of the SHR process for a country, region, or city is to identify the scope and purpose as well as establish the specific strategic objectives (technical, economic, environmental, and societal)—including the stakeholders to be involved, the heating technologies to be considered, and the governance models that should be deployed. Ideally, SHRs should seek optimality from a total economic resource perspective—i.e., one that incorporates societal costs and excludes distortionary subsidies and taxes — rather than from a narrower perspective of financial or business costs. Total economic resource optimality also allows for the balancing of measures across the energy system: savings in households against optimization in grids, changes in conversion technologies[74] and energy resources, as well as larger modal shifts (between individual and centralized heating systems, for example).

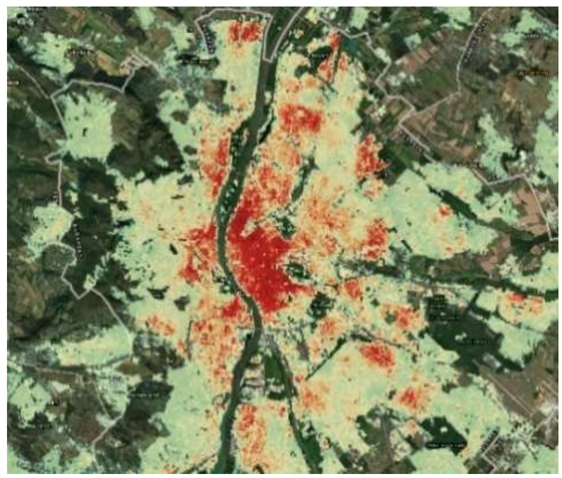
[74] The term *conversion technology* encompasses a range of technologies used to convert solid waste into useful products, chemicals, and fuels.

The scope of the SHR should be aligned with local heating targets and national decarbonization strategies. Unlike other energy sectors, the heating sector is highly dependent on local supply, and the heat planning process is normally conducted at the city or municipal level. Therefore, local government should be responsible for the coordination of stakeholders and the implementation of the heating infrastructure, while regional/national governments should coordinate and guide local actions. Ideally, all SHRs would follow national transitioning targets; respect countries' NECPs, NDCs, etc.; and aim to transition their heating systems by mid-century (i.e., a 30–40-year horizon). Some national-level analyses will still be useful in determining overall heating demand while also identifying national resource capacities (e.g., the amount of sustainable biomass production), energy efficiency/demand reduction targets, etc.

In addition, as part of each country's SHR, an economic analysis framework would define various parameters and trade-offs (e.g., the cost of carbon, health impacts, welfare costs from air quality) in order to help citizens and policy makers quantify the full potential impact of transitioning to a sustainable heating system in their cities/countries.

A key goal of each SHR should be to identify areas that can be supplied with central and individual heating. In this regard, a clear distinction needs to be made between DH and non-DH areas for heat supply based on a geospatial assessment of local parameters, such as heat demand and population densities (see Figure V.3). SHRs tend to be better suited to areas where DH exists, can be expanded, or could be introduced. For less dense and more rural areas, adoption of eco-biomass stoves/boilers or electrification of heating systems with heat pumps (based on an economic LCOH analysis) should generally be prioritized, along with building renovations.[75]

Figure V.3: Spatial mapping of heat density in Budapest, Hungary



In an SHR geospatial assessment, access to information on heating demands, the state of the building stock, supply options, and potential local heat resources are crucial. When investigating the potential of DH, it is important to perform a mapping of the locations of demand, heat supply, and local resources in order to apply geospatial analyses to evaluate and identify priority areas[76].

Table V.4 describes the three main approaches for acquiring the necessary information to assess heating demand—measuring actual consumption, bottom-up heat consumption estimation or top-down spatial distribution of heat demand. The choice of approach typically depends on the availability of data and/or access to perform measurements, and resources for the assessment. Space heating demand largely depends on the ambient temperature, which naturally varies across climate zones, seasons and years. For DH systems, large demand variations can occur on a seasonal, daily, or hourly level which should be converted into a heat duration curve (Figure V.4). This allows the demand to be analyzed to determine the extent of different load types in the area, e.g., baseloads and peak loads. A duration curve can also be

[75] For more information on district heating costs in the EU, see European Commission (2021), *sEEnergies: Quantification of Synergies Between Energy Efficiency First Principle and Renewable Energy Systems*, available at: https://zenodo.org/record/4892271#.Y8sPNHbMKUm.
[76] This SHR outlines the approaches related to DH. However, a similar type of spatial assessment can also be relevant in a broader integrated energy analysis, where other sectors, such as individual heating, cooling, and electricity, are also assessed.

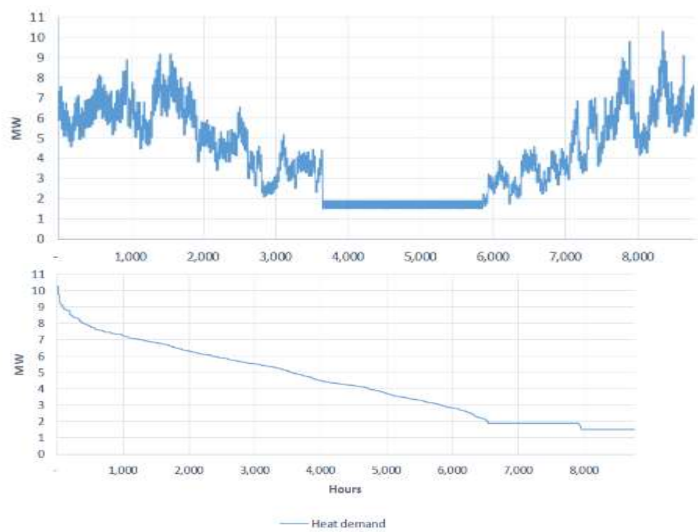
applied in the design of the supply side, especially when determining the supply needs, including peak heating loads and the potential for heat storage or heat demand response options.

Table V.4: Main Approaches to Assessing Heating Demand

Heating Demand Assessment Approach	Data Description	How to access data	Comments
1) Measuring Actual Consumption	Actual information on consumption quantities	On-site metering	Preferable for obtaining a high time resolution, such as 1-hour intervals, to accurately measure the variability of the heat load.
2) Estimating heat consumption of buildings through bottom-up modelling	Calculated estimation of heat demand by modelling heat consumption in single buildings, in a specific area, and subsequently aggregating them	From national building registers or, if those are unavailable, develop data through fieldwork and surveys	Requires information about the building stock (e.g., location, ambient temperature, construction time of the building, and surface area); example: Forecast[77]
3) Spatial distribution of heat demand through top-down modelling	Geographical Information System (GIS) tools to estimate the distribution of single buildings' floor areas from satellite imagery to disaggregate the reported aggregate demand of a buildings	These tools are based on energy statistics, e.g., national or regional heat demands, local building regulations, end-use equipment, and end-use behaviors	The building-level demand forecast is based on the information of type, age, and usage of buildings. It is used to develop heat atlases that are applied to identify areas of priority, such as high-potential DH areas with high heat density and proximity to local heat sources. Examples: PETA[78] and Hotmaps.

Source: M. Yuan, et al. (2022), *Framework for Developing Sustainable Heating Roadmaps in Europe and Central Asia*, Aalborg University.

Figure V.4: Example of the temporal distribution of the heating demand in Danish District Heating system



Source: M. Yuan, et al. (2022), *Framework for Developing Sustainable Heating Roadmaps in Europe and Central Asia*, Aalborg University.
Note: Vertical axes representing measured demand and horizontal axes showing hours of the year. The upper panel: real-time distribution; lower panel: duration curve.

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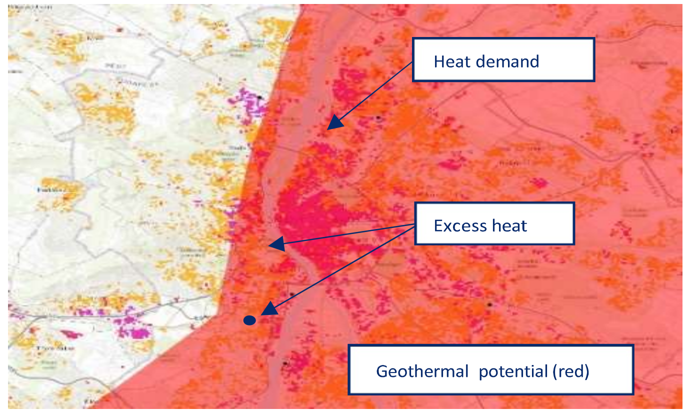
[77] The Forecasting Energy Consumption Analysis and Simulation Tool (FORECAST) is a long-term scenario tool that models energy savings potentials for the built environment. Based on bottom-up modelling of different building types, it provides cost curves that relate energy-saving potentials for buildings and the investment needed considering both technological and socio-economic drivers.

[78] The Pan- European Thermal Atlas (PETA) is an interactive map that models heat and cold demand on a hectare level. This high-resolution spatial analysis enables the user to identify dense heat demand areas that have a potential for district energy as well as estimate costs for the district energy grids. Along with heat and cold mapping, PETA also spatially maps the locally available RE resources that could be made part of the local district energy networks, enabling efficient allocation of potential RE resources such as biomass, geothermal and excess heat.

In an SHR, the geospatial assessment of heating demand should be combined with an identification of potential heat sources in proximity to demand centers. This includes RE sources such as geothermal and large-scale solar thermal as well as waste heat from local industrial processes or from cooling in the service industry (Figure V.5). Solar thermal, geothermal, and local biomass potential can typically be identified via various online atlases and through geospatial mapping that would include information on solar irradiation, geothermal activities, and biomass availability. Determining geothermal potential would typically require some level of geological investigations of the underground reservoirs.

Figure V.5: Examples of spatial mapping of heat demand and local resource availability in Budapest, Hungary



Source: www.heatroadmap.eu/peta4

In addition, certain characteristics (e.g., temperature, heat quantity, heat temporality, and geography) will be needed to determine the heat quality and thereby the potential for exploiting a local heat source. Local biomass potential can also be identified through geospatial mapping, which can help define upper limits in the sustainable supply and use of biomass in the heating sector. The levelized cost of the various RE heat sources for DH is site-dependent but can in many locations be cost-competitive with conventional fossil-fuel plants such as CHPs and heat boilers. However, the cost structure of RE is typically different from that of conventional plants, as shown in Table V.5. These costs should also be assessed so the most optimal sustainable heating solutions can be recommended and prioritized.

Table V.5: Cost of District Heating Systems in the European Union

DH Configuration	Equipment and Installation Cost (€/kW)	Maintenance Cost (€/kW)	Efficiency (%)
Residual heat flow from industry	1140	21	350
Co-generation	1500	21	350
Geothermal	1500	78	460
Air-source Heat Pump	2000	21	310
Solar thermal	700	10	100
Peak boilers	150	1	90
Thermal storage	125	97	80

Source: Cambridge Econometrics (2022), *Modelling the socioeconomic impact of zero carbon housing in Europe*, https://www.camecon.com/what/our-work/european-climate-foundation-modelling-the-socioeconomic-impacts-of-zero-carbon-housing-in-europe.

The timeline for SHR development depends on many factors but can take around 12-16 months. Figure V.6 offers an indicative timeline for the various design phases. It can be divided into three distinct phases: preparatory, data collection, and capacity building. Getting local stakeholders on board early in the roadmap development helps avoid pitfalls based on local experiences. The local experts and stakeholders may come from several different domains including line ministries, academic experts, local governments and urban planners.

Figure V.6: Suggested Timeline for Developing an SHR

Sustainable Heat Plan Roadmap Timeline

	Phase 1	Phase 2	Phase 3
	Preparatory Work (2-3 months)	**Data Collection and Analysis (6-8 months)**	**Capacity Building and Dissemination (4-5 months)**
Activities	List of activities	List of activities	List of activities
	Problem Formulation	Identify relevant data sources (Surverys, national registers etc.)	Validation workshops with local experts (energy planners, researchers, policy makers)
	Stakeholder Identification	Demand and reource assessment	Refine analysis based on feedback from experts
	Engaging local energy experts	Geo-spatial mapping of demands and resources	Report key findings in policy briefs
	Existing policy review	Making of costs curve for district heating share and energy rennovations level in the buildings	Publish findings (videos, reports, webistes, online data and mapping reprositories)
	Understanding local needs	Integrated heat planning and energy systems modellings	Webinars and trainings for policy makers, energy planners, local stakeholders, energy utilities etc.
	Inception Meetings	Identify optimal district heating share and rennovations rate for different regions	-

	Preparatory Work (2-3 months)	Data Collection and Analysis (6-8 months)	Capacity Building and Dissemination (4-5 months)
Outcomes	List of Outcomes	List of Outcomes	List of Outcomes
	Established local contacts (Mins of Energy, Mins of Planning etc.)	Established reprository of energy demand data and local thermal atlas	Deatiled reports, data repositories
	Formulated overview of local energy (heat) issues	Identified suitable areas for district heat expansion and building rennovations	Key policy recommendations
	Listed pertinent data requirements	Identified optimal share of district heating, building rennovations and associated costs	Trained local experts for heat plan implmentation
	Detailed work plan for heat roadmap development	Key findings and recommendations from integrated planning	-

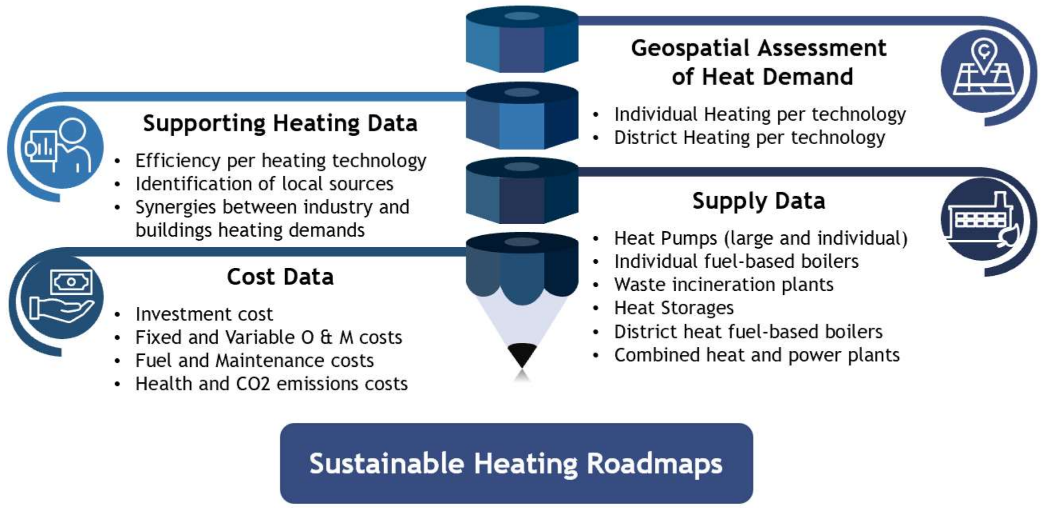
Source: M. Yuan et al. (2022), *Framework for Developing Sustainable Heating Roadmaps in Europe and Central Asia*, Aalborg University.

A key outcome of the first, **preparatory** phase should be a list of relevant data requirements. These are then used to inform the **data collection and analysis phase**, which should result in an established repository of heat demand data and local maps to be used for future projects and development. The geospatial assessment should be able to provide heat demand assessment and resource assessment, including an approximation of individual heating demand and DH data, availability of local resources such as the geothermal potential for heating, and industrial excess heat. Additionally, essential data on the supply side include information on supply capacities in the energy system (for instance, the installed and potential capacity of CHP plants).

Figure V.7 showcases some pertinent data requirements for developing SHRs. The evaluation should be able to identify regions for either development or expansion of DH networks, or deployment of non-DH sources (e.g., heat pumps, biomass boilers) in less dense areas. In cases of low levels of data availability, data can either be produced directly (e.g., through metering or similar methods to make actual on-site measurements) or estimated based on international or national statistics, assumptions, and/or field work/surveys.

Once the analysis is finished, the roadmap moves to the **capacity building and dissemination phase**. In this last phase, findings are published, workshops are held, staff are trained, and policy makers are informed about economically efficient energy-savings options as well as overall options and investment needs for transitioning to sustainable heating systems.

Figure V.7: Data Requirements for Developing SHRs



Source: Adapted from M. Yuan et al. (2022), *Framework for Developing Sustainable Heating Roadmaps in Europe and Central Asia*, Aalborg University.

Overall, the SHR approach includes a higher level of integrated analysis than conventional heating planning, as it includes spatial and temporal dimensions of the heating demand assessment, coordinated with broader sector and environmental strategic objectives. The SHR is designed to be an integrated approach that aims to identify appropriate long-term strategies for developing sustainable heating systems while avoiding mismatches between investments in energy savings and the expansion of infrastructure and supply capacity. An SHR enables energy planners to design efficient heating systems that can be instrumental in reaching national decarbonization as well as efficiency and economic goals[79]. A case study of the SHR applied in Romania appears in Annex J.

[79] For more information on SHRs, please see Heat Roadmap Europe (https://heatroadmap.eu/).

VI. Government Programs for Sustainable Heating

Main Messages:

- A combination of political, infrastructural, economic, financial, technical, and informational barriers makes the transition to sustainable heating particularly difficult. Because they typically co-exist, these barriers can lead to vicious cycles of under-investment, poor efficiency, and lock-in with unsustainable fuels.
- Comprehensive government strategies and programs are needed, guided by long-term heating sector strategies and targets and complemented by enabling reforms, to address the barriers holistically and create the conditions for uptake of sustainable heating solutions. Public building programs can lead by example and help build a market and value chain for sustainable heating solutions.
- Government programs should be tailored to local market conditions, barriers, and opportunities. Program design should also draw on international experiences and good practices, but more research is needed to systematically evaluate different approaches to government program design and develop lessons that can be applied internationally. Government financing should be used judiciously and avoid crowding out private capital.
- Attention should also be paid to the non-financial aspects of program design, including behavior-informed outreach, access to credible information, gender aspects, and technical support for audits and quality assurance.
- Government programs also need to target support at lower-income households to make sure public funds support those most in need and unable to make the transition on their own. Such programs should reflect the specific challenges of such households by providing access to affordable financing, social assistance for potentially higher energy bills, and energy efficiency measures, and by ensuring program accessibility.

a. Barriers to investment in sustainable heating and energy efficiency

There are a variety of barriers that have made the transition to sustainable heating particularly difficult. These include policy, infrastructure, economic and financial, technical, and informational barriers. Some of these barriers are well known from research on clean energy and energy efficiency more broadly, and include the prevalence of subsidized fossil fuel, high heating and electricity prices, the high upfront investment cost of cleaner alternatives, limited access to financing, long asset lifetimes, and limited knowledge and information among consumers. However, there are other barriers that are specific to the heating energy transition in ECA:

a. **Multijurisdictional responsibilities.** Heating sector policy requires coordination across ministries and across levels of government, which makes coordinated interventions difficult to plan and implement. National governments often have policymaking and regulatory functions (e.g., energy and heating strategies, building codes and energy performance certificates, energy sector regulations and tariffs, air quality standards, biomass certification, and infrastructure planning), while regional, provincial, and local governments may be in charge of enforcing and implementing policies despite being often understaffed and under-resourced. Interpretation of regulations, coordination of programs and communications, sharing of resources, etc. often create conflicts.

b. **Prevalence of unregulated or poorly regulated markets for solid heating fuels.** The lack of formal regulation or enforcement of regulation in firewood and biomass markets, coupled with illegal and informal logging, lack of certification, etc. often leads to underpriced firewood and charcoal and unsustainable biomass harvesting and use. In some countries this also applies to locally mined coal used for heating. The prevalence of underpriced, unsustainable solid fuels makes the transition to clean heating fuels extremely challenging, especially in rural areas.

c. **Uneven access to network infrastructure.** Unlike for electricity networks, many governments do not have plans for nationwide expansion of natural gas or DH networks, or consider such network expansion as unviable. This leaves many households with permanently limited fuel options for heating—often only electric heating, coal, charcoal, and firewood. Among these, solid fuels such as firewood and coal are often the only affordable and readily available alternatives, leading to lock-in of unsustainable fuel use.

d. **Uneven prevalence of building-level hot water plumbing.** Many of the more sustainable heating solutions (e.g., high-efficiency ground-source or air-water heat pumps, pellet boilers) require building-level internal networks such as hot water piping or radiators. Where these do not exist, they are very expensive to retrofit, limiting affordable heating options to lower-efficiency solutions such as room-level firewood or coal stoves or room-level electric heating.

e. **Lack of qualified local auditors, installers, and maintenance service providers.** Typically, heating solutions require local service providers for design, installation, and maintenance. Substantial and well-developed markets exist for coal, firewood, inefficient stoves, and firms to install or service traditional heating technologies, resulting in competition, easy availability, and convenience. But the capacity of the sustainable heating supply chain remains underdeveloped, with many energy auditors, installers, etc. lacking the training required to size and install newer technologies (such as heat pumps) or to couple heating upgrades with energy efficiency measures.

f. **Lack of consumption-based billing.** Many DH providers charge their consumers by heated floor area rather than heat consumed. This acts as disincentive to invest in energy efficiency on the demand side, and reforms face substantial opposition.

These barriers can lead to vicious cycles of under-investment, poor efficiency, and maintaining the status quo. For households, this often results in low-efficiency housing units, using cheaper but lower-efficiency heating appliances and cheaper, unsustainable solid fuels. Their buildings may also be old and noncompliant with current building codes, have had past unlicensed renovations, lack internal piping networks, and so on, which make renovations and adoption of cleaner heating options a challenge. In the case of DH, stalled reforms, fuel subsidies, low heating tariffs, and a lack of consumption-based billing can lead to high losses, low quality of service, lack of revenues for new investments, etc.—which in turn lead to inefficient energy use (e.g., the opening of windows or DH disconnections in favor of potentially less efficient electric, coal or wood heating).

Individually, solutions to each of these barriers have been identified and addressed by governments both inside and outside ECA. Underpriced fossil fuels can be addressed with energy subsidy reform, and underpriced DH can be addressed through pricing reforms and universal consumption-based metering and billing (as has been done in Belarus, Georgia, Moldova, Poland, Russia, Ukraine and Uzbekistan). Unregulated firewood or charcoal markets can be addressed through sustainable biomass certification, better regulations of the biomass supply chain, and enforcement of existing laws and regulations (EU, North America). High upfront investment cost can be addressed through financial incentives such as tax incentives/waivers, removal of import tariffs, subsidies/grants/rebates, soft loans and guarantees (e.g., Denmark, France, Germany, Japan, Sweden, Poland, U.K., and the U.S.). Multijurisdictional responsibilities can be addressed through steering committees, coordinating bodies, or other mechanisms to help coordinate programs, allocate resources, and allow for the exchange of information and discussions of issues (e.g., Bosnia and Herzegovina, Poland).

However, individual policy measures to address individual barriers are often insufficient to promote the multitude of barriers that prevent the uptake of clean heating solutions at scale. Thus, a comprehensive government response is required. Long-term targets, public sector planning and regulations, programs including incentives and financing, communications and outreach, and training are all important elements for a holistic government response to enable the sustainable heating transition. These should be combined with enabling sector reforms to improve governance and incentives, pricing reforms, institutional strengthening, and other enabling reforms to incentivize market-based uptake of sustainable heating solutions, and measures to promote energy efficiency along the heating value chain.

b. Long-term targets, roadmaps, and coordination mechanisms to guide and coordinate government interventions in the heating sector

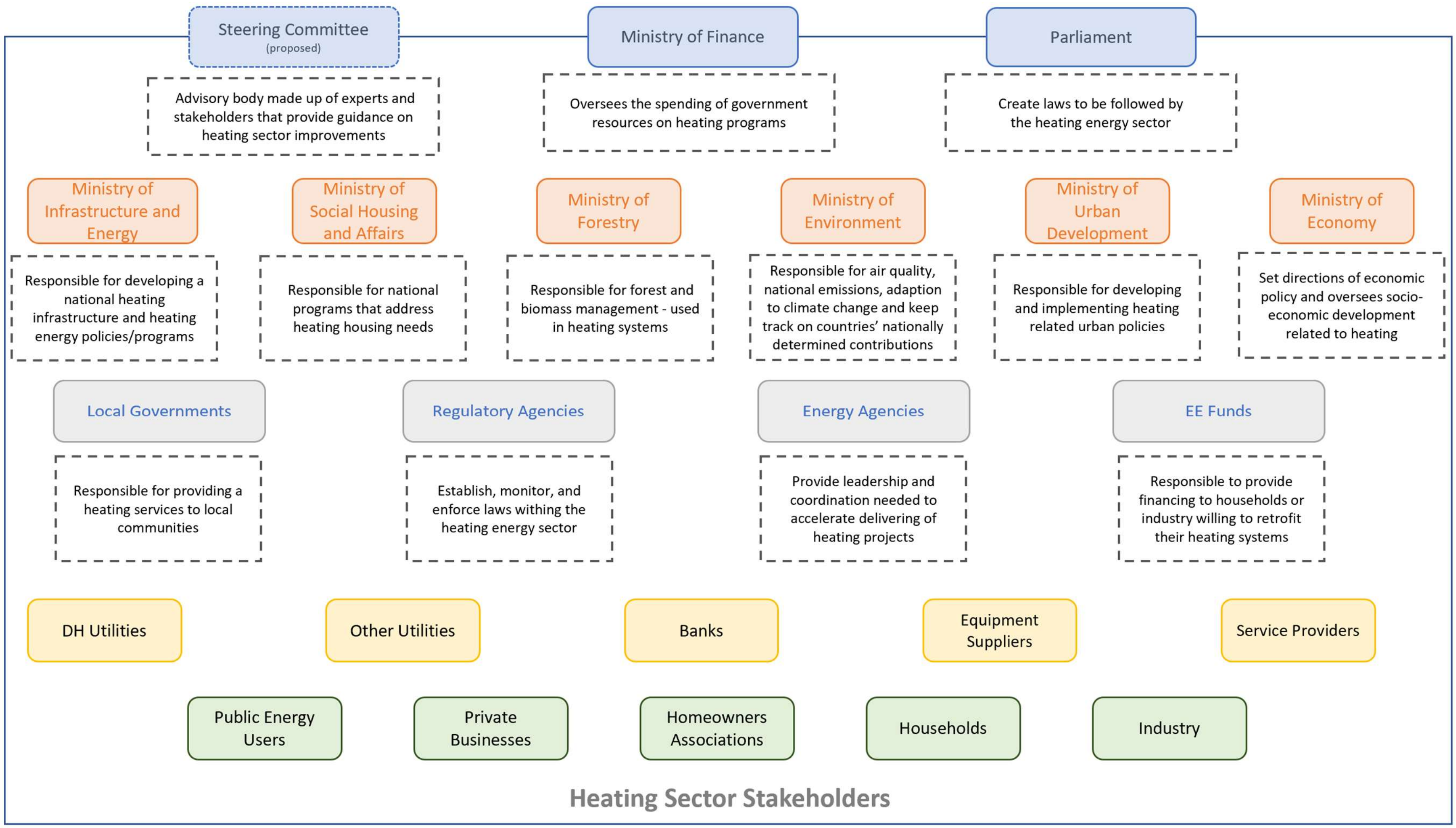
Government interventions in the heating sector should be guided by long-term targets for heating energy consumption and emissions, embedded in the country's broader set of long-term energy and climate targets. So far, heating has received insufficient attention in such broader government targets in NDCs, NECPs, and other national strategies and should therefore be a priority for all ECA countries. These plans need to be properly integrated and coordinated, so building renovations, energy efficiency targets, air quality schemes, and other plans can all be considered in a more integrated way.

The choices of technologies and fuels should be informed by SHRs based on national and sub-national assessments reflecting the geospatial nature of the sustainable heating transition, such as dense urban and sparsely populated rural areas and available heating resources. Such analyses should also consider parallel sector plans and targets which could impact the viability and environmental and social impacts of various options—such as plans to decarbonize the electricity sector that would impact the sustainability of electric heat pumps, or plans for sustainable biomass that would affect biomass use in eco-design boilers and stoves.[80]

Besides the numerical targets, central governments should play a critical role in the establishment of a national vision — which defines by when unsustainable heating fuels and practices should be phased out — and the coordination and strengthening of (i) sub-national heating sector policies and initiatives and (ii) the management of regional/municipal DH utilities. The fragmented nature of the heating sector means that many relevant government decisions on heat sector policies, regulations, planning, and management need to be taken by municipal and other subnational government bodies. This includes the management of DH providers, which are often owned and/or controlled by sub-national governments.

[80] It is important to consider the seasonality of heating in this context. In the Kyrgyz Republic, for example, where shortages of electricity can occur during winter months, replacing inefficient electric heaters with heat pumps is now a priority.

Figure VI.1: Typical Institutional Setup for Sustainable Heating



Source*:* Authors.
Note: EE = energy efficiency.

Without a national vision and coordination, a harmonized approach to sustainable heating will not be possible. Governments should therefore strongly consider establishing a high-level Steering or Coordination Committee to improve communication and cooperation among these bodies, ensure policies and programs are consistent and complementary, promote the exchange of best practices, incentivize innovation and experimentation through centrally financed support programs, and strengthen their capacity to plan, oversee, and manage heating sector policy. (Figure VI.1 includes an indicative list of institutions and stakeholders involved in the sustainable heating transition.)

c. Financing programs to promote the uptake of clean heating solutions

Unlike the transition in the power sector, where almost all customers rely on centralized utilities (and thus most of the fuel-switching investment decisions rest with the national governments, utilities and regulators), the sustainable heating transition will require millions of households and businesses to make individual investment decisions on energy efficiency, cleaner fuels, and technologies to enable a country-wide shift. Given the market failures and barriers noted at the outset of this chapter, government intervention will be necessary to catalyze the heating energy transition. Therefore, governments will need to design, launch, and monitor national-level sustainable heating programs—covering building thermal renovations, fuel switching, and upgrading of heating systems with a mix of financing, incentives, technical support, and outreach. This section is meant to inform these government design choices.

In terms of prioritization of supported investments, government interventions to promote sustainable heating should be based on the framework proposed in Chapter V, namely, to seek to reduce demand for heating in buildings, bolster and decarbonize DH, and promote clean individual heating systems. In their choice of supported heating technologies, they should also be guided by long-term targets for the heating sector and SHRs to ensure that they promote the most economic sustainable heating solutions.

Governments should pursue a multi-pronged approach comprising parallel programs for public, commercial, and residential buildings. Many governments often begin with programs in public buildings, to demonstrate sustainable heating technologies, approaches, and benefits and to lead by example. This also allows them to develop some of the market infrastructure needed for a broader rollout (e.g., technical standards, implementation guides, audit templates, training) while stimulating demand for goods and services that can help build the domestic supply chain of importers, wholesalers, retailers, and installers/service providers of heating equipment and energy efficiency materials and services. Such market development can also help bring down equipment and material costs over time and provide newer firms with a track record and reputation in the market. Because of the demonstration potential, these programs should seek to combine best practices—deep renovations and comprehensive sustainable heating measures, best available technologies, etc.—with strong dissemination of measures, costs, benefits, and lessons.

This section focuses on the design of financial interventions to promote the uptake of sustainable heating solutions in two areas: public buildings and private buildings. Besides these financial interventions, government programs should be bolstered through non-financial interventions (discussed in Section d) and enabling reforms (discussed in Section e). They should also be subject to periodic evaluations so continual adjustments can be made based on lessoned learned and evolving market conditions.

Design of financing programs for sustainable heating in public buildings

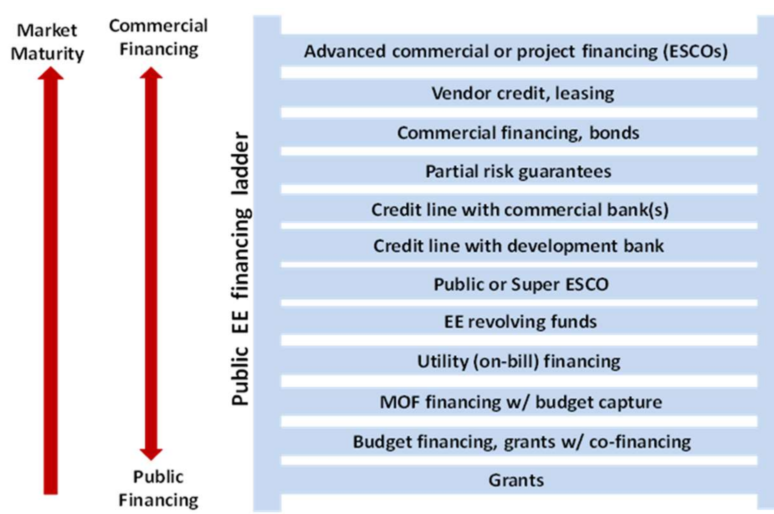
As noted previously, the public sector can offer an entry point and lead by example by using investment in public buildings to create new markets, build confidence in newer technologies, and provide incentives and short-term low-cost financing to catalyze desirable changes in investment habits and behavior.

Financing programs for sustainable heating in public buildings share many characteristics with energy efficiency programs and should thus be combined with them where possible. The design of such programs can therefore draw extensively on experience with public sector energy efficiency programs.

Government programs for sustainable heating in public buildings need to be designed on the basis of local policy, regulatory, and market conditions. In most developed countries, investments are often supported either through annual budgetary outlays (such as annual capital investment programs) or through commercial financing or bonds. However, in most developing countries, including those in ECA, annual budget allocations may not be sufficient and commercial financing may be difficult if public entities have borrowing restrictions, are uncreditworthy, lack proper financial management systems and controls, etc.

Therefore, the World Bank has developed an indicative "financing ladder" (Figure VI.2) public facilities (including public buildings) can use to develop alternative modes of financing until commercial financing is more viable. The ladder includes common mechanisms such as budget financing and commercial financing, but also several intermediate steps that could facilitate a transition to more commercial models, such as public energy efficiency revolving funds, utility on-bill financing, public or super ESCOs, and credit lines with development banks. Selecting the most suitable option depends on several factors, including the current legislative and regulatory conditions, market maturity, the state of the local energy efficiency service industry, and the technical and financial capacity of public agencies to undertake energy efficiency and/or sustainable heating projects. Once the option is selected, it must then be carefully designed to suit the local market characteristics. Over time, as local markets evolve, the goal should be to move up the ladder to more commercial financing mechanisms.

Figure VI.2: Financing Ladder for Public Buildings



Source: World Bank (2014), *Western Balkans: Scaling Up Energy Efficiency in Buildings,* World Bank.
Note: EE = energy efficiency; ESCO = energy service company; MOF = Ministry of Finance.

For most ECA countries, given the relatively nascent state of implementation experience and underdeveloped energy-efficiency and sustainable-heating markets, financing mechanisms in the middle rungs of the ladder have generally been more suitable to initiate such programs. These include:

- **Budget financing with capital recovery**. Under this option, the ministry of finance, or another parent budgeting agency, provides the budgetary resources necessary for an energy efficiency investment and then recovers the investment by reducing future budgetary outlays (thus capturing the energy cost savings). This is also known as the "budget capture method". This can work for central and municipal entities and, since there is almost no risk of nonpayment, it can work for municipalities without credit histories as well.
- **Energy efficiency revolving fund**. Under this option, an independent financing institution called an energy efficiency revolving fund (EERF), is created using public funds to provide financing to public sector EE projects. Since both the borrower and lender are publicly owned, such funds may often offer lower-cost financing with longer tenors (repayment periods) and less-stringent security requirements than typical commercial loans. It can also offer other products, such as guarantees, forfaiting, and energy service agreements (ESAs)[81]. As the financing is repaid from energy cost savings, it can be redeployed to new projects, thereby "revolving" over time. Some financing products have the added advantage of not being classified as public debt.
- **Public ESCO.** Established by the government, a public (or "super") ESCO functions as an ESCO for the public sector market, entering into ESAs and outsourcing actual project implementation to small, private ESCOs and other energy service providers. A primary function of the public ESCO is to facilitate access to project financing by developing relationships with local or international financial institutions. The public ESCO may also provide credit or risk guarantees for ESCO projects, or act as a leasing or financing company to provide ESCOs and/or customers with EE equipment on lease or benefit-sharing terms.

For more information, please refer to the World Bank's Live Wire 2018/94 (Energy Efficiency in the Public Sector)[82], Live Wire 2018/88 (Financing Energy Efficiency Part 1: Revolving Funds)[83] and recent World Bank publications on energy efficiency in the ECA Region[84].

Design of financing programs for sustainable heating in private buildings

Given the scale of the challenge, sustainable heating programs for private buildings will have to be the core of all ECA countries' sustainable heating strategies, especially in the residential sector. These programs should draw on international experiences and good practice. Examples of programs that are already active in ECA countries or could be well-suited are presented in Table VI.1. However, international experience and systematic research is still limited, which means that there is no agreed best practice or standardized set of recommendations for program design. This means that programs should be tailored to the specific market conditions, barriers, and opportunities in the country, and allow for experimentation to identify what works best in the local context.

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[81] Through the use of energy service agreements (ESAs), the EERF offers a full package of services to identify, finance, procure, implement, and monitor projects for public clients. The client is only asked to pay what it is currently paying for energy (i.e., its baseline energy costs), from which the EERF makes the new (lower) energy payments and recovers its investment cost and associated fees until the contract period ends. For public clients, ESAs are generally not viewed as debt, but rather as long-term service contracts, thereby allowing financing of central government entities that are typically not allowed to borrow, and municipalities that may have reached their debt limits or have borrowing limitations.

[82] https://openknowledge.worldbank.org/bitstream/handle/10986/31023/132945-BRI-PUBLIC-LW94-LJ-Fin-OKR.pdf.

[83] https://documents1.worldbank.org/curated/en/561571536097283340/pdf/129733-BRI-PUBLIC-VC-LW88-OKR.pdf.

[84] See for example World Bank (2014), *Western Balkans: Scaling Up Energy Efficiency in Buildings*; World Bank (2015), *Institutional Review of Energy Efficiency in Türkiye;* and World Bank (2019), *Albania: Sustainable Financing Mechanism for Energy Efficiency Retrofit of Public Buildings*.

Table VI.1: Characteristics of International Clean Heating and Energy Efficiency Programs

Program Characteristics/ Program Name	Type of Financial Support	Administration/ Management	Eligibility	Funding Source
Clean Air Priority Program (CAPP)—Poland	Tax incentives, grants	National Fund for Environmental Protection and Water Management (NFOŚiGW)	Polish SFHs owners who use inefficient solid-fuel boilers	NFOŚiGW revenues (from environmental permits and fees), World Bank and European Union
Energy Efficiency and Renewable Sources Fund (EERSF)—Bulgaria	Loans and credit guarantees (plus technical consulting)	Public fund working with commercial banks	Bulgarian enterprises, municipalities, and private households	Global Environment Facility grant, Government of Austria, Government of Bulgaria
Efficient Homes Program—Romania	Grants	Romanian Government Ministry of the Environment, Waters and Forests through the Environment Fund Administration department	Households installing windows replacements, insulation, solar panels or other RE sources, ventilation systems, LED lighting, motion sensors, and new valves and pipes	Tax revenues
Out of Oil and Gas Campaign—Austria	Grants	Central Government	Households installing solar thermal and/or air/water heat pump	Tax revenues
Reduced value-added tax (VAT) for Energy Efficiency—France	Tax exemption	Central Government	Firms/households that purchase approved energy efficient heating/cooling systems	VAT revenue
Programs from the Massachusetts Clean Energy Center—United States	Tax exemptions or rebates, loans, grants, and other means of financing including the aggregation of buying power among households	Massachusetts Clean Energy Center (quasi-public agency under the Green Communities Division of the state Dept. of Energy Resources)	Households earning 60–80% of Massachusetts median income	Electric bill surcharges and the Massachusetts Renewable Energy Trust Fund
New Czech Green Savings Program—Czech Republic	Grants	State Environmental Fund of the Czech Republic under the Czech Republic Ministry of the Environment	Owners or builders of SFBs ad MFBs, both individuals and legal entities investing in energy efficiency	Revenue from the sale of EUA (European Union Allowance) and EUAA (European Union Aviation Allowance) units
Eco Fund—Slovenia	Grants, soft loans, and coordination with Energy Advisory Network, financing environmental protection awareness activities	State-owned public fund with operational ties to the Slovenian Ministry of Environment and Physical Planning	Households, companies, and municipalities	Part of the proceeds generated by the privatization of state enterprises, claims (receivables) on outstanding debts transferred to the Fund on the date of its establishment by the Ministry of Environment and Physical Planning (MEPP), transfers from the state budget, loan repayments and interest on loans, and from grants and loans provided by foreign donors and IFIs.

Source: Authors.

With regard to **the choice of financing mechanisms,** governments should aim to use public funds judiciously and avoid crowding out private capital. This means that incentives should generally be temporary so as to catalyze markets but not make building owners reliant on grants. Government funding should also be designed to "crowd-in" (rather than crowding out) commercial financing, through such measures as bank lending schemes and guarantees. Often-used instruments include the following:

- **Tax credits, rebates, exemptions, or reductions** can be introduced to encourage sustainable-heating investments and equipment purchases. They can take the form of reductions in personal or company income taxes, such as import tax/VAT waivers or exemptions for eligible equipment (e.g., solar panels, heat pumps, efficient windows) with lower support for higher income brackets. Some examples are the "Reduced VAT for Energy Efficiency" program in France and programs from the Massachusetts Clean Energy Center in the United States (see Annex L) .
- **Investment grants, subsidies or rebates** are cash incentives from the government to offset a portion of the investment cost for sustainable heating investments. This is often done to stimulate markets, to help low-income households purchase sustainable heating systems, or to overcome real or perceived market barriers (such as the potential for higher energy bills, uncertainty about new technologies or fuels, behavioral inertia, and transaction costs).
- **Low-interest loans** can make financing more attractive and affordable for building owners and encourage banks to offer financing in new markets. Governments can also use them to encourage banks to join national programs and offer better terms (e.g., longer loan tenors).
- **Utility demand-side management programs** are regulatory mechanisms that oblige utilities to implement energy efficiency measures in their customers' premises as part of their energy service license. To meet these obligations, utilities may (i) directly invest in energy efficiency measures in residential buildings, (ii) offer on-bill financing or rebates for certain energy-efficient products or services, or (iii) purchase energy savings achieved by others. Utility programs, or energy efficiency obligation schemes in the EU, may include demand-response programs, which encourage end-users to make short-term changes in energy use in response to price signals (e.g., to reduce peak demand); such schemes could be extended to heating in more-mature markets. Utilities would then be able to recover their investments and administrative costs either through the base tariff or through a public benefit surcharge on their energy bills.
- **Financial interventions on the supply side** involve a variety of steps governments can take to promote sustainable heating products. For example: (i) *Bulk procurement and distribution* involve the purchase of energy-efficient or clean heating appliances in bulk and distributed to customers with a modest or no mark-up. (ii) *Manufacturer partnerships* can also be fostered by governments to encourage certain products. For example, the government could agree that manufacturers of eligible equipment would offer a discount or coupons to customers in exchange for the government funding a major outreach campaign which includes references to those eligible brands and models. Such schemes have been used in India, Thailand, and the U.S.

In practice, to address the co-existing barriers laid out in Section a of this chapter, government programs often use a mix of incentive schemes (e.g., partial CAPEX grants, rebates, interest subsidies, tax incentives) and financing mechanisms (e.g., loans and credit lines, credit guarantees, utility on-bill financing, equipment leasing, vendor credit) as core elements of energy efficiency and sustainable heating programs.

In terms of the **institutional setup for implementation**, government programs for private buildings are often delivered through financial intermediaries (such as development, commercial, or community banks), tax agencies (through tax credits or exemptions), public agencies, or third parties appointed by the government (such as energy-efficiency or environmental funds, energy agencies, public ESCOs, or municipalities), or through private companies (such as equipment vendors or energy utilities). A centralized institutional approach, such as an EERF or a national ESCO, has the advantage that—if appropriately resourced—it can serve as a "one-stop shop" for financing, incentives, information, and technical expertise for clean heating solutions. A fund can also be designed to have "revolving" characteristics in which (i) loans are provided and repaid over time, which can allow it to grow over time; or (ii) specific revenue streams (such as carbon or environmental taxes, fines, license fees, or carbon market revenues) can flow in and subsidies flow out. Some disadvantages are that EERFs can compete with commercial banks, be expensive and time-intensive to establish, be influenced by political considerations, and lack incentives to operate efficiently.

Those models more reliant on public financing are typically found in countries where commercial banks and potential service providers are unfamiliar with clean energy investments or unwilling to extend credit to the target markets (such as uncreditworthy or poor households). In more-mature markets, funding or financing is more often provided through more-commercial schemes, such as financial intermediaries, ESCOs, utility companies, and/or equipment vendors. Table VI.2 shows the various options for financial mechanism to promote sustainable heating.

Targeting and eligibility criteria should be developed so the right types of building structures, equipment, and owners can be prioritized and targeted. In terms of the eligible part of the population, governments should determine their policy objectives and identify target markets based on market studies and desirable socioeconomic priorities. This could imply targeting SFHs in suburban areas where air pollution is high (often due to inefficient burning of coal or firewood). Alternatively, the program could target MFBs (because of the high share of the urban poor living in MFBs and the high energy-efficiency potential) or the lowest-income homeowners (who may already suffer from underheating and inability to afford heating fuels). Governments may also consider targeting buildings with very high energy use (e.g., private hospitals) or firms that are vulnerable to high energy and heating costs.

In terms of formal eligibility requirements to mitigate fraud and ensure the program is on sound legal footing, governments may require verified housing ownership, a structurally sound building, no utility-payment or property-tax arrears, plans to remain occupants for at least 5 years, and others. Programs targeting MFBs typically require the creation and registration of homeowner associations (HOAs) to allow them to make renovation decisions, sign contracts, and collect fees (see Box VI.1).

Governments should also consider current and projected demographic trends. Understanding such trends is essential to inform the design of sustainable heating programs as they have a direct impact on heating loads, housing types, and spatial planning aspects. Unlike other regions, ECA is unique in having countries with both declining and growing populations, and a substantial shift from rural to urban areas: according to UNdata[85], while ECA's total population is expected to increase by only 1 percent in the next three decades, the percentage of people living in urban areas is estimated to increase by 9 percent. In some subregions, such as Türkiye and Central Asia, the urban population is expected to see increases of 28 percent and 74 percent, respectively. At the same time, because of a combination of urbanization and population decline, some countries are expected to see severe drops in rural populations. For example, in the ECA countries that are EU members (Bulgaria, Croatia, Romania, Poland), the rural population is expected to decline by 36 percent, and in the Western Balkans by 44 percent.

[85] https://data.un.org.

Table VI.2: Financing Mechanisms

Instrument	Implementation Mode	Description	Pros	Cons	Example
Loans	Government loans, EE funds, ESAs	Government agency, independent entity, or quasi-independent entity providing financing for EE and upgrades to heating systems, when local commercial banks are unable/unwilling to enter market	• Efficient uses of public resources wherever the liquidity of the local banking system is a constraint • Well suited for building renovations and heating equipment with particularly upfront costs, and very suitable if the targeted consumers or firms have sufficient credit history or collateral • Can be sustainable; mandated to promote EE or clean energy • Can develop specialized products; centralized experience and lessons	• May exclude less-well-off households or businesses (waiving these requirements is also not recommended, as this may encourage borrowing by households and businesses that may have insufficient funds to repay the loan) • May distort market • Could create monopoly • May not operate efficiently • Can be captured by political interests	• Eco Fund (Slovenia) • Kosovo Energy Efficiency Fund • Armenia R2E2 Fund • EERSF (Bulgaria) • NFOŚiGW (Poland)
	Commercial/ community bank loans	Commercial/Community banks provide loans for EE or clean energy	• Sustainable • Allows for competition of financing and builds off existing credit system	• Only serves creditworthy customers • May involve high interest rates • Banks may lack incentive to market aggressively • Developed financial market familiar with EE or clean energy and Creditworthy customers system	• EERSF—Bulgaria
	Credit Lines	Credit facility extended by a bank or other financial institution to businesses or individual customers that enables them to draw on the facility when funds are needed	• Flexibility	• Only serves creditworthy customers • May involve high interest rates • IFI credit lines could impose fiscal burden to government	• Across ECA
Credit guarantees	Financial intermediaries	A public or private agency (e.g., development or commercial bank, insurance or guarantee company) guarantees a portion of loan losses from defaults to encourage banks to lend for EE and defray perceived risks	• Efficient use of public resources wherever the main constraint in the local banking system is the perceived risk of heating- or energy-efficiency-related lending	• Have historically been less common internationally because of the high demands on administrative capacity of the government and the implementing institutions	• EERSF—Bulgaria
Green mortgages		Subsidized or preferential mortgages to promote energy efficient building construction and retrofits based on predefined green measures	• Allow investors to make long-term plans • Works within existing mortgage market • Leverages commercial financing	• Certification of green buildings could be a major barrier • Banks may be unwilling to offer special rates for green homes • Government subsidies could impose fiscal burden	• Many EU countries
Property assessed clean energy (PACE) loans		Loans for eligible clean energy solutions that are taken on the property rather than the owner; in the event of a sale, the remaining balance is transferred to the new owner	• Can be done sustainably • Can reduce barrier if the homeowner plans to move within loan period • Can work within existing mortgage systems and lenders	• Contractors may have incentives to promote larger capacities in order to increase sales • Can discourage new owners from purchasing if it comes with debt burden	• US
Utility on-bill financing	Utility EE programs	Electricity or DH utility implements energy efficiency or clean energy solutions in residential buildings	• Can be done sustainably • Builds off utility relationships,services and collection schemes • Allows for simple collections (on-bill repayment) • Effective delivery mechanism to implement programs • Utilities can procure some items (e.g., heat pumps) in bulk and secure better pricing	• Utilities may lack incentives to provide services, offer financing, or promote energy efficiency if it reduces energy sales • Regulations may limit new utility services, billing • Can create a monopoly • Requires payment discipline and adequate billing practice • Financial capacity of utilities to provide upfront financing may be limited	• US, Canada

Energy supply contracting	ESCO financing	Contract in which the supplier installs and operates the heating system and sells the heat on a unit basis at an agreed price for a certain period (also called 'heating-as-a-service', chauffage)	• Combines equipment supply, O&M and financing in one transaction • Incentive for supplier to offer model in order to increase market share • Incentive is for supplier to offer most efficient heat supply options	• Model does not work well for energy thermal renovations, since incentive for supplier is to maximize heat sales • Higher risks for suppliers result in higher fees for heat supply to consumers	• US, Canada, EU
Equipment leasing	Supplier intermediaries	Contract in which the owner (lessor) of sustainable heating equipment (leased asset) provides it for use by the lessee at an agreed monthly fee for a certain period	• Combines equipment supply and financing in one transaction • Incentive for supplier to lease in order to increase market share	• Leasing would limit homeowners to specific heating products offed by lessor • Leasing does not work well for energy thermal renovations • Leasing fees may be expensive for lower income households	• US, Canada, EU
Vendor Credit		Type of financing arranged by a vendor with or without a finance provider to enable it to provide credit terms to a buyer for sustainable heating equipment.	• Combines equipment supply and financing in one transaction • Incentive for supplier to offer credit in order to increase market share	• Vendor credit would limit homeowners to specific heating products offed by vendor • Vendor credit may not work for energy thermal renovations • Vendor credit fees may be expensive for lower-income households	• US, Canada, EU
Emission trading	Carbon finance	Contractual arrangement where one party agrees to purchase the verified carbon emission reductions resulting from an investment by the end user to shift to cleaner heating and energy efficiency.	• Provides an additional source of revenue for the project sponsor which can reduce longer payback periods • Incentive is tied to actual investment performance and results	• M&V protocols can be onerous including agreeing on necessary adjustments to project baselines	• EU, Canada, China, Japan, New Zealand, South Korea, Switzerland and the United States.

Source**:** Authors. Part of the information presented is a condensed and adapted version of the options presented in World Bank, *Western Balkans: Scaling Up Energy Efficiency in Buildings*, 2014 (Washington, DC: The World Bank Group).
Note: EE = energy efficiency; EERSF = Energy Efficiency and Renewable Sources Fund; ESA = energy service agreement; O&M = operations and maintenance.

Box VI.1: Homeowner Associations and Scaling Up Energy Efficiency

Collective decision-making in MFBs and weak HOAs is often a key challenge for both energy efficiency and heating investments. If decision-making structures for investments and mechanisms for financing capital-intensive upgrades are not well established, it is difficult for MFBs to upgrade their heating systems, switch to cleaner fuels, or implementing building-level energy efficiency measures. Experience in ECA has shown that governments can support the development and functioning of HOAs by improving legislation to strengthen the legal standings of HOAs, set and enforce standards for MFB maintenance, and provide training and public outreach on collective decision-making as well as building management and maintenance.

But there are obstacles to strengthening HOAs, such as:

- *The heterogeneity of HOA residents*. Many MFBs have homeowners with a variety of incomes, education levels, and priorities. This can result in poorer residents being unable to make contributions toward maintenance expenses or vote in favor of renovations.
- *The technical capacity of HOAs*. It is difficult for homeowners to establish and operate HOAs (including reviewing energy audits, supervising contractors, etc.) on their own. Wealthier HOAs can hire professional managers or maintenance firms, but lower-income households cannot—and usually their buildings are the oldest and in most need of repair.
- *The poor condition of the buildings*. Poorly functioning HOAs and chronic under-maintenance and repair of MFBs have led to massive investment needs. Many homeowners do not believe they can mobilize funds or afford all the needed investments.
- *Limited access to financing*. HOAs have difficulty borrowing because banks do not view them as creditworthy and are typically unwilling to lend on a project finance basis. HOAs also have difficulties opening bank accounts, signing contracts, and enforcing homeowner dues.

Lithuania offers an example of an alternative to working through HOAs. Between 1996 and 2013, a municipality implemented energy efficiency improvements and heating upgrades in more than 2,400 buildings (generating savings about 82 GWh per year) despite the lack of borrowing and technical capacity on the part of homeowners and HOAs. The Residential Energy Efficiency Program provided loans and subsidies, combined with technical assistance, to achieve this. To address HOA deficiencies, the program allowed building renovations to be initiated by the municipality, which appointed project administrators for multi-apartment buildings with weak or non-existent HOAs. The appointed building-administration company (often a municipally-owned maintenance company) took loans on behalf of the homeowners to finance the energy efficiency investment costs. The company recovered the investment costs through a monthly building management fee paid by homeowners based on the estimated energy cost savings achieved. The municipal project administrator assumed the loan repayment risk.

While the consent of homeowners was required to implement energy-efficient retrofits in their buildings, the program also provided additional incentives to facilitate consent from low-income households. After completion of the renovations, all low-income households received a subsidy covering 100 percent of the preparation and renovation costs in addition to their heating allowance subsidy. For low-income households that voted against the renovation, the state reduced their heating subsidy by 50 to 100 percent over three years.

Sources: World Bank, *Bulgaria: National Program for Energy Efficiency in Public Buildings—Program Design Report for the Second Phase*, Report No. AUS0000388, July 2018. World Bank, *Keeping Warm: Urban Heating Options in the Kyrgyz Republic—Summary Report*, prepared by Ani Balabanyan, Kathrin Hofer, Joshua Finn, and Denzel Hankinson, 2015; International Housing Coalition, *Homeowners Associations in the Former Soviet Union: Stalled on the Road to Reform*, prepared by Barbara J. Lippman, 2012; and ESMAP, *Case Study on the Residential Energy Efficiency Program in Lithuania*, prepared by Viktoras Sirvydis, 2014.

Targeting specific segments of the population (e.g., by beneficiary income level or housing type) for financial incentives can help ensure that the limited government funds are directed to the most vulnerable beneficiaries. As noted in Chapter II, about one-third of ECA households are energy-poor. About eight countries report having more than 42 percent of their residents spending 10 percent or more of their household income on energy. For the sustainable heating transition, this creates a huge risk that (i) the energy-poor may already be unable to afford to adequately heat their homes and meet their energy needs and (ii) these households are more likely to use traditional and unsustainable fuels, such as coal and firewood, and less able to afford a shift to more-sustainable heating options. In Poland, for example, about 60 percent of SFH owners who are reliant on dirtier solid fuels are from the bottom 40 percent in the income distribution. Therefore, government programs must be designed to explicitly serve this group—with suitable financing, delivery, and outreach efforts tailored to meet their needs.

As an example, some of the Massachusetts Clean Energy Center (CEC) programs restrict eligibility to lower-income households by requiring documentation to show that the applicants earn no more than 80 percent of the state's median income. In general, the most suitable targeting incentives depend critically on the country's administrative capacity and fiscal space. In countries possessing a high administrative capacity and limited fiscal space to fund broad government interventions, a granular targeting approach for grants that varies with income and housing conditions could be optimal. With this approach, authorities could achieve high coverage of the vulnerable population with adequate support while limiting the inclusion error. For countries with low administrative capacity and sufficient fiscal space to accommodate some inclusion errors, a well-designed program targeting beneficiaries of existing general social assistance measures that target the poorest could be used. Other eligibility criteria are equipment- or vendor-specific, to ensure that only the most economic types of heating solutions receive support. In Massachusetts, the only eco-design woodstoves eligible for tax credits are those with built-in catalytic converters, and such technologies tend to be more expensive than other varieties on the market. (International examples of technology-specific programs supporting sustainable heating systems can be found in Annex K.)

The scale and choice of the financial incentives may need to be tailored to the targeted population—informed by market studies and household surveys, which are generally the best tools for identifying household practices, needs, and constraints.

The following is advised for programs targeting lower-income households:

- First, because the upfront investment costs may be prohibitively high, programs targeting lower-income households need to have higher levels of financial incentives. Further, many lower-income households rely on heating fuels that require no or very limited cash expenditure, such as firewood or charcoal. Therefore, a number of government programs provide high shares of grants and subsidies to incentivize uptake. Most governments limit support to around 85-95 percent for the poorest segment, as a 100 percent grant could remove incentives for households to constrain costs. Efforts should be made to ensure that the grants are properly targeted, and that disbursements can be made quickly.
- Second, to tackle the issue of higher heating bills resulting from cleaner fuels, efforts should also be made to either develop targeted support programs or strengthen general social assistance programs so households are not penalized for making such investments. Such schemes should be targeted at the most in need, relatively easy to apply for and verify eligibility, and well communicated so eligible households will apply. Efforts should also be made to: (i) discourage overconsumption by limiting the allowances to a level sufficient to meet only basic levels of comfort, (ii) encourage energy efficiency through parallel incentive and financing programs, and (iii) consider mechanisms to increase allowances if the households switch to cleaner heating options.[86] Complementary investments in energy efficiency measures and other measures to lower monthly bills (e.g., rooftop solar PV panels) should also be encouraged. A recent set of energy audits on typical SFBs in Bishkek showed that the monthly energy bills can be reduced by more than half with a combined investment in energy efficiency measures, heat pumps, and rooftop solar PV.
- Third, programs targeting lower-income households need to provide for the fact that those households tend to have very limited access to commercial borrowing to cover their share of the costs. For most programs, some level of co-financing will be required which will imply the need for suitable financing mechanisms. Allowing lower-income households to access financing may require guarantees or other schemes that blend public and commercial financing (e.g., utility on-bill financing, repayable grant) to make them more affordable.

[86] For a more detailed discussion of social safety nets for energy, see World Bank (2022), *ECA Policy Note: Energy Crisis – Protecting Economies and Enhancing Energy Security in Europe and Central Asia*, http://hdl.handle.net/10986/38101.

- Fourth, programs targeting lower-income households need to pay special attention to ensure program accessibility during the application, implementation, and acceptance/payment phases. Households at the lower end of the income spectrum may face language or literacy barriers or may have much less experience with or trust in interactions with government services in general. Local governments can play a facilitating role by helping to recruit customers, answer questions, and provide additional information. However, poorer households tend to have less access to the internet and some media outlets, may not understand eligibility requirements, may have more difficulty selecting heating and energy efficiency options. Social norms can also discourage adoption of newer fuels and technologies, and assessing the pros and cons of alternative heating systems can be complicated—and information from contractors may not be credible or reliable.[87] "Program agents" or "program operators" could be recruited (paid for by the program) to go door-to-door to help lower-income households understand the program requirements and complete applications, advise them during the energy audit/implementation phase, and assist them during the acceptance/payment stage. It can also help reduce application/implementation errors and mistakes. Such a system is now being developed to support the Clean Air Priority Program (CAPP) in Poland (see Annex L).

Reflecting **gender considerations** in the design of heating programs is crucial to reduce persistent gender gaps in the energy sector. In line with large and persistent gender gaps in the economy in general[88], a 2015 World Bank regional study found that there is a gap between men and women regarding their awareness and knowledge of energy efficiency and their ability to take actions to improve energy use in their households[89]. This gap puts women, particularly those in female-headed households, at a disadvantage, as they are less likely to apply for and benefit from such programs. In addition, the same report shows that in all sample countries[90], it is largely a man's responsibility to procure wood and coal for heating. In the Western Balkans, men took the lead in collecting heating fuels over 60 percent of the time and shared responsibility with women in 25 percent of households surveyed. However, there was a more even balance when it came to feeding the fuel into the heating device[91]. Because of that, some female-headed households, especially those headed by elderly women, affirmed their preference for using electricity for heating, and for heating smaller spaces, to avoid the cost and labor associated with heating their house with wood and coal. Furthermore, as women are typically more likely to spend extensive periods at home performing household activities related to maintaining the heating systems, and they are more exposed to harmful pollutants and poor indoor air quality.

Through the right design, government programs can address such gaps and increase knowledge about the investment options available—while helping to increase women's voice and agency, one of the four pillars

[87] J. Karver, R. Badiani-Magusson, and J. Carroll (2022), "Clean air and heating choices: How to change homeowners' behavior in Poland," World Bank blog post, available at: https://blogs.worldbank.org/climatechange/clean-air-and-heating-choices-how-change-homeowners-behavior-poland.

[88] According to the World Bank, the ECA regional gender pay gap between men and women is about 30 percent. It is more significant in the Caucasus and Central Asia countries (27 percent in the Kyrgyz Republic; 36 percent in Armenia; 51 percent in Tajikistan) and in Belarus (26 percent), and less stark in new EU member states. In addition, women's labor force participation is lower than men's across the region, but significantly lower in some states, such as Kyrgyzstan (78 vs 47 percent), Türkiye (78 vs 39 percent), Turkmenistan (75 vs 47 percent) and Uzbekistan (79 vs 52 percent). Some of these countries also show higher unemployment rates for women, while in the rest of the region unemployment rates do not vary significantly by gender.

[89] Rebosio Calderon, P. Michelle, and Sophia V. Georgieva. 2015. *Toward Gender-informed Energy Subsidy Reforms: Findings from Qualitative Studies in Europe and Central Asia.* Washington, DC: World Bank.

[90] Armenia, Belarus, Bulgaria, Croatia, the Kyrgyz Republic, Romania, Tajikistan and Türkiye.

[91] World Bank, 2023. *Behavioral diagnostic of sustainable heating transitions in the Western Balkans: Evidence from Bosnia & Herzegovina, Kosovo, North Macedonia and Serbia*. Draft final note, January 25, 2023.

of the World Bank Group's gender strategy for 2016–2023[92]. In Poland, for example, women also show attitudes that are more conducive towards pro-environmental behaviors including sustainable heating and energy efficiency, they are less likely than men to plan to take actions towards such investments; thus, efforts to enhance women's agency is likely to lead to positive outcomes.[93]

Box VI.2: Gender in Energy Subsidy Reforms

Global studies on gender and energy suggest that energy reforms may have unequal effects on the well-being of both men and women. Since the 1990s, most ECA countries have embarked on energy sector reforms, and the World Bank report *Toward Gender-Informed Energy Subsidy Reforms: Finding from Qualitative Studies in Europe and Central Asia* presents an integral part of a set of qualitative studies on poverty and social impacts of energy subsidy reforms in ECA. It illustrates the extent to which energy subsidy reforms in various ECA states[94] have affected men and women differently. The study collected data by interviewing focus groups between February 2013 and May 2014; 208 focus groups and 131 interviews were conducted.

It found that gender issues related to the reforms vary substantially across the ECA's subregions, settlement types (urban or rural), and social and ethnic groups, among other elements. For instance, in Belarus, where tariffs for energy utility services had not grown substantially at the time of research, and customer relations regarding energy services were still predominantly managed by state-owned communal housing institutions, respondents had fewer observations on how rising energy costs might affect men's and women's behaviors. However, for rural residents in Armenia, the Kyrgyz Republic, and Tajikistan—especially those in remote locations— energy reforms prolonged shortages or weaker electricity supply, and increased costs for wood and coal. Such households rely more heavily on collected fuels such as brushwood, manure, and agricultural subproducts. This directly impacts the workload of women, who are most often responsible for collecting these fuels.

Overall, the research finds that gender differences had more severe impacts in rural areas relative to urban ones; in Central Asia relative to Eastern Europe; and among the Roma minority compared to non-Roma in the new EU member states.

Qualitative findings indicate that gender-related vulnerabilities in energy reforms occur for the following reasons:

- Women are more likely to sacrifice their time/well-being to cope with higher costs of energy, relative to other household members.
- Women are potentially important agents in encouraging behavioral change toward energy efficiency but are not as proactive in trying to implement energy efficiency improvements.
- Female-headed households are at an economic disadvantage due to women's overall lower incomes and additional constraints that may prevent them from complementing their income with additional jobs and/ or participating in labor migration.
- Energy affordability for elderly women who live alone and on a fixed low income deserves special consideration across the region.
- Women are less aware of their rights as energy consumers and less successful in addressing their concerns with energy providers.
- Women are less informed about tariff reforms in general.
- Cultural norms and time-consuming applications may be a disincentive for vulnerable men to pursue social assistance.

Source: World Bank. 2015. *Toward Gender-Informed Energy Subsidy Reforms: Findings from Qualitative Studies in Europe and Central Asia.* Washington, DC. https://openknowledge.worldbank.org/handle/10986/22100.

Women are also more likely to reduce heating and expenditure on their own needs in the household's efforts to manage energy expenses. According to a qualitative World Bank report[95], in Armenia and Türkiye, women who stay at home during the day were less likely to heat the house when other family members were out. In the Kyrgyz Republic, women were more likely to cut spending on themselves first—such as for clothes or entertainment—than men. And benefit more from the renovations and heating system upgrades in public buildings (e.g., schools, hospitals, kindergartens) in terms of improved comfort levels and safer and better working environments.

Apart from economic aspects, there are also gender preferences when it comes to ambient temperatures. An assessment made by ESMAP[96] analyzed differences in behavior and perceptions of energy efficiency in public buildings in Türkiye. It found out that female employees are particularly affected by thermal

[92] World Bank, *World Bank Group Gender Strategy (FY16-23): Gender Equality, Poverty Reduction and Inclusive Growth*, available at https://documents.worldbank.org/en/publication/documents-reports/documentdetail/820851467992505410/world-bank-group-gender-strategy-fy16-23-gender-equality-poverty-reduction-and-inclusive-growth.

[93] https://www.gov.pl/web/klimat/badania-swiadomosci-ekologicznej

[94] Armenia, Belarus, Bulgaria, Croatia, the Kyrgyz Republic, Romania, Tajikistan, and Türkiye.

[95] World Bank. 2015. *Toward Gender-Informed Energy Subsidy Reforms: Findings from Qualitative Studies in Europe and Central Asia*. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/22100 License: CC BY 3.0 IGO

[96] Ezgi Canpolat and Ursula Casabonne. 2021. *Gender Differences in Behavior and Perceptions of Energy Efficiency in Public Buildings in Türkiye.* Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/35654.

discomfort during the winter months, while male employees experience thermal discomfort during the summer months. In the quantitative survey, when directly asked whether respondents thought inefficient heating and cooling systems impact men or women more, 47 percent of participants reported that women are mostly affected, while only 11 percent said that men were more affected. In response to such differences in thermal demands, female employees often seek individual solutions, such as bringing in portable heaters from home, to avoid feeling cold during the winter months.

Therefore, gender aspects should be addressed in the design of heating programs. Female-headed household's economic vulnerability needs to be considered and programs should ensure that women have equal access to financing mechanisms, incentives, and program information and outreach. It is crucial to strength administrative systems—e.g., for information, grievance, and redress—to reduce the influence of traditional "gender norms" in interactions with institutions.

In addition, communication campaigns regarding heating programs should be designed to target both men and women, presented using simple language, and communicated through local channels (e.g., local news outlets, public offices, building managers, local utility service centers). Finally, qualitative and quantitative analyses should be performed to better understand aspects of gender vulnerability. Data on economic activity, employment, migration, salaries and pensions of men and women, etc. should be assessed to determine how heating programs might impact heating affordability for men and women.

d. Non-financial, complementary program interventions

Government programs should also couple financing and financial incentives with technical assistance (such as energy audits, guides, and training) to help homeowners make more informed choices and help lower their transaction costs. Such technical support should facilitate all aspects of participation in the government programs, from the application stage through audits and designs to procurement, installation, and commissioning. Support should also be provided to address any supply-side bottlenecks that arise, including training and certification of technicians, to ensure the quality of renovations, equipment selection, and installations. Public outreach and behavior change campaigns are also critical to ensure strong program participation and help nudge consumer decisions. Households also need to be made aware of the program eligibility criteria, procedures, financial incentives, financing options, and technology choices and their relative costs and benefits. The World Bank has developed extensive guidance materials on outreach programs, a sample of which is summarized in Box VI.3.

Box VI.3: Behavior Change Campaigns

Research has shown that understanding what motivates people and influences their behavior is central to successful policymaking—and this is the case broadly across different sectors, including energy efficiency. The World Bank ESMAP report *"Integrating Behavior Change in Energy Efficiency Programs in Developing Countries* describes methods and approaches for integrating behavior change strategies into energy efficiency programs and presents the important role that communication for behavior change can play in improving the impacts and outcomes of interventions for energy efficiency. Most of these approaches can be extended to sustainable heating.

The behavioral approach to policy design draws on psychological, social, and contextual explanations of human behavior to provide innovative, usually inexpensive solutions that are often used as complements to traditional policy approaches. Its application usually starts with defining the problem, diagnosing any barriers preventing people from adopting the desired behavior, and then designing interventions to address those barriers.

Communication plans typically begin with researching opinions and social norms and identifying target audiences and optimal behaviors; this is followed by planning, implementation, and monitoring and evaluation. Before mass media products are rolled out to consumers, messages and materials are pre-tested, and channels are selected that best support their reach and credibility.

Effective communication can help people initiate and sustain positive attitudes about a situation. Communicating with energy consumers and other key stakeholders about the benefits of energy efficiency, and the strategies that can help reduce energy use and costs, is most effective when the information is presented in a compelling way and is based on sound research. Engaging communications experts who are familiar with local cultures and marketing channels is critical—a campaign that works well in one region will not necessarily translate to another region. Understanding the local context is critical for success. In all cases, the messages of a behavior change campaign should be crafted so that they are simple, concrete, credible, and convey a story. Designing effective messages for a campaign is a highly creative process that requires experienced communicators on a project team.

For communication campaigns associated with energy reforms, the World Bank's "Good Practice Note 10: Designing Communication Campaigns for Energy Subsidy Reform" also offers insights relevant to the sustainable heating transition. It notes that effective public communication campaigns should demonstrate why certain reforms are necessary and how they ultimately benefit consumers, and what social protection mechanisms will help alleviate impacts on poor and vulnerable households, to build support for reforms and minimize negative perceptions. Communications should be evidence-based and consistent across ministries, agencies, and government-owned energy industries.

The Good Practice Note identifies the following practices that contribute to a successful communication campaign:

- Determine the objectives, timeline, budget, and governance for the campaign.
- Map key stakeholders and consider their level of interest and influence.
- Conduct opinion research to understand stakeholder views and perceptions.
- Create and pre-test compelling messages that address stakeholders' commonly held views and build awareness of the scope of consumer price subsidies and their influence on the economy.
- Assign credible messengers and spokespeople.
- Identify the best channels for communicating messages to different stakeholders and encouraging two-way dialogue.
- Set measurable goals to track the communication campaign's effectiveness.

There are three distinct phases of reform during which communications campaigns are appropriate. When the impacts of reform are being researched and policy is being designed, external communications should raise awareness about the need for reform. When a detailed plan is developed, communications on the final policy should raise awareness of the plan and measures to mitigate adverse impacts. During implementation, communications should share results and needed adjustments of the reform.

Sources: ESMAP (2020), *A Practitioner's Guide to Integrating Behavior Change in Energy Efficiency Projects in Developing Countries*," ESMAP Knowledge Series 029/20, Washington, DC: World Bank; World Bank (2018), *Good Practice Note 10: Designing Communication Campaigns for Energy Subsidy Reform*, prepared by Heather Worley, Sara Bryan Pasquier, and Ezgi Canpolat.

A summary of suggested non-financial, complementary program interventions is presented in Table VI.3.

Table VI.3: Complementary Measures to Support Program Financing and Incentives

Complementary measure	Description
Market studies, behavior norms, and practices	Market studies identify current heating technologies and costs, heating demand, availability and costs of local fuels, information on the building stock, and income levels (to assess affordability of investments and fuels). Consumer and behavioral assessments assess which media outlets households typically receive information, their priorities for selecting a heating system, and their ability to assessing these options considering local contexts, social norms, customs, and behavioral habits.
Program marketing, outreach, and behavior change	Design marketing and outreach to maximize coverage of the target market and develop appropriate information materials, social interactions and educational programs in order to maximize program participation rates, understanding of program procedures, and sustained shifts in consumer preferences for sustainable heating options and practices.
Technical information (pre-financing stage)	Development and dissemination of simple, credible information to help households decide to participate in the program, such as energy efficiency and heating calculators, case studies of completed renovation/heating upgrades, summary of technical options, etc.

Technical information (implementation stage)	Development and dissemination of simple, credible information on implementing renovations and heating upgrades, such as technical guides, energy audit templates, standard terms of reference, a list of approved contractors, list of eligible equipment and materials, energy bill calculators, completion checklists, how-to videos and other online training, etc.
Technical training	Development and dissemination of technical training for equipment and service providers on program guidelines and criteria, technical guides, energy audit templates, common errors from early investments, list of eligible equipment and materials, completion checklists, other online/face-to-face training, etc.
Program monitoring, evaluation, and reporting	Implementing agencies should have good databases of buildings containing data on heating system, fuel, and consumption. They should also maintain a consolidated monitoring and reporting system (with a comprehensive set of indicators), periodic program evaluations (process and impact) to assess effectiveness and results and make needed adjustments, and periodic surveys (to assess satisfaction, qualitative impacts, program feedback, common issues, demographic information).
Technical information (completion stage)	Development and dissemination of information on completion protocols and guidelines, procedures for final payments, acceptance and certification requirements, monitoring of energy bills, good practices in O&M, etc.
Program results and lessons dissemination	Periodic dissemination of program results in order to maintain strong public support and to share emerging good practices and lessons learned.

Source: Authors.

e. Enabling reforms

To ensure government programs are efficient and effective, several complementary, enabling reforms may be needed to level the playing field for sustainable heating solutions and reduce their incremental cost. Which enabling reforms are most impactful depends on the country context. Often, these include a combination of the following:

a. **Gradual phase-out of fossil fuel subsidies, removal of direct and indirect subsidies for electricity and DH, and better targeting of cross-subsidies in electricity and DH tariffs.** The gradual phase-out of fossil fuel, electricity, and DH subsidies is important to create a level playing field for more sustainable heating fuels and technologies and encourage energy efficiency investments. Cross-subsidies, such as tiered pricing for households based on consumption (either as increasing block tariffs or volume-differentiated tariffs), can often be better optimized for equity and efficiency.

b. **Adequate pricing of externalities associated with unsustainable heating options, such as environmental and health impacts, with complementary measures to protect the poor and vulnerable.** This could include carbon pricing and taxation of fuels that lead to local pollution. Because such fiscal measures tend to be regressive, they should be accompanied by social safety nets and other measures to protect the poor and vulnerable.

c. **Consider measures to reform the DH sector, such as unbundling heat generation from distribution and introducing standard heat supply contracts with private producers and universal consumption-based metering and billing.** This could allow private developers to enter the heating market by mobilizing financing and technical know-how to construct and generate clean heating supply and modernize DH networks. Enhanced billing allows price signals to flow through to consumers and incentivizes efficient energy use. Reforms may also include measures to improve governance, transparency, and institutional strengthening.

d. **Promote sustainable biomass through the formalization, regulation, certification, and pricing of informal markets for biomass fuels (e.g., firewood, wood pellets, wood chips), including better forestry chain management and mandatory sustainability certification of biomass used for heating (Box VI.4).** Markets for traditional biomass, especially firewood, are often informal and poorly regulated, which means that overharvesting (through illegal logging), regulating of fuel quality, adequate pricing of environmental externalities (to prevent both overconsumption and emissions), etc. can only be achieved through the gradual formalization of these markets.

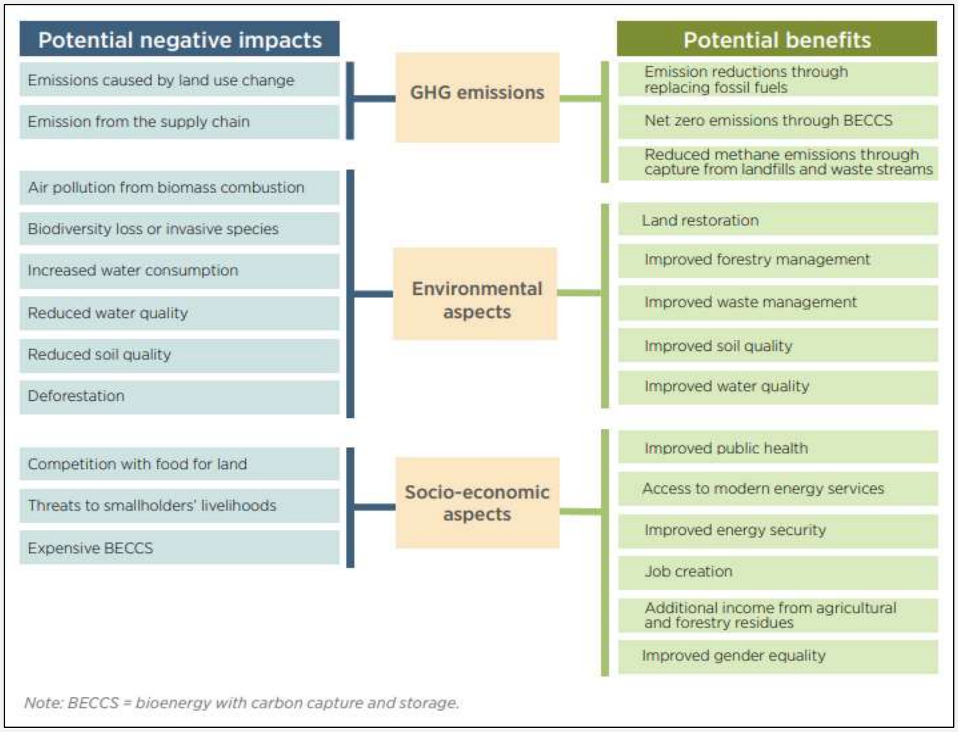
Firewood is of particular concern, as it is often the least-cost fuel (as noted in Chapter IV) and is often used inefficiently and unsustainably.

Box VI.4. What Is Sustainable Biomass?

Parameters that determine sustainable biomass use are, among other things, related to (i) the underlying *management* system associated with regulatory and institutional frameworks, (ii) the application of third-party sustainable management *certification* systems (and associated chain of custody certification), and (iii) the application of *quality standards* for fuel and combustion technology.

Broadly, the sustainability of biomass energy use is commonly discussed along three dimensions: (i) how the biomass is sourced, (ii) the technology used to generate energy, and (iii) the associated GHG emissions and pollution particles emitted. While several international organizations discuss these various dimensions of sustainability for biomass energy use, there is no common standard. However, there is growing convergence around some common features that are being identified as core elements (Figure VI.3).

Figure VI.3: Biomass Sustainability Framework



Source: IRENA (2022), *World Energy Transitions Outlook 2022: 1.5°C Pathway,* International Renewable Energy Agency, Abu Dhabi.

Regulatory frameworks. Several internationally recognized standards have been established. Initially developed for application in the EU, these standards were subsequently adopted within the framework of the International Standards Organization (ISO). Among these standards, ISO 17225 plays a central role (Table VI.4). It consists of nine parts and sets out the general requirements for solid biofuels, classifying them according to origin, market/trading forms, and general properties.

The chemical composition of biomass energy has many effects on thermal utilization. For example, the ash content influences deposit formation and fly ash emissions—and thus the choice of the appropriate combustion technology and the logistics of ash storage and ash use/disposal. Wood-based biomass fuels (coniferous and deciduous wood, bark, logging residues, and short-rotation coppice) contain usually relatively low amounts of nitrogen (N), sulfur (S) and chlorine (Cl). Except for bark, they are also characterized by low ash content. In contrast, straw, cereals, grasses, grains, and fruit residues can contain relatively high levels of N, Cl and S, which is of special relevance for NO_x, hydrochloric acid (HCl), dioxins and furans (PCDD/F) and sulfur oxide (SO_x) emissions as well as corrosion of the combustion technology.

Table VI.4: Solid Biofuel Characteristics as defined by ISO 17225

Biomass Origin	***Trading Forms***	***Properties***
• Woody biomass (forestry & arboriculture) • Herbaceous biomass (agriculture & horticulture) • Aquaculture • Mix of biomasses	• Briquettes • Pellets • Wood Chips • Logs & Firewood • Sawdust • Shavings • Bark • Straw • Grain • Olive residues • Fruit residues • Other	• Moisture content • Dimension • Particle size distribution • Ash content • Fixed carbon content • Volatile matter • Sulfur content • Chlorine content • Gross heating value • Particle density • Bulk density

Source: ISO 17225.

In many countries, especially in the EU and North America, the production of biomass is governed by a broader regulatory framework based on the source, e.g., forests or agriculture. The EU Energy Directive and associated regulations can be differentiated concerning two core aspects: sustainability of biomass supply and sustainability of biomass use. This regulatory framework is further supported by national legislation, regulations, and standards. The EU regulatory framework considers the entire value chain—production, trade, and use—and can serve as an example for other countries working to develop and enhance their governance frameworks. Although this framework is still evolving, the rules and regulations can serve as guidance for ECA countries, especially for DH, industrial use, and household heating. At the same time, it should not be regarded as a blueprint because location, country, and biomass end-use-specific considerations need to be incorporated.

Source*:* World Bank, *"*Background note on Sustainable Biomass for Energy Supply" (unpublished), World Bank, 2022; IRENA (2014): Global bioenergy supply and demand projections. A working paper for Remap 2030, IRENA, Bonn; European Commission (2019): Brief on biomass for energy in the European Union. The European Commission's Knowledge Center for Bioeconomy, European Union 2019.

e. **Better design, enforcement, and updating of building codes and certification.** Building codes, which specify minimum energy efficiency performance for new buildings, can be an effective tool for ensuring adherence to good design and construction practices when practically formulated, regularly updated, and properly enforced. They can also be an effective and economic tool for helping overcome persistent market barriers to the delivery of energy-efficient buildings. Building codes should be revised at least every five years to incorporate increasingly stringent requirements, along with establishing control and monitoring systems to enforce compliance at both the design and commissioning stages[97]. For both new and existing buildings, efforts should be made to improve the energy performance certification system for buildings, which will allow owners and prospective buyers to be more aware of their buildings' performance and likely energy bills.

f. **Energy-efficiency performance standards for heating products.** Regulations in the form of technical standards for heating products (e.g., stoves, boilers, heat pumps) are crucial in allowing for the gradual transformation of the market over time in the areas of energy performance, operations, and safety. These standards should be developed and introduced at the national level after broad consultations with manufacturers, energy experts, consumer advocates, and other stakeholders. As with building codes, these standards should be developed based on existing market conditions, periodically updated, and well enforced.

g. **Air quality standards and bans of polluting fuels and technologies.** Development and enforcement of clean air standards (e.g., restrictions on the combustion of solid fuels, fuel quality standards, emission reduction devices, chimney requirements) and other sectors (e.g., industry, transport, power) are important enabling reforms to create demand for cleaner heating solutions. Because household heating is such a critical factor in urban air pollution, these measures may take

[97] Feng Liu et al. (2010), *Mainstreaming Building Energy Efficiency Codes in Developing Countries: Global Experiences and Lessons from Early Adopters*, World Bank/ESMAP Working Paper No. 204, World Bank, https://openknowledge.worldbank.org/handle/10986/5915.

the form of bans of polluting heating fuels (e.g., coal, oil, gas, traditional firewood) and outdated, inefficient heating systems in certain areas.

h. **Strengthening of social safety nets.** Reasonably well-targeted heating allowances and similar social protection programs are important to protect the most vulnerable, especially when implementing mandatory bans of polluting heating options or energy price reforms. However, such schemes should be targeted to the most in need, relatively easy to apply for and verify eligibility, and well communicated so eligible households apply. Coverage (inclusive of the bottom 20-40 percent of the population by income), targeted, scalable, fiscally prudent, and market oriented. These programs should also be transparent, fully budgeted, time-bound and easy to access.

i. **Prosumer regulations.** Governments should also develop regulations and incentives to encourage the installation of rooftop and/or ground-mounted solar PV to support the electrification of heating for buildings. Excess electricity can be sold to the grid under a net billing scheme.

j. **Home-owner association (HOA) legislation.** Collective decision-making in MFBs and weak HOAs are often key challenges to both energy efficiency and heating investments. Many lessons in this regard have been learned during energy efficiency programs for MFBs. To complement interventions in MFBs, governments should consider regulations and incentives to register HOAs and improve their ability to collect fees (for both short-term repairs and longer-term capital renovations), sign contracts, open bank accounts, take loans, make decisions, etc.

k. **Reforms to support businesses and skilled employment across the sustainable heating value chain.** Conditions for firms active in the value chain for heating equipment and related investments should be improved through (i) legal and market measures to improve labor conditions, long-lasting careers, and attractiveness to women, to youth, and to workers from other sectors; (ii) improved school curricula to showcase opportunities for employment in the sustainability, energy, and climate sectors; (iii) improved building energy rehabilitation training and skills curricula adapted to specific national/regional needs and gaps, and minimum content guidelines for specialized training programs; (iv) compulsory continuous training ("upskilling") in new approaches/technologies for workers who are already in the sector, and opportunities for people outside of the sector to re-skill and join the sector workforce; (iv) certification schemes for firms, with simplified procedures and common reference frameworks so that good quality of workers is ensured; (v) quality assurance mechanisms for installation services; and (vi) promotion of one-stop-shops for integrated energy audit and advice and renovation project management.

VII. Toward a Framework for the Sustainable Heating Transition

As an essential component of the global shift to carbon neutrality by mid-century, the transition to sustainable heating is a major and urgent challenge. Many of the existing institutions, systems, fuels, and technologies will have to undergo a massive shift in order to achieve this goal, as well the relevant enabling policies, financing and business models, and communications. The good news is that notable progress has already been made in many areas, and emerging technologies and approaches are being tried and tested that will greatly help in this endeavor. Unfortunately, these efforts are not yet at the scale and level of ambition needed. If they are successful, however, the potential benefits could be substantial in terms of economic opportunities (e.g., energy security, reduced fiscal spending on energy and energy subsidies, new business and job creation), poverty reduction (e.g., reduced heating costs, better indoor comfort, lower health impacts), and environmental impacts (e.g., reduced local and global emissions).

a. Key takeaways

Based on the data collected and analyses conducted for this report, eight conclusions and takeaways have emerged. These include:

1. ***Heating in ECA is not currently sustainable.*** Heating in the region remains the most critically important energy service in the region due to its long, harsh winters. However, the quality, sustainability, and affordability of existing heating options remain very poor. Inefficient building stocks, old and dilapidated heating networks, high dependency on fossil fuels, lack of affordability and sufficient heating, and local and global environmental impacts exact a huge toll on its citizens—particularly the poor. Therefore, the status quo is not sustainable.
2. ***Many countries lack the plans and institutional infrastructure needed for the sustainable heating transition.*** Many countries have adopted nationally determined contributions (NDCs), and many others have medium-term decarbonization, RE, and energy-efficiency action plans, LTRSs, and NECPs as well as national adaptation plans (NAPs). However, transition strategies and plans for sustainable heating are broadly lacking. Without such strategies, developing the right policies, investment plans, market development, etc. cannot be efficiently done. And without a clear vision articulated and coordinated by the government, businesses, households, utilities and others are likely to make suboptimal investment decisions regarding their heating supply. Such strategies need to consider future heating demand, demographic shifts, likely housing typologies, access to clean heating sources, technologies options, and other information. The paucity of centralized, reliable, and up-to-date information on heating remain a key barrier to effective planning. Efforts should be made to develop improved repositories of national data and then develop implementable plans including SHRs. Steering or coordination committees are also recommended to provide strategic directions and coordinate policies, resources and programs.
3. ***Energy price reforms are a critical step in the transition.*** As noted in Chapter VI, the gradual phase-out of fossil fuel subsidies, removal of direct and indirect subsidies for electricity and DH, introduction of universal consumption-based billing for DH, pricing of biomass, etc. are all critical to providing the price signals required to incentivize the switch to more-sustainable fuels, technologies, and energy efficiency. Adequate pricing of externalities associated with unsustainable fuels and fuel use, such as environmental and health impacts, is also important to

ensure the optimal heating solutions are prioritized. In such cases, measures need to be introduced to protect the poor and vulnerable.

4. ***Heat demand must be substantially reduced by 2050 through energy efficiency.*** Without energy efficiency, the cost of the transition would be orders of magnitude higher. However, a combination of warming temperatures, more-efficient new buildings (including demolition of very old buildings that are not viable for refurbishment), renovated existing buildings, newer heating technologies, more efficient DH networks, and other factors can contribute to a substantial reduction in heat demand in the ECA region. Estimates indicate demand could be reduced by 45-55 percent depending on the policy ambitions and commitments. While this will help facilitate and lower the costs of the sustainable heating transition, it will also have implications for heating fuel choices and technologies, especially for DH. Huge investments will be needed to scale up building renovation programs, encourage deeper renovations (including NZEBs), improve building codes, and take other measures which will require massive mobilization of institutions and investments. With less than 27 years remaining until 2050, and with on average less than 5 percent of the regional building stock renovated, this means 3.5 percent of the total remaining building stock will have to be renovated each year (about 3.7 million buildings each year, assuming about 106 million buildings in the region) at a cost of about US$45-76 billion annually, depending on the scenario. While most of the transition will be in the residential sector, investments in the public sector can help stimulate markets, demonstrate new technologies and approaches, and lead by example. For residential buildings, some share of public financing for investment subsidies will be necessary given the higher payback periods for older buildings and the need for structural and other repairs. However, given the limitations on available public financing, efforts will have to be made to better leverage more commercial financing for private buildings.

5. ***District heating should be bolstered where economically viable, or else phased out*.** As shown in Chapters III and IV, in dense urban areas, DH will likely remain the most economic option. However, the poor historical performance of many DH utilities in the region, coupled with the huge projected reductions in heat demand and the need to identify and develop cleaner sources of heating, will necessitate a paradigm shift for the sector. Before major new DH investments can be financed, systemic reforms are likely to be needed in order to improve governance, regulatory, operational, and financial performance. The rapid assessment methodology presented in Chapter III offers a useful approach for a quick screening, but deeper assessments will be needed to define reform actions needed to turn around low performers. Once performance improvement plans (PIPs) are agreed and in place, SHRs are recommended—so that geospatial data can be combined with potential clean-heating-source mapping and demand centers in order to identify viable areas for DH coverage, and to determine which potentially cheaper RE and clean energy sources could be used to offset fossil fuels. This would help governments formulate appropriate policies, plans, and programs to support these systems as well as suitable fuels for the peri-urban and non-urban areas. Other measures to improve viability (e.g., building level substations, densification of DH networks, low temperature systems, heat storage, district cooling) should also be considered. Reform-minded utilities should be supported through the transition where economically viable; others may have to be substantially restructured, broken into smaller systems, or even phased out over time. If, in some areas, DH may not be fully economic but offers the most affordable and politically desirable option, then agreeing on a suitable package of reforms, coupled with shifting to cleaner heating sources where available (e.g., from heat-only coal boilers to gas CHP plants),

may be the best near-term option until lower-cost heating technologies and systems become more commercially available.

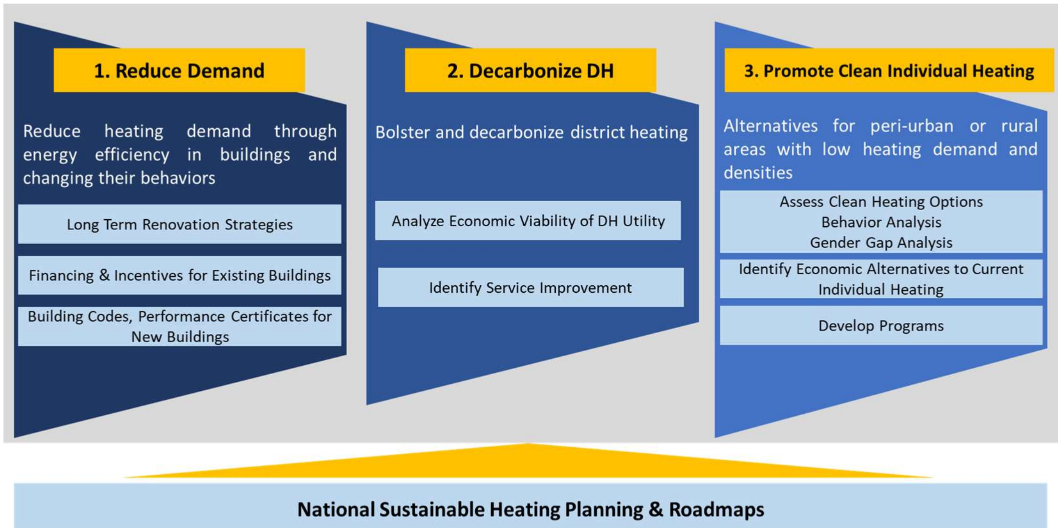
6. ***Where DH is not viable, economic least-cost decentralized heating should be identified and promoted.*** Based on the results of the SHRs, economically viable clean-heating alternatives should be promoted. As shown in Chapter IV, these economic least-cost options will likely include sustainable biomass stoves and boilers (where sufficient woody and/or agricultural resources exist) or heat pumps (where biomass is not available). Such programs should be tailored to the specific market conditions, barriers, and opportunities in the country. If biomass is the preferred option, governments must do more to mandate high-efficiency and eco-stoves/eco-boilers, set fuel quality standards, and certify sustainably-harvested biomass products (e.g., wood chips, pellets) to ensure such fuels are consumed in a more responsible and sustainable manner. For heat pumps, while their carbon footprint is still tied to that of the local grid, existing commitments and investment plans to increase the level of RE will make grids cleaner over time. In this case, parallel investments to increase grid capacities may be needed. If heat pumps can be installed alongside small-scale solar panels to offset the increased electricity use, it could substantially ease pressures on the grid while helping to substantially offset the cost of operating the heat pump, making a win-win for households including the poor. However, their upfront cost remains the principal barrier, and efforts will be needed to help bring down costs, offer incentives, and provide suitable financing to make them more affordable. All options should be bundled with energy efficiency investments to make them more affordable and designed to provide greater support for the poorest and most vulnerable households.

7. ***Technical standards should be raised to increase efficient heating equipment in the market.*** In addition to cleaner fuels, more-efficient heating appliances and systems are needed in order to manage heat demand and make heating bills more affordable, especially for the poor. Therefore, the less-efficient models should be phased out from the market through regulatory standards. This includes conventional wood stoves and boilers, conventional gas stoves, and electric heaters in favor of eco-design wood stoves/boilers, condensing gas boilers, and heat pumps. This may imply investments in regional testing facilities, increased use of labeling, minimum specifications for public purchasing, and other measures. Where government financing or incentives are planned, as noted in Chapter VI, eligibility criteria should tie these funds to the most efficient and economic models. Use of strategies like bulk procurement and distribution or manufacturer partnerships can help promote more-efficient models and bring down consumer prices.

8. ***Programs need to be designed to make judicious use of public funds to stimulate markets and change behaviors.*** The transition to sustainable heating will require strong government commitment, investment, and action, but the focus of public funding should be to overcome key market barriers and affordability concerns, as discussed in Chapter VI. As shown in Chapter V, for most building owners, the combination of energy efficiency and sustainable heating is likely to yield energy cost savings that can be used to recover all or a portion of the investments. This can then allow governments to work with banks and other financial institutions to develop appropriate financial products, possibly blended with subsidies and risk-sharing mechanisms to support these household investments. Where subsidy schemes are needed, they should be well targeted and (except for the very poor) temporary. Investments in decarbonizing DH should also seek some commercial financing where possible. Well-designed communications and outreach can be used to help instill changes in behavior regarding investments in energy efficiency, heating

technologies, and fuels. These should be based on market and household surveys, tailored to local customs and norms, and adjusted for target income levels, gender and age.

Figure VII.1: Framework for Sustainable Heating



Source: Authors.

In terms of fuels, some general conclusions are proposed:

(i) ***Coal is increasingly uneconomic, and plans should be put in place to phase out its use for heating.*** The analyses in Chapter IV show that coal-based heating is no longer economically least-cost for building-level or individual heating systems, due largely to the environmental costs—in terms of both air pollution and GHG emissions. Therefore, efforts need to be made to phase out coal while introducing programs to facilitate adoption of cleaner heating fuels, technologies, and energy efficiency measures. The most efficient policies are outright bans on the sale of coal to households, a ban on the sale of new coal boilers, and a plan to phase out existing coal boilers (with incentives to switch to cleaner options). Where this is not possible, more gradual plans to phase out coal with the introduction of price reforms, a carbon tax on coal, taxes on coal boilers/ stoves, etc. (with parallel subsidies for cleaner fuels) are recommended.[98] For coal-based DH, including coal heat-only boilers and CHPs, efforts should be made as noted above to implement an agreed set of reforms, strengthen DH, and identify viable cleaner-heating sources, including possible conversion from coal to gas CHPs—but only as a transition fuel and as part of a longer-term decarbonization plan until lower-cost heating technologies and systems become more commercially available.

(ii) ***Natural gas will likely continue to play a role in the transition.*** While clean alternatives may exist in most countries, there are cases where the alternatives are simply too expensive, difficult to access in sufficiently large quantities (to replace the magnitude of gas-based heating in ECA), or will still take many years to become fully commercial. In countries with ample industrial waste heat, solar resources, geothermal potential, biomass, or sufficient electricity supply (as is the case

[98] Poland, for example, launched its Clean Air Priority Program (CAPP) in 2018 to help SFHs transition away from coal through a mix of tax incentives, subsidies, financing, and technical support. Also, since 2021, the government has no longer allowed coal boilers to receive any government support, and it recently announced a phaseout of coal used for space heating in urban areas by 2030 and in rural areas by 2040.

in Bulgaria, Türkiye, and Belarus), it would likely be difficult to justify new gas installations for DH or individual systems. However, in parts of Central Asia where few of these options exist and there is heavy reliance on coal (e.g., Kyrgyz Republic, Kazakhstan), natural gas may offer a viable transition fuel. While the application of gas will be location-specific and should be used judiciously, some broad guidelines are proposed: (i) gas should be the least-cost economic option (taking into account fuel subsidies, environmental/health, and other impacts); (ii) gas should be used primarily to offset dirtier fuels such as coal; (iii) gas investments should not introduce any new infrastructure or equipment that would lock in its use for more than a 10-15 year period; and (iv) such investments should be aligned with the principles of the Paris Agreement (see Section c) and the country's long-term decarbonization strategy.

(iii) ***The use of hydrogen could also support the heating transition, but there is growing consensus that hydrogen is not the most efficient, economical, or sustainable option.*** Green hydrogen has also been considered as a candidate for a clean heating fuel, given its potential for a less-disruptive transition from traditional, centralized fossil-fuel infrastructure. However, many experts believe that the inefficiency and low cost-competitiveness of hydrogen for heating makes it unsuitable—a view that is supported by 32 independent studies[99], including those by the IPCC[100] and IEA[101]. Most of these studies conclude that hydrogen will be more expensive in terms of energy system costs and/or consumer costs due to: (i) higher energy system costs when compared with alternatives (e.g., heat pumps, DH, solar thermal); (ii) higher consumer heating costs; and (iii) higher environmental impacts of hydrogen, including land needs, compared with low-carbon alternatives. Hydrogen also requires significant energy to produce—at least five times more energy than heat pumps today. As the cost of RE declines, the cost of green hydrogen will also decline, but so will that of heat pumps that run off RE-based electricity. And hydrogen is associated with major infrastructure investments—from electrolysis plants to compressing stations to distribution networks—that require long-term investment horizons with uncertainties about returns on investment.

Based on these lessons, the World Bank has developed a new portfolio of projects to support the sustainable heating transition (Box VII.1) and plans to scale up its support in the coming years—including in ECA countries such as Bosnia and Herzegovina, Kosovo, Kyrgyz Republic, Moldova, and North Macedonia.

[99] J. Rosenow, "Is heating homes with hydrogen all but a pipe dream? An evidence review", *Joule*, Vol. 6, Issue 10, October 19, 2022. Available at: http://www.janrosenow.com/uploads/4/7/1/2/4712328/is_heating_homes_with_hydrogen_all_but_a_pipe_dream_final.pdf.

[100] https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_FullReport.pdf.

[101] https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf.

Box VII.1. Examples of World Bank Sustainable Heating Projects

Belarus Biomass DH and Sustainable Energy Scale-Up (2014, 2019). The operations included: (i) replacement of DH gas-fired boilers and CHPs to biomass (mainly woodchip) boilers, upgrades of DH networks, and decentralizing of building-level substations; and (ii) conversion of gas boilers to biomass CHP plants in MFBs, building-level substations, and thermal renovations in MFBs.

Moldova DH Efficiency Improvement 1 and 2 (2014, 2020). The projects included general upgrading of the DH system (e.g., replacement of pipes, modernization of pumping stations), transition to 137 building-level substations, and modernization and installation of natural gas-fired CHP units. The first project also supported the merger of the municipality-owned DH-utility with two state-owned CHP operators.

Kyrgyz Republic Heat Supply Improvement (2017, additional financing in 2020). The project is supporting the Bishkek DH system through upgrades to part of the heat transmission network (Vostok), renovation and installation of new building-level heating substations, installation of heating and hot-water meters for billing, upgrading of the billing and accounting systems, and pilot thermal renovations of public buildings. The original project also included a component, later dropped, to pilot efficient and clean heating stoves.

Poland Clean Air through Greening Residential Heating Program-for-Results (2021). This results-based loan supports Poland's 10-year Clean Air Priority Program (CAPP), which seeks to replace coal heating boilers in more than 3 million single-family homes (with natural gas, biomass wood pellets and electric heat pumps) and support thermal renovations of the homes through a combination of tax relief, tiered subsidies (based on income levels), financing from commercial banks, and technical support.

Serbia Scaling Up Residential Clean Energy (2022). This project supports thermal renovations, boiler and fuel replacement, and rooftop solar PV in residential buildings (mostly single-family homes) through the provision of partial grants.

Source: World Bank project reports.

b. Investment needs

The investment required for the sustainable heating transition in the ECA region would be in the trillions of US dollars. Estimating the cost of replacing all individual systems using unsustainable fuels, retrofitting the existing DH systems, and retrofitting 14 billion m^2 of building floor area (of which 11 billion m^2 represents residential buildings and 3 billion m^2 is commercial and public buildings) provides a first-order estimate of the investment cost at about US$2 trillion. For this report, an **investment cost model** was developed comprising three investment scenarios, each with varying energy efficiency renovation costs and levels of ambition. All three scenarios assumed an implemented rate of 3.5 percent of eligible buildings and heating systems each year through 2050. The target was to renovate 95 percent of the region's building stock by 2050.

The first scenario has a total investment cost of US$2.0 trillion, which includes US$1.3 trillion for building renovations and US$752 billion for heating system replacements. This scenario assumes a reduction in space heating demand (due to retrofitting) of 20 percent and a renovation cost of US$90/$m^2$. In the second scenario, the total investment cost is US$2.3 trillion, including US$1.7 trillion for building renovations and US$564 billion for heating system replacements. This scenario assumed a decrease in space heating demand of 40 percent and a renovation cost of US$120/$m^2$. The third scenario has an overall investment cost of US$2.5 trillion: US$2.2 trillion for building renovations and US$376 billion for heating system upgrades. For this scenario, the demand reduction was assumed to be 60 percent (representing deeper renovations) at an investment cost of US$150/$m^2$.

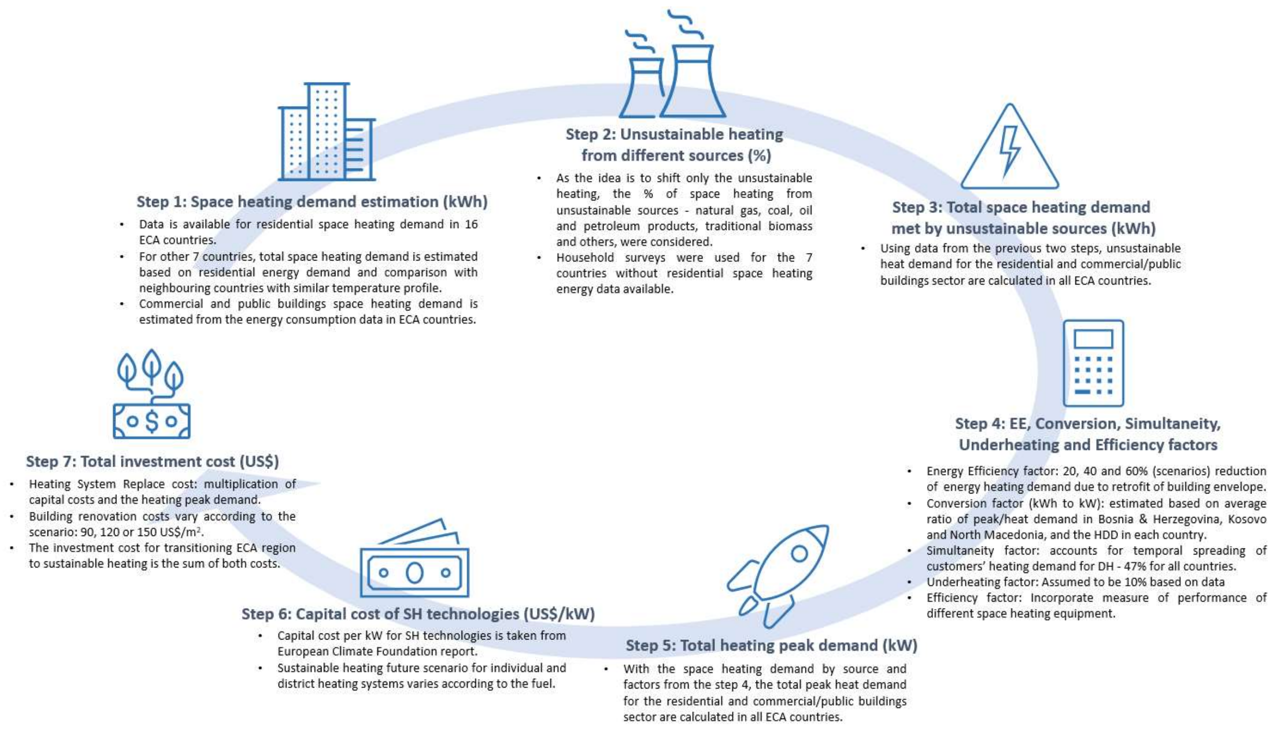
This economic analysis showed that the benefits of the sustainable heating transition exceed the costs. The economic net present value (NPV) was projected to be approximately US$402 billion (scenario 1), US$421 billion (scenario 2), and US$440 billion (scenario 3). The economic internal rate of return (EIRR) was calculated to be 10.2 percent (scenario 1), 9.5 percent (scenario 2) and 9.0 percent (scenario 3). Note that the NPV and EIRR estimations account for fuel savings due to energy efficiency (envelope retrofit and heating system replacement), reduction of CO_2 emissions, maintenance savings, and health benefits (due to NO_x, SO_x and $PM_{2.5}$ reductions). However, other important socioeconomic benefits—such as improved energy security, lower energy subsidies, reduced energy poverty, extended building lifetime, property prices, and better comfort—were not quantified included in this analysis.

As part of the investment cost model, a **financial analysis** of the transition was also performed. In this analysis, CO_2 emissions and health benefits were not included, but subsidies and a value-added tax (VAT) were considered. This analysis was performed to estimate the subsidies required for a positive financial NPV to transition the region to sustainable heating.

The approach and methodology used to estimate the investment requirements (both economic and financial) are described in Figure VII.2. The model included seven steps, starting with the heating demand estimation and ending with the final investment cost calculation. It used data presented in Chapter II to compute the total space heating demand and fuel switching from the building sector[102]. The peak heat demand was multiplied by the capital cost of sustainable heating technologies to determine the investment required for the sustainable heating transition across ECA.

The main model assumptions and the sustainable-heating future-technology split are detailed in Table VII.1 and Table VII.2.

Figure VII.2: Structure and Sequence of the Investment Cost Model



Source: Method developed by the World Bank.
Note: The renovation of exterior doors and windows, exterior walls, installation of thermal insulation of the roof/ceiling, and installation of thermal insulation of the ceiling were all accounted for. The heated area was considered 100% of the floor area.

[102] **Residential buildings:** data were available from 16 ECA countries and approximations were used for the other 7. **Commercial and public buildings:** space heating demand was estimated from the energy consumption data.

Table VII.1: Investment Model Assumptions

	Scenario 1 - Low EE	Scenario 2 - Moderate EE	Scenario 3 - Aggressive EE
Reduction on Space Heating Demand	20%	40%	60%
Retrofitting Cost	US$90/m^2	US$120/m^2	US$150/m^2

Source: Assumptions developed by the World Bank.

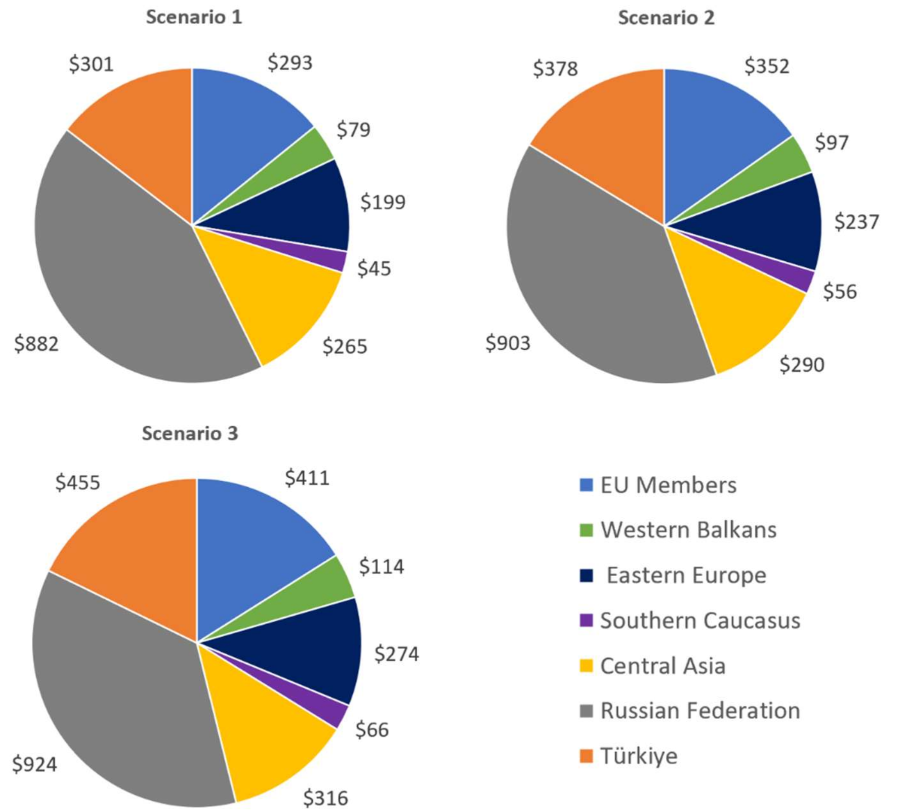
Table VII.2: Sustainable Heating Future Technology Split

	Old Heating Technology/Fuel	New Heating Technology/Fuel
Individual Heating	Natural Gas	100% Heat Pump
	Coal	50% Eco-design Wood Boiler 50% Heat Pump
	Oil and Petroleum products	50% Eco-design Wood Boiler 50% Heat Pump
	Traditional Biomass	50% Heat Pump 25% Eco-design Wood Boiler 25% Eco-design Wood Stove
	Electricity*	100% Heat Pump
	Others	100% Heat Pump
DH	All unsustainable fuel sources	25% Sustainable Biomass 15% Geothermal 10% Solar Thermal 25% Waste Heat 25% Heat Pump

Source: Assumptions developed by the World Bank.
* The model assumes that all electric heating are inefficient resistance heaters.

The investment cost estimates are presented in Figure VII.3 and Table VII.3 for all three scenarios. These investment cost estimates exclude potential benefits, which are considered and incorporated into the NPV and EIRR calculations. In the model, Russia has the highest investment cost in the region, corresponding to over 40 percent of the required investment cost (depending on the scenario) due to the size of its space-heating demand and its broad DH coverage, which tends to be more expensive to renovate compared with individual heating systems. Because of their sizes and limited DH coverage, the Western Balkans and Southern Caucasus countries had the lowest investment costs.

Figure VII.3: Total Investment Cost (Heating System Replacement & Thermal Retrofit), by Sub-Region (US$, billions)



Source: Based on the methodology developed by the World Bank.

Table VII.3: Total Investment Cost per Country (US$, millions)

	Scenario 1 - Low Energy Efficient		Scenario 2 - Moderate Energy Efficient		Scenario 3 - Aggressive Energy Efficient	
	Building Renovation (90 US$/m2)	**Heating System Replacement[103]**	**Building Renovation (120 US$/m2)**	**Heating System Replacement**	**Building Renovation (150 US$/m2)**	**Heating System Replacement**
Albania	$7,110	$697	$9,480	$523	$11,850	$348
Armenia	$10,553	$1,337	$14,070	$1,003	$17,588	$669
Azerbaijan	$15,058	$5,140	$20,077	$3,855	$25,096	$2,570
Belarus	$27,919	$16,693	$37,226	$12,520	$46,532	$8,346
Bosnia and Herzegovina	$16,385	$3,657	$21,846	$2,743	$27,308	$1,829
Bulgaria	$31,098	$4,485	$41,465	$3,364	$51,831	$2,242
Croatia	$18,398	$4,215	$24,530	$3,162	$30,663	$2,108
Georgia	$11,520	$1,823	$15,360	$1,367	$19,200	$911
Kazakhstan	$44,580	$60,017	$59,441	$45,013	$74,301	$30,009
Kosovo	$5,922	$1,181	$7,896	$886	$9,870	$591
Kyrgyzstan	$11,110	$4,119	$14,813	$3,089	$18,516	$2,060
Moldova	$9,063	$2,324	$12,084	$1,743	$15,105	$1,162
Montenegro	$2,239	$443	$2,985	$332	$3,731	$221
North Macedonia	$8,546	$1,124	$11,394	$843	$14,243	$562
Poland	$128,345	$43,650	$171,126	$32,738	$213,908	$21,825
Romania	$48,926	$13,482	$65,234	$10,112	$81,543	$6,741

[103] Replacement of individual heating and district heating systems

Russian Federation	$413,730	$468,187	$551,640	$351,140	$689,550	$234,093
Serbia	$24,190	$7,098	$32,253	$5,324	$40,316	$3,549
Tajikistan	$10,595	$1,889	$14,126	$1,417	$17,658	$944
Türkiye	$261,000	$39,621	$348,000	$29,716	$435,000	$19,811
Turkmenistan	$12,076	$9,359	$16,101	$7,019	$20,126	$4,679
Ukraine	$112,740	$30,204	$150,319	$22,653	$187,899	$15,102
Uzbekistan	$79,284	$31,616	$105,712	$23,712	$132,140	$15,808
Total	**$2,062,745**		**$2,311,449**		**$2,560,153**	

Source: Based on the method developed by the World Bank.

The results from the economic assessment—the NPV and the EIRR—are presented in Table VII.4 for all three scenarios. The NPV and EIRR estimates combine building energy efficiency measures and heating system replacements, with an implemented rate of 3.5 percent per year through 2050 and an economic discount factor of 6 percent. For this analysis, fuel savings due to energy efficiency (envelope retrofit and heating system replacement), reduction of CO_2 emissions, health benefits—due to NO_x, SO_x and $PM_{2.5}$ reduction—and maintenance savings were all considered. Capital, fuel and maintenance cost were also included in the analysis.

Table VII.4: Net Present Value and Economic Internal Rate of Return

	Net Present Value	Economic Internal Rate of Return
Scenario 1	$401,999,789,090	10.14%
Scenario 2	$420,999,106,030	9.47%
Scenario 3	$439,998,422,971	9.00%

Source: Based on the method developed by the World Bank.

The financial model (Table VII.5) shows the subsidies required to achieve a positive financial NPV for the sustainable heating transition. As with the economic assessment, it combines building energy efficiency measures and sustainable heating system replacement, with an implemented rate of 3.5 percent per year through 2050 (27 years). However, as noted earlier, it differs from the economic analysis by including a financial discount factor and VAT of 10 percent and does not incorporate any environmental or health benefits. Capital costs as well as fuel and maintenance cost/savings were included.

Table VII.5: Subsidies Financial Assessment

		Subsidies - Heating Systems	Subsidies - Building Renovation	Total Subsidies
Scenario 1	**Subsidies**	$537,938,407,045	$1,008,995,294,080	$1,546,933,701,126
	% of Subsidies in total investments	65	70	68
Scenario 2	**Subsidies**	$372,418,897,185	$1,249,232,268,862	$1,621,651,166,047
	% of Subsidies in total investments	60	65	64
Scenario 3	**Subsidies**	$227,589,326,058	$1,441,421,848,686	$1,669,011,174,744
	% of Subsidies in total investments	55	60	59

Source: Based on the method developed by the World Bank.

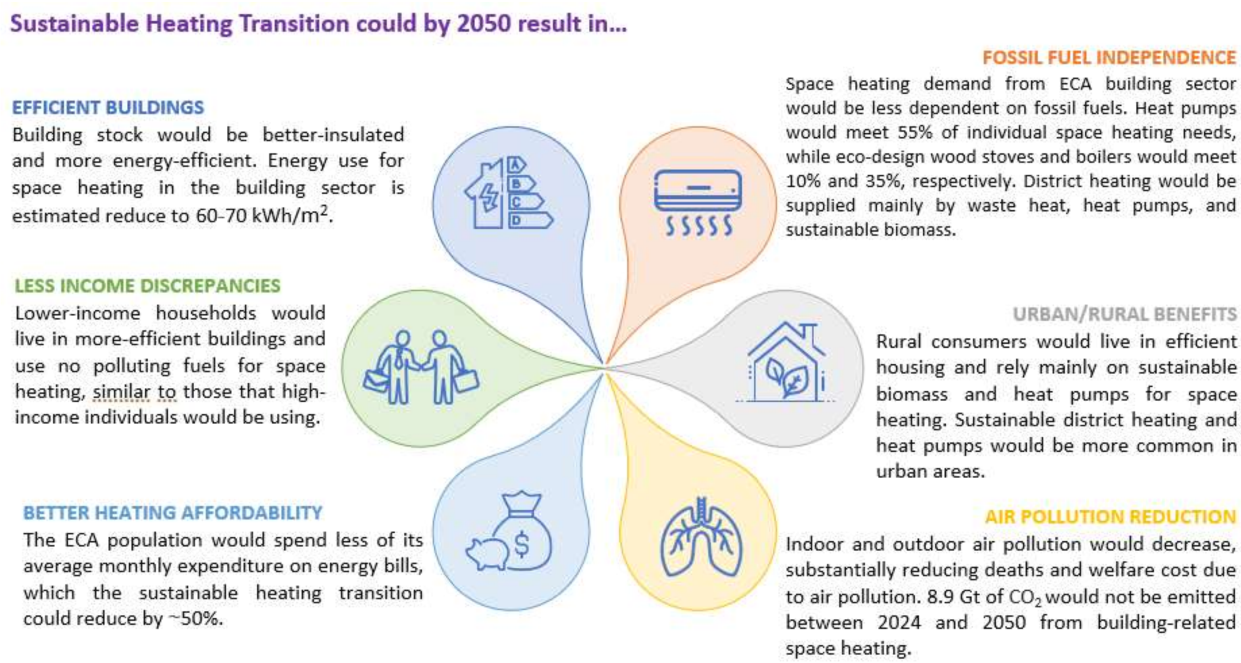
Based on the financial analysis, the subsidies required to implement the sustainable heating transition in ECA amount to US$1.54-1.67 trillion, which represents about 59-68 percent of the total transition costs. While this appears high, it should be noted for comparison that these figures represent about 50 percent of the subsidies that ECA countries will spend on fossil-fuel subsidies (US$115 billion annually)[104] if current

[104] IMF (2022). https://www.imf.org/-/media/Files/Topics/Environment/energy-subsidies/fuel-subsidies-template-2022.ashx IMF (2022). https://www.imf.org/-/media/Files/Topics/Environment/energy-subsidies/fuel-subsidies-template-2022.ashx

subsidies are maintained through 2050. Similarly, the level of subsidies calculated for the sustainable heating transition represent approximately 1.3 percent of the ECA region's annual GDP, whereas the region currently spends 2.5 percent of its annual GDP on fossil-fuel subsidies, as described in Chapter II.

Clearly the sustainable heating transition would represent a massive undertaking and investment on the part of ECA countries. But as noted in Chapter II, the current status of space heating in the region is neither sufficient nor sustainable. The sustainable heating investment would be transformative for the countries and its citizen, addressing many of the systemic issues noted in Chapter II. The potential benefits are summarized in Figure VII.4.

Figure VII.4: Sustainable Heating Transition Potential Results



Source: Based on the method developed by the World Bank.

c. Heating and Paris alignment at the World Bank

The World Bank Group has added "Paris alignment" into its Climate Corporate Commitments for its operations and country strategies. From July 1, 2023, all new World Bank lending operations going to Board approval will be required to be aligned with the Paris Agreement[105]. This would mean that the development objective of an operation in support of poverty reduction and shared prosperity is consistent with a country's pathway towards low-GHG emissions and climate-resilient development in line with the goals of the Paris Agreement.

This implies that Bank operations will have to: (i) check for consistency with client country climate strategies, NDCs, LTSs, NAPs, etc., (ii) avoid negative impacts on client countries' transition to low GHG emission development pathways, and (iii) identify and manage material impacts of physical climate risks that might hinder an operations' development objectives (Figure VII.5). It is expected that projects will be

[105] The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at the UN Climate Change Conference (COP21) in Paris, France, on December 12, 2015. It entered into force on 4 November 2016. See https://unfccc.int/process-and-meetings/the-paris-agreement.

assessed multiple times in the course of preparation so that they are properly aligned, the case adequately made, and also disclosed in line with other policy partners.

Figure VII.5: World Bank Paris Alignment Assessment

Source: World Bank Paris Alignment Assessment, https://www.worldbank.org/en/publication/paris-alignment.

This means that, when designing and implementing World Bank heating and energy efficiency projects, certain processes should be followed to ensure their alignment with the Paris Agreement. For most emission-reducing projects, such as those covered in this report, investments are generally considered to be universally aligned. This includes energy-efficient thermal renovations, or switching from solid fuels such as coal to cleaner fuels such as heat pumps or wood pellets.

However, based on the Bank's energy sector note[106], there are five cases where such investments may be neither universally aligned nor non-aligned. These include: (i) unbated, emissions-intensive heat generation in a grid-connected system; (ii) transportation and storage of natural gas and distribution of emissions-intensive heat; (iii) heat and fuel subsidy reform and commercial and collection loss reduction; (iv) efficiency improvement of heating equipment with no Scope 1 emissions[107]; and (v) clean household energy services reliant on fossil fuels. Each are briefly discussed below.

Under case (i), an DH investment involving the combustion of fossil fuels to generate heat would require a least-cost modeling of the system, subject to limits on GHG emissions that are consistent with a Paris-aligned long-term decarbonization pathway appropriate for the country's heating sector. Where such modeling is undertaken, the question being posed is not *whether* the asset being financed is aligned, but *which* assets are on the decarbonization pathway and *how* they should be operated to remain on the pathway. For case (ii), pipelines or storage tanks delivering natural gas mainly to grid-connected, gas-based heat generation plants in a DH system may be assessed by modeling least-cost decarbonization of the system. Similarly, heat being distributed may become decarbonized over time through increasing levels of cleaner sources (e.g., biomethane, very-low-caron methane, very-low-carbon hydrogen). One

[106] World Bank, 2023. *Energy and Extractives: Sector Note on Applying the World Bank Group Paris Alignment Assessment Methods*. World Bank, https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099825304072326685/idu0c3637e5e09852043de09ff80cd898f92b2df

[107] Part of the GHG Protocol Corporate Standard, "Scope 1" emissions are direct GHG emissions that occur from sources that are controlled or owned by an organization (e.g., emissions associated with fuel combustion in boilers, furnaces, or vehicles).

transition risk for DH is a shift from centralized to decentralized heating, potentially making the DH system uneconomic over the long run. For case (iii), commercial and collection losses lower the effective prices paid by consumers and can thus and have the same effect as consumer price subsidies which discourage the adoption of more efficient appliances and equipment and encourage non-essential consumption of heat and heating fuel. Thus, activities which reform price subsidies and reduce commercial and collection losses help lower emissions, promote rather than prevent the energy transition, and reduce transition risks, making them aligned with the mitigation goals of the Paris Agreement.

Under case (iv), improving the efficiency of heating assets that do not generate on-site emissions—such as equipment using purchased electricity (e.g., air-to-air heat pumps) or heat—it can be considered aligned because improving efficiency does not prevent the transition to low-GHG-emissions development pathways, nor will the economics of the activity be undermined by transition risks. For household heating services reliant on fossil fuels (case v), stoves burning natural gas or LPG can reduce the global warming potential of emissions because traditional stoves burning solid fuels emit a considerable amount of black carbon, the global warming potential of which is two to three orders of magnitude higher than that of CO_2. Therefore, financing of technologies using LPG or natural gas is considered aligned as long as households are moving up the tiers in the multi-tier framework for defining and measuring energy access[108], reaching a higher tier in the manner financed by the operation is the most affordable option, and no mains gas pipelines are constructed for this purpose. If households are already in the highest tier, further assessment needs to be carried out.

[108] For more information on the multitier access framework, see Bhatia, M.; Angelou, N. 2015. Beyond Connections: Energy Access Redefined. ESMAP Technical Report 008/15. World Bank, http://hdl.handle.net/10986/24368.

Annexes

Annex A: Global Projections and Experiences with Sustainable Heating

a. Global projections related to heating decarbonization pathways

The energy sector cannot decarbonize without a transition to sustainable heating. At the global level, approximately 50 percent of energy consumption is for heating and cooling, including industrial process heat, space and water heating, and cooking. Of this, nearly 46 percent is consumed for heating (and to a lesser extent for cooking) in residential, public, and commercial buildings. In terms of emissions, the building sector accounts for nearly 30 percent of global CO_2 emissions[109], of which about 80 percent go towards space heating[110]. Heating also contributes to air pollution, with about one-eighth of $PM_{2.5}$ emissions caused by the combustion activities for space and water heating largely from the use of firewood and coal boilers and stoves, and in 2021, over 19 000 people died prematurely every day from breathing polluted air, the majority in emerging market and developing economies[111]. The current heating system thus threatens the environment and public health.

Despite the large contribution of heating to global energy use and GHG emissions, the decarbonization of the power sector has received much more attention in terms of policy discussions, strategies, and investments. By 2020, 145 countries had introduced policies to support RE in the power sector, while only 61 countries had national RE-based heating/cooling policies. As of November 2021, out of all countries that had set RE targets in their nationally determined contributions (NDCs), 170 plans focused on the power sector, compared with only 54 plans that had clear RE heating/cooling objectives[112]. Most of the NDCs that did include heating focused on building energy-efficient codes and largely ignored the provision of heat supply or fuel switching. Modeling scenarios reflecting "current policies" or "business-as-usual" therefore often see only a relatively small contribution by the heating sector to GHG emission reductions by 2050.

Table A.1 includes a number of energy and building sector decarbonization scenarios, detailing different pathways from various think tanks, agencies and governments. It shows there are a variety of possible pathways to achieve decarbonization of the heating sector which include various combinations of heat supply and fuels, and demand reductions.

The scientific community's perspectives on the decarbonization of the building sector in various regions and countries are also helpful for better understanding possible decarbonization pathways. Academia has produced various integrated building stock energy models to create emission reduction decarbonization scenarios by 2050. The summary of the main decarbonization scenarios is presented in Table A.2[113].

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[109] IEA (2022) Global CO2 emissions from fuel combustion by sector with electricity and heat reallocated, World. https://www.iea.org/data-and-statistics/data-tools/greenhouse-gas-emissions-from-energy-data-explorer

[110] IEA (2022), https://www.iea.org/reports/heating

[111] IEA (2022), "The Future of Heat Pumps", IEA, OECD/IEA, December 2022.

[112] IRENA (2022), *World Energy Transitions Outlook 2022: 1.5°C Pathway*, International Renewable Energy Agency, Abu Dhabi.

[113] Interestingly, these decarbonization scenarios can achieve emission reductions within the range of the 2°C scenario but fall short of achieving the 1.5°C scenario decarbonization targets as per the Paris climate agreement. The authors conclude that national decarbonization strategies need to enhance the current annual renovation rate to 2.4% and increase electrification of buildings' final energy consumption (FEC) by 4-14% to an average of 50% in all regions to meet the goal of 1.5°C. Source: C. Camarasa et al. (2022), "A global comparison of building decarbonization scenarios by 2050 towards 1.5–2°C targets", *Nature Communications*, *13*(1), 1-11.

Table A.1: Global decarbonization pathways related to heating

Report	Decarbonization Pathways	Heating-Related Projections/Targets	Heating-Related Technologies/Policies
Net Zero by 2050 - A Roadmap for the Global Energy Sector[114] (IEA)	**Net-Zero Emissions by 2050 Scenario (NZE):** to achieve net-zero CO2 emissions by 2050 for the energy sector, including space heating	• No new sale of coal and oil boilers (2025) • All new buildings are zero-carbon-ready[115] (2030) • Most appliances and cooling systems sold are best in class[116] (2035) • 50% of existing buildings retrofitted to zero-carbon-ready levels (2040) • 50% of heating demand is met by heat pumps (2045) • More than 85% of buildings are zero-carbon-ready (2050) • In buildings, fossil fuel demand to drop to 30% by 2030 and 2% by 2050 • Reduction of emissions from buildings by 40% by 2030 and more than 95% by 2050 • Electricity to become the dominant fuel, providing 66% of the building's energy requirement by 2050. • Homes using natural gas for heating declining from 30% (2020) to less than 0.5% (2050) • DH[117] will provide more than 20% of the final energy demand for space heating in 2050. Bioenergy[118] will supply 50% of DH production. • By 2050, two-thirds of residential buildings in advanced economies and ~40% of residential buildings in emerging markets/developing economies install heat pumps	• Electrification and Energy Efficiency are the two main drivers of decarbonization • High-efficiency electric heat pumps become the main technology choice for space heating • Behavior changes such as reducing indoor temperature settings for space heating will play a key role • Governments support biogas installations and distribution to move away from traditional uses of biomass for heating by 2030 • Digitization and Smart Control to reduce emissions from buildings by enabling efficiency gains
Quantifying the Impact of Low-carbon Heating and Cooling Roadmaps[119] (Heat Roadmap Europe)	**HRE 2050** (Heat Roadmap Scenario for 2050). Focused on the EU 14 countries	• By 2050, heat pumps provide ~50% of heating demand and largely in rural areas, due to their distinct advantage of efficiency and integration with the electricity sector • 30% reduction of heating demand for space heating in the industry, residential and tertiary sectors • DH supplying a minimum of 50% of the heating demand in 2050 from 12% in 2015. Expansion of the DH market is essential, especially in urban areas • Excess heat recovery from industrial and power plants provides 25% of DH heat • Possible sources of heat for DH network – 25-35% from CHPs, 20-30% from large heat pumps using RE, 25% from industrial excess heat, 5% from other RE (e.g., geothermal, solar thermal) and less than 6% from heat-only boilers • 86% reduction of the CO_2 emissions from the heating sector compared to 1990 levels	• Implementation of DH, also including the recovery of otherwise unused excess heat, use of (relatively efficient) RE like geothermal and solar thermal, and the use of heat pumps at building-level (in rural areas) and in DH networks (in urban areas) • Consider energy efficiency from both the demand and the supply side of the heating sector • Deeper renovations with an integrated new energy system and redesign of the heating sector

[114] S. Bouckaert et al. (2021), *Net Zero by 2050: A Roadmap for the Global Energy Sector.*
[115] A zero-carbon-ready building is a highly energy-efficient building that either uses RE directly or uses energy supply that is fully decarbonized, such as electricity or district heating.
[116] Not further defined in the report.
[117] According to the report, district heat will remain an attractive option for many compact urban centers where heat pump installation is impractical.
[118] The report defines bioenergy as biogases, liquid biofuels. and modern solid biomass harvested from sustainable source. It excludes the traditional use of biomass.
[119] S. Paardekooper et al. (2020), *Heat Roadmap Europe 4. Quantifying the Impact of Low-Carbon Heating and Cooling Roadmaps 2018*, Aalborg University.

World Energy Transitions Outlook 2022: 1.5°C Pathway[120] (IRENA)	**1.5°C Scenario:** Target to achieve an annual reduction of 36.9 Gt of carbon dioxide by 2050	• 30% increase in solar thermal, geothermal and DH solutions, from 46 EJ in 2019 to 60 EJ in 2050, in the heating sector • 65% reduction of biomass consumption (including traditional), from 28.4 EJ in 2019 to 9.5 EJ in 2050, in buildings • 195% increase in solar thermal and geothermal consumption, from 2.1 EJ in 2019 to 6.2EJ in 2050, in buildings • 1725% surge in DH generation based on RE, from 0.4 EJ in 2019 to 7.3 EJ in 2050, in buildings • 50% decrease in energy demand for space heating in the 1.5°C Scenario, driven by energy efficiency measures and the adoption of more efficient heating devices • Zero energy-related CO_2 emissions from buildings by 2050. • Rise from 21% in 2019 to over 50% by 2050 in the share of direct electricity in total final energy consumption • Growth from 12% in 2019 to 19% by 2030 of direct RE in end-use sectors[121] • 450% increase in deployment of heat pumps installed, from 53 million in 2019 to 290 million in 2050. • Increase from 26% in 2019 to 90% by 2050 on the RE share in electricity generation	• Decarbonizing heating will require changes to building codes, energy performance standards for appliances, and mandates for RE-based heating technologies, including solar water heaters, RE-based heat pumps and geothermal heating • Heat pumps play a crucial role in space heating; Electrification of end-use sectors – use of clean electricity in heat application and RE present in the electricity sector - mainly include solar PV, wind, solar thermal, and biomass • Energy conservation and efficiency – to reduce energy demand and increase the efficiency of heating technologies • Financial incentives and customized loans to promote RE for direct use and DH • Mandated connections to DH and district cooling networks in new urban developments, public buildings, and other opportune locations
The Long-term strategy of the United States[122]	**Pathways to Net-Zero Greenhouse Gas Emissions by 2050**	• Achieve 100% clean[123] power generation by 2035 • Due to energy efficiency measures, energy demand in buildings will reduce by 9% in 2030 and 30% in 2050 • The share of electricity in final energy demand grows, as heating is electrified, from about 50% in 2020 to 90% by 2050 • Heat pumps and other electric heaters and electric cooking account for more than 60% of sales by 2030 and nearly 100% of sales by 2050 • Reduction in 1 Gt of CO2eq annual emission by 2050 with better insulation, advanced heat pumps for space and water heating • Decrease in 2 Gt of annual reductions by 2050 many uses as possible to clean energy, such as boosting heat pumps in buildings • The rapid deployment of heat pumps for space heating and cooling is the central strategy for the efficient, flexible electrification of buildings	• The priority is to rapidly improve energy efficiency and increase the sales share of clean and efficient electric appliances—including heat pumps—while also improving the affordability of energy and equitable access to efficient appliances, efficiency retrofits, and clean distributed energy resources in buildings • The key driver of reducing building emissions is the efficient use of electricity for end uses - such as heating, hot water, cooking, and others. Alongside the decarbonization of electricity, these changes can bring building sector emissions to near-zero by 2050

[120] IRENA (2022), *World Energy Transitions Outlook 2022: 1.5°C Pathway*, International Renewable Energy Agency, Abu Dhabi.
[121] The transportation, industrial, commercial and residential sectors are called end-use sectors because they consume primary energy and electricity produced by electric power sector (EIA, 2019).
[122] *The Long-Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050.* United States Department of State and the United States Executive Office of the President, Washington DC. https://www.whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf
[123] The report considers clean power generation the electricity produced from fossil fuels and biomass with carbon capture and storage (CCS), nuclear, RE, and non-fossil combustion.

Table A.2: Summary of main decarbonization scenarios from the academia

Region/Country	Model	Decarbonization Scenarios	Outcomes	Technology and Demand Development	Policy Instruments
NW Europe	Invert/EE-lab[124]	Directed Vision[125]	CO_2 emission reduction by 89% (2020-2050)	• Concerted thermal renovation • Coherent DH uptake planning • Individual RE heating in low-heat-density areas • Phasing out fossil fuels (natural gas from 2030)	• Deep renovation subsidies and obligations • Zoning, obligations, cost reduction and investment subsidies for DH
		Diversification[126]	CO_2 emission reduction by 89% (2020-2050)	• Individual technology mix (heat pumps, biomass boilers, and solar thermal systems) and smart heating • Phasing out fossil fuels (natural gas from 2030)	• Prohibition of new fossil fuel heating systems from 2030 • High subsidies for heat pumps • Support for smart thermostats
USA	Scout[127]	Decarbonization scenario	CO_2 emission reduction of 64% (2020-2050)	• Demand reduction and energy efficiency are achieved via the use of the best commercially available and targeted high-efficiency –heating, cooling, lighting, envelope, water heating, refrigeration, and appliances • Higher RE power supply achieved via $25/t CO_2 carbon tax • Electrification incentive with 20% capital cost credit	• Aggressive deployment of building efficiency measures – highly insulating thermal envelopes and use of air-sealing technologies • High share of RE electricity generation through carbon taxation • Incentivized electrification of building technologies (capital cost credit) – deployment of heat pumps.
UK, Sweden, and France	ECCABS[128]	BAU-T	CO_2 emission reduction by 47–76% (2020-2050)	• Improved building envelope, ventilation with heat recovery, improved efficiency of lighting and appliances • Photovoltaic (PV) panels, solar hot water, biomass boilers • Thermostats set to 20C	• Increased decarbonization of the energy supply • Large rollout of heat pumps
Germany	CoreBee[129]	Decarbonization scenario	CO_2 emission reduction by 89% (2020-2050)	• Prosumer strategies for micro-combined heat and power • Building envelope and heating system upgrade combined with small-scale RE (solar thermal and PV system)	• Cost-optimal and long-term renovation strategy for building as per EC's EPBD

[124] A. Müller, *Energy Demand Assessment for Space Conditioning and Domestic Hot Water: A Case Study for the Austrian Building Stock* (2015), https://www.researchgate.net/publication/278455110_Energy_Demand_Assessment_for_Space_Conditioning_and_Domestic_Hot_Water_A_Case_Study_for_the_Austrian_Building_Stock.
[125] Directed Vision: It focuses on energy efficiency policies in terms of renovation obligations and financial support and promotion of district heating through more stringent spatial heat planning policies.
[126] Diversification: It uses a highly diversified heating technology stock—i.e., a decentralized technology mix (heat pumps, biomass boilers, and solar thermal systems) and smart heating.
[127] J. Langevin et al., "Assessing the Potential to Reduce U.S. Building CO_2 Emissions 80% by 2050", *Joule*, 2019.
[128] E. Mata et al., "Contributions of building retrofitting in five member states to EU targets for energy savings", *Renewable and Sustainable Energy Reviews* 93, 759–774 (2018).
[129] F. Filippidou and J. P. Jiménez Navarro, *Achieving the cost-effective energy transformation of Europe's buildings Energy renovations via combinations of insulation and heating & cooling technologies: Methods and data*, European Commission, Joint Research Centre, 2019. https://doi.org/10.2760/278207.

Canada	NATEM[130]	Deep decarbonization scenario	CO_2 emission reduction by 60% between 1990 and 2050	• Electrification of space heating and water heating technologies • By 2050, hydro, wind, and pumped storage become the main electricity supply technologies • Share of natural gas drops from 92% to 5% in the residential and commercial energy consumption	• Massive investment in RE and nuclear generation, combined with a significant decrease in generation from existing thermal plants • Promote energy efficiency improvements
China	DREAM[131]	Decarbonization scenario	CO_2 emission intensity of electricity production is reduced from 0.54 kg CO_2/kWh in 2020 to 0.09kg CO_2/kWh in 2050, with r	• High RE penetration in the power sector – RE-based electricity increasing to 89% in 2050 • Aggressive building energy efficiency policies for new and existing buildings • Technology efficiency improvement and enhance fuel switch for electrification • Improve electrification rate for heating, water heating, and cooking. Overall social scale electrification rate reaches 70% in 2050	• Promote net-zero energy buildings (NZEB) • Retrofit existing buildings • Use high-efficiency appliances in buildings • RE penetration in buildings • Electrification of building technologies for heating, water heating, and cooking

[130] V. Kathleen et al. (2017), "Exploring deep decarbonization pathways to 2050 for Canada using an optimization energy model framework", *Applied Energy*, Volume 195, 2017, Pages 774-785, ISSN 0306-2619.
[131] R. Wang, S. Lu and W. Feng (2020), "A novel improved model for building energy consumption prediction based on model integration", *Appl. Energy* 262 (2020).

b. Global experience with sustainable heating

Strategies for the transition to sustainable heating in the advanced economies reviewed for this report tend to combine energy efficiency scale-up with a mix of targets for RE-based heat sources and regulatory measures to phase out or limit the use of fossil fuels in buildings. Table A.3.presents policies and strategies introduced in different countries aimed to accelerate the transition to a more sustainable heating sector. In addition, Table A.4 includes examples of countries that have enacted heating fuel bans, such as oil-fired boilers already banned in countries such as Austria, Norway, and Sweden.

Table A.3: Policies/Strategies for Decarbonization of Heating

Country/Region	Policies/strategies for decarbonization of heating	Objectives/Approaches/Targets
European Union (EU)[132]	Renovation wave for Europe	• At least double the annual energy renovation rate of residential and non-residential buildings by 2030 • Renovate 35 million building units by 2030 and keep the renovation rate post-2030 to reach EU-wide climate neutrality by 2050
United Kingdom[133]	Heat and Buildings Strategy	• Incentivize sustainable heating technologies and building renovation in all its 30 million homes, workplaces, and public buildings • Reduce the costs of installing a heat pump by at least 25-50% by 2025 • Ensure heat pumps are no more expensive to buy and run than gas boilers by 2030 • Reach minimum market capacity of heat pump installation to 600,000 per year by 2028 • By 2025 all new buildings will be built with high levels of energy efficiency and banned from installing gas and oil boilers
Denmark[134]	Climate Status and Outlook 2021	• Phase out of the last coal-fired CHP plants, increase deployment of wind power and photovoltaic modules, expand the number of heat pumps to produce DH, and reduce the amount of CHP plants based on natural gas • Replace approximately 50% of Danish households that are currently heated by oil/natural gas with DH by 2028 and the other 50% to switch to electric heat pumps by 2030
Germany[135]	Energy Efficiency Strategy for Buildings	• Brings together the three aspects of power, heat and energy efficiency to form a clear policy framework for the energy transition in the building sector • As for buildings, every newly installed heating system should be operated with at least 65% RE • Germany's coalition government has agreed to phase out natural gas in new buildings in 2024
Chile[136]	National Heat & Cold Strategy	• Reduce by 65% the GHGs associated with heat and cold generation • Increase to 80% the sustainable energy used for heating and cooling by 2050 • Decarbonize the heating sector by electrifying heating demands and promoting the use of modern biomass • Professionalize the solid biofuels market, prohibit the trade of non-certified biomass and invest in RE • Enhance district energy projects and the use of geothermal and aerothermal heat pumps
Canada[137]	Net-Zero Emissions Accountability Act 2030 Emissions Reduction Plan	• Enforce net-zero ready building codes, decarbonizing space and water heating, improving energy efficiency, and accelerating private financing and workforce development • Retrofit homes nearly 600,000 (11.4 million in total) and 32 million m^2 of commercial property annually until 2040, at a cost of roughly CAD $21 billion per year through various programs such as Canada Greener Homes, Green and Inclusive Community Buildings, and Canada Infrastructure Bank's Growth Plan

[132] https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en.
[133] https://www.gov.uk/government/publications/heat-and-buildings-strategy#:~:text=Details,for%20households%20across%20the%20country.
[134] https://energy.ec.europa.eu/system/files/2014-11/dk_letter_0.pdf.
[135] https://www.bmwk.de/Redaktion/EN/Publikationen/energy-efficiency-strategy-buildings.pdf?__blob=publicationFile&v=7.
[136] https://www.bnamericas.com/en/news/ministry-of-energy-launches-national-heat-and-cold-strategy.
[137] https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/net-zero-emissions-2050/canadian-net-zero-emissions-accountability-act.html.

Japan[138]	Sixth Strategic Energy Plan Plan for Global Warming Countermeasures	• All new constructions should be net-zero-energy houses or net-zero-energy buildings by 2030 • Define a path to achieve a mid-term target of 46% greenhouse gas emission reduction by 2030 compared to 2013. Set a target for carbon neutrality by 2050. • Establish 2030 quantitative targets compared to 2019 levels. Industrial heat pumps installed capacity to increase 10 times. Commercial and residential heat pump water heaters installed units to raise 280 and 230 percent, respectively[139]

Table A.4: Fuel Ban Policies

Country	Fuel ban
Austria[140]	• Bans new installations of oil-fired heating systems in 2021, gas systems in 2025 and by 2035, oil systems are to be entirely banned.
China[141]	• Sales of coal and oil boilers installed in buildings or used for DH, together with sales of gas heating equipment that is not compatible with hydrogen, are completely phased out by 2035.
Denmark[142]	• Bans oil and coal used for heating purposes by 2030. Calls for 100% RE in the heating and electricity sectors by 2035.
Finland[143]	• On 1 April 2019, an Act banning the use of coal for energy generation in 2029 was passed. The ban will apply as of 1 May 2029 and incentives for energy utilities to implement the change already by 2025 are being prepared. The same requirements apply both to private and public buildings.
France[144]	• The Climate and Resilience bill is a new law that imposes stronger sanctions for pollution of soil, air and water, and is expected to reduce fossil fuel use for residential heating and electricity generation.
Germany[145]	• Bans all oil-fired installations by 2026 if a low-carbon alternative is available.
Japan[146]	• Japan plans to phase out inefficient coal-fired power plants but does not have an official commitment to do so. On the contrary, Japan is anticipating new, likely more efficient coal plants to come online by 2035.
Norway[147]	• Bans the use of oil and paraffin for heating in all buildings from 2020.
Sweden[148]	• Currently bans all oil-fired boilers and pressures the building and heating industries to rely on DH.
United Kingdom[149]	• The UK government announced that by 2025, all new homes will be banned from installing gas and oil boilers and will instead be heated by low-carbon alternatives, especially RE alternatives such as heat pumps. The ban is part of a UK action plan to reach carbon net zero by 2050.
United States	• There are no bans on heating fuels at the federal level, but some states (California is the most advanced in this regard) are putting in place measures to completely phase out natural gas usage.

[138] https://www.enecho.meti.go.jp/en/category/others/basic_plan/.
[139] https://www.greendc.vn/the-role-of-heat-pumps-towards-decarbonization-japans-policy-market-and-technology.html.
[140] Cool Products for a Cool Planet, "Member States' ambition to phase out fossil-fuel heating – an analysis Background briefing, July 2021, pp. 6, downloaded at https://www.coolproducts.eu/wp-content/uploads/2021/07/ECOS-Coolproducts-Background-Briefing-MS-ambition-to-phase-out-fossil-fuel-heating.pdf
[141] An Energy Sector Roadmap to Carbon Neutrality in China, International Energy Agency, 2021, pp. 136 downloaded at https://iea.blob.core.windows.net/assets/bcf51d31-b7c6-4183-944f-707d05021356/AnenergysectorroadmaptocarbonneutralityinChina.pdf
[142] Cool Products for a Cool Planet, "Member States' ambition to phase out fossil-fuel heating – an analysis Background briefing, July 2021, pp. 6, downloaded at https://www.coolproducts.eu/wp-content/uploads/2021/07/ECOS-Coolproducts-Background-Briefing-MS-ambition-to-phase-out-fossil-fuel-heating.pdf
[143] Publications of the Ministry of Economic Affairs and Employment "Finland's Integrated Energy and Climate Plan 2019." pp. 44 downloaded at https://ec.europa.eu/energy/sites/ener/files/documents/fi_final_necp_main_en.pdf
[144] https://www.bloomberg.com/news/articles/2021-07-20/france-cracks-down-on-car-home-and-plane-emissions-in-new-law
[145] Cool Products for a Cool Planet, "Member States' ambition to phase out fossil-fuel heating – an analysis Background briefing, July 2021, pp. 6, downloaded at https://www.coolproducts.eu/wp-content/uploads/2021/07/ECOS-Coolproducts-Background-Briefing-MS-ambition-to-phase-out-fossil-fuel-heating.pdf
[146]See International Energy Agency "Japan 2021 Energy Policy Review" downloaded at https://iea.blob.core.windows.net/assets/3470b395-cfdd-44a9-9184-0537cf069c3d/Japan2021_EnergyPolicyReview.pdf, pp. 32
[147] https://www.nibe.eu/en-gb/about-nibe/news/2017/2018-12-05-norway-leading-the-way-to-decarbonising-heat
[148] Ibid.
[149] https://www.thermalearth.co.uk/blog/gas-boilers-banned-new-homes-2025. Also see "UK housing: Fit for the future?" at https://www.theccc.org.uk/publication/uk-housing-fit-for-the-future/

Annex B: Building Stock Data

- Table B.1: Residential Building Stock Data

Country	# of SFH	# of MFB	Total # of Dwelling	SFH area (m2)	MFB area (m2)	Total area of dwellings (m2)	Year	Source
Albania	654,463	357,600	1,012,063	-	-	63,000,000	2011	National Census - Institute of Statistics
Armenia	422,217	468,194	890,411	70,815,300	29,435,200	100,250,500	2021	Statistical Committee of the Republic of Armenia
Azerbaijan	1,193,013	631,166	1,824,179	-	-	109,400,000	2009	National Census - The State Statistical Committee of the Republic of Azerbaijan
Belarus	1,349,078	2,970,607	4,319,685	-	-	256,400,000	2019	National Census - National Statistical Committee of Republic of Belarus
Bosnia and Herzegovina	1,076,600	542,585	1,619,185	124,683,708	38,244,922	162,928,630	2016	GIZ
Bulgaria	1,490,460	1,714,115	3,204,575	118,300,032	122,314,615	240,614,647	2020	EU - LTRS
Croatia	1,372,929	380,492	1,753,421	90,371,355	56,553,324	146,924,679	2020	EU - LTRS
Georgia	592,720	464,452	1,057,172	74,116,450	32,573,742	106,690,192	2014	National Statistics of Georgia
Kazakhstan	2,056,438	3,058,822	5,115,260	194,289,000	193,451,500	387,740,500	2022	Bureau of National Statistics
Kosovo	256,693	156,190	412,883	43,108,460	12,291,952	55,400,412	2011	National Census - Kosovo Agency of Statistics
Kyrgyzstan	1,016,793	300,296	1,317,089	-	-	85,622,000	2021	National Statistical Committee of the Kyrgyz Republic
Moldova	901,500	417,900	1,319,400	65,082,949	22,182,282	87,265,231	2020	EU - LTRS
Montenegro	178,342	69,012	247,354	-	-	17,673,241	2011	National Census - Statistical Office of Montenegro
North Macedonia	607,095	232,079	839,174	69,191,312	13,871,487	83,062,799	2021	National Census - State Statistical Office
Poland	8,236,028	6,576,972	14,813,000	534,980,000	426,070,000	961,050,000	2019	EU Buildings
Romania	5,721,438	3,371,562	9,093,000	370,260,000	111,350,000	481,610,000	2019	EU - LTRS
Russian Federation	15,347,079	37,415,121	52,762,200	1,205,312,500	2,651,687,500	3,857,000,000	2020	Russian Federal State Statistics Service
Serbia	1,897,910	1,278,337	3,176,247	139,250,201	89,892,799	229,143,000	2021	Statistical Office of the Republic of Serbia
Tajikistan	940,950	289,050	1,230,000	-	-	63,000,000	2011	UNECE
Türkiye	5,957,958	18,042,042	24,000,000	500,000,000	1,900,000,000	2,400,000,000	2019	GIZ
Ukraine	8,604,223	8,803,479	17,407,702	-	-	999,454,108	2021	State Statistics Service of Ukraine
Uzbekistan	5,967,865	1,315,267	7,283,132	721,574,183	64,946,228	786,520,411	2021	World Bank

- Table B.2: Public and Commercial Building Stock Data[150]

Country	Type of Buildings	# of Buildings	Total area (m2)	Year	Source
Albania	Non-residential Building Stock	56,000	16,000,000	2011	National Census - Institute of Statistics
Belarus[151]	Public Buildings	8,178,000	-	2015	World Bank - ESMAP
Bosnia and Herzegovina	Public Buildings	-	9,277,844	2020	Energy Community
	Commercial Buildings	-	9,843,875		
Bulgaria	Public Buildings	-	57,138,956	2020	EU - LTRS
	Commercial Buildings	-	47,784,330		
Croatia	Public Buildings	91,588	15,762,479	2020	EU - LTRS
	Commercial Buildings	51,082	41,731,075		
Kosovo	Public Buildings	1,800	2,540,000	2013	EPTISA
	Commercial Buildings	58,100	7,860,000		
Kyrgyzstan	Public Buildings	9,780	10,351,811	2019	World Bank - ESMAP
Moldova	Public Buildings	7,305	5,082,337	2020	EU4Energy- LTRS
	Commercial Buildings	-	8,353,258		
Montenegro	Public Buildings	-	4,800,000	2013	Energy Community
North Macedonia	Public Buildings	-	8,483,400	2013	Energy Community
Poland	Public Buildings	420,000	465,000,000	2020	EU - LTRS
	Commercial Buildings	7,607,000			
Romania	Public Buildings	76,813	35,130,000	2020	EU - LTRS
	Commercial Buildings	55,842	26,880,000		
Russian Federation	Non-residential Building Stock	-	740,000,000	2012	U.S. Department of Energy
Serbia	Public Buildings	-	45,252,000	2013	Energy Community
Türkiye	Non-residential Building Stock	-	500,000,000	2019	GIZ
Ukraine	Public Buildings	-	115,725,700	2013	Energy Community
Uzbekistan	Public Buildings	42,222	72,771,572	2022	World Bank
	Commercial Buildings	135,255	21,640,800		

[150] Total public and commercial building stock were estimated based on the regional m2 per capita for Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Montenegro, North Macedonia, Serbia, Tajikistan, Turkmenistan and Ukraine as no data were available for both types of buildings.
[151] Total Volume of Public Buildings: 99,627,000 m3. Data available only in m3.

Annex C: Sources for Figures in Chapter II

Table C.1: Sources of Figures in Chapter II

Country	Housing Stock Characteristics and Dwellings per 1,000 inhabitants / Average floor area per capita		Age of Housing Stock		Percent distribution of households by type of fuel used for space heating		Share of energy sources in total energy used by Households for Space Heating		Percent of fuels consumed in DH		Percent of average monthly expenditure on energy sources		Space Heating Demand		Household Expenditure on Energy as a Share of Total Expenditure, by Country and Income Quintile (%)	
	Source	Year	Source	Year	Source	Year	Source	Year	Source	Year	Source	Year	Source	Year	Source	Year
Albania	Institute of Statistics of Albania	2011	Institute of Statistics of Albania	2011	Household Budget Survey	2018	Eurostat	2020	No DH	-	Household Budget Survey	2018	Eurostat	2019	Household Budget Survey	2018
Armenia	Statistical Committee of the Republic of Armenia	2021	UNECE	2014	The Integrated Living Conditions Survey (ILCS)	2016	-	-	IEA - World Energy Balance	2019	The Integrated Living Conditions Survey (ILCS)	2016	IEA - World Energy Balance	2019	The Integrated Living Conditions Survey	2016
Azerbaijan	The State Statistical Committee of the Republic of Azerbaijan	2009	-	-	Caucasus Research Resource Center	2011	-	-	IEA - World Energy Balance	2019	Household Budget Survey	2005	IEA - World Energy Balance	2019	Household Budget Survey	2005
Belarus	National Statistical Committee of Republic of Belarus	2020	-	-	UNICEF - MICS	2019	IEA - Energy Efficiency Indicator	2019	IEA - World Energy Balance	2019	-	-	IEA - Energy Efficiency Indicator	2019	-	-
Bosnia and Herzegovina	GIZ	2017	GIZ	2017	Household Budget Survey	2015	Eurostat	2020	IEA - Electricity and Heat Generation	2019	Household Budget Survey	2015	Eurostat	2019	Household Budget Survey	2015
Bulgaria	EU - LTRS	2019	EU - LTRS	2019	Gallup International	2007	Eurostat	2020	IEA - Electricity and Heat Generation	2019	-	-	Eurostat	2019	-	-
Croatia	EU - LTRS	2019	EU - LTRS	2019	-	-	Eurostat	2020	IEA - Electricity and Heat Generation	2019	Household Budget Survey	2010	Eurostat	2019	Household Budget Survey	2010
Georgia	National Statistics of Georgia	2014	National Statistics of Georgia	2014	UNICEF - MICS	2018	Eurostat	2020	No DH	-	Household Integrated Survey	2020	Eurostat	2019	Household Budget Survey	2020
Kazakhstan	Bureau of National Statistics	2022	UNECE	2017	Republic of Kazakhstan - Bureau of National statistics	2018	IEA - Clean household energy consumption	2018	IEA - World Energy Balance	2019	Household Budget Survey	2017	IEA - Clean household energy consumption	2019	Household Budget Survey	2017
Kosovo	Kosovo Agency of Statistics	2011	RES Foundation - Smart Stover Partnership	2015	UNICEF - MICS	2020	Eurostat	2020	IEA - Electricity and Heat Generation	2019	Household Budget Survey	2017	Eurostat	2019	Household Budget Survey	2017
Kyrgyzstan	National Statistical Committee of the Kyrgyz Republic	2021	National Statistical Committee	2011	UNICEF - MICS	2018	IEA - Energy Sector Review	2020	IEA - World Energy Balance	2019	The Kyrgyz Integrated Household Survey (KIHS)	2020	IEA - Energy Sector Review	2019	The Kyrgyz Integrated Household Survey	2020

Moldova	LTRS	2020	-	-	-	-	Eurostat	2020	IEA - Electricity and Heat Generation	2019	Household Budget Survey	2019	Eurostat	2019	Household Budget Survey	2019
Montenegro	Statistical Office of Montenegro	2011	RES Foundation - Smart Stover Partnership	2015	Household Budget Survey	2015	-	-	No DH	-	Household Budget Survey	2015	IEA - World Energy Balance	2019	Household Budget Survey	2015
North Macedonia	Republic of North Macedonia State Statistical Office	2021	Republic of North Macedonia State Statistical Office	2018	State Statistic Office	2019	Eurostat	2020	IEA - Electricity and Heat Generation	2019	Household Budget Survey	2019	Eurostat	2019	Household Budget Survey	2019
Poland	EU Buildings	2019	Statistics Poland	2018	Central Statistical Office, Poland	2018	Eurostat	2020	IEA - Electricity and Heat Generation	2019	Household Budget Survey	2019	Eurostat	2019	Household Budget Survey	2019
Romania	EU - LTRS	2019	EU - LTRS	2019	Household Budget Survey	2018	Eurostat	2020	IEA - Electricity and Heat Generation	2019	Household Budget Survey	2018	Eurostat	2019	Household Budget Survey	2018
Russian Federation	Russian Federal State Statistics Service	2020	-	-	Household Budget Survey	2007	-	-	IEA - World Energy Balance	2019	Household Budget Survey	2020	IEA - World Energy Balance	2019	Household Budget Survey	2020
Serbia	Statistical Office of the Republic of Serbia	2021	Statistical Office of the Republic of Serbia	2011	Household Budget Survey	2019	Eurostat	2020	IEA - Electricity and Heat Generation	2019	Household Budget Survey	2019	Eurostat	2019	Household Budget Survey	2019
Tajikistan	UNECE	2011	-	-	HSITAFIEN	2015	-	-	IEA - World Energy Balance	2019	HSITAFIEN	2015	IEA - World Energy Balance	2019	HSITAFIEN	2015
Türkiye	GIZ	2019	-	-	European Union Statistics on Income and Living Conditions	2019	IEA - Energy Efficiency Indicator	2019	No DH	-	Household Income and Consumption Expenditures Survey	2019	IEA - Energy Efficiency Indicator	2019	Household Income and Consumption Expenditure Survey	2019
Turkmenistan	-	-	-	-	-	-	-	-	IEA - World Energy Balance	2019	-	-	-	-	-	-
Ukraine	State Statistics Service of Ukraine	2021	-	-	GIZ/WB - Jobs, Skills, and Migration Survey	2013	Eurostat	2019	IEA - Electricity and Heat Generation	2019	Household Living Conditions Survey	2010	Eurostat	2019	-	-
Uzbekistan	World Bank - National Program for Buildings EE Improvement in Uzbekistan	2022	-	-	The Ministry of Regional Development of Ukraine	2016	-	-	IEA - World Energy Balance	2019	-	-	IEA - World Energy Balance	2019	Household Living Conditions Survey	2010

Annex D: Summary of Existing Allowances Schemes for Energy Expenditure in ECA Countries

Table D.1: Summary of Existing Allowances Schemes for Energy Expenditure in ECA countries

Country	Heating / Electricity / Gas Allowances
Albania	Cash benefit of 640 ALL (EUR 5.17) for all those recognized as consumers in need with a monthly consumption threshold of 200 kWh and an additional subsidized cash benefit of 648 ALL (EUR 5.23) per month to protect temporarily vulnerable households.
Armenia	50 percent bill compensation is in place for poor households in border communities for electricity and natural gas consumption. A special power tariff for low-income households is also in place. From February 2022, electricity tariff was increased for all consumer segments in Armenia except for vulnerable households making up 11 percent of all households. The daily tariff for them will be 29.99 drams (0.075 EUR) per kWh.
Azerbaijan	No information on allowance schemes available.
Belarus	Heating and hot water tariffs for population are administratively set at about 20 percent of cost recovery levels. Gas and electricity tariffs are about 90-95 percent of cost recovery. Housing and utilities subsidy program (means-tested energy assistance) is in place and compensate utility expenditures if the monthly utility bills exceed 15 (20) percent of total households' income in rural (urban) areas. However, it is extremely small in coverage and budget, and because of very restrictive eligibility requirements, covers only 0.5 percent of the population. Administrative price control for energy products remains in place. The Russian support and preferential prices for Russian energy products allowed the government to not have to raise prices for housing, utilities, and electricity.
Bosnia and Herzegovina	In the Brčko District, the government subsidizes part of electricity consumption up to the amount of the amount of 371.77 BAM (€186). In Canton Sarajevo, the government subsidizes the electricity, natural gas, and DH cost of 1,400 households that meet certain income and social vulnerability criteria. At the national level, individuals that are beneficiaries of permanent financial assistance and retired individuals that meet certain eligibility criteria have the right to a reduction in electricity costs (about 67,000 beneficiary households). In July 2022, the Government of the Federation of Bosnia and Herzegovina decided to provide a direct subsidy of 20 BAM (€10) per month for 5 months to about 70,000 vulnerable households.
Bulgaria	Persons and families whose average monthly income for the 6 months is lower than or equal to the differentiated heating income, from BGN 150.00 (€77) to BGN 277.50 (€142), are eligible for heating assistance. From July 2022, the government adopted measures to compensate businesses for higher electricity price up to a ceiling of BGN 250 (€128) in order to provide predictability in the coming months. The government had previously frozen power, heating, and water prices for households at their current levels from December to March 2022 to reduce vulnerability in winter months.
Croatia	Beneficiaries are given a housing allowance which includes the cost of electricity, gas, and heating for up to 50 percent of the monthly amount of the Guaranteed Minimum Benefit (GMB). The monthly amount of the benefit is up to maximum HRK 200 (€27). In addition, recipients of GMB who use wood for heating are entitled to a heating allowance of 3 cubic meters of firewood once a year. In February 2022, the number of eligible households who receive vouchers for electricity and/or gas bills has increased to over 90,000.
Georgia	Socially vulnerable families receive an electricity subsidy amounting to 0.039 GEL/kWh (0.015 EUR/kWh). Families having more than 4 children are entitled to a monthly subsidy of 5 GEL (€1.8), plus 2.5 GEL (€0.9) for each child above 4, to cover electricity consumption. Households living in high mountain regions receive a 50 percent discount on electricity tariffs up to a maximum consumption of 200 kWh.
Kazakhstan	Housing assistance to low-income and vulnerable groups to cover expenses for housing utilities costs.
Kosovo	Electricity subsidy for families benefiting from the Social Assistance Scheme (SNS), Martyrs' Families and War Invalids Scheme (FDIL), Blind Persons Scheme (SPV) and the Paraplegic and Tetraplegic Scheme (SPPT).
Kyrgyzstan	Families living in mountainous regions are entitled to a specific electricity subsidy. An increase in salaries of low-paid groups and a monthly benefit package for vulnerable groups have recently been introduced within the anti-crisis plan.

Moldova	500 MDL per month as aid for the cold season of the year (January-March and November-December) given to the disadvantaged families. In addition, certain socially vulnerable families in Chisinau are entitled to a subsidy covering about 40 percent of the heating costs in the cold period of the year.
Montenegro	Vulnerable consumers requiring health and social care are entitled to a subsidy covering 50 percent of their monthly electricity bills for up to 600 kWh of consumed electricity. In 2021, the government approved a temporary increase in the coverage and subsidy amounts of the bill discount program, with a total cost of EUR 3 million provided by the state-owned power utility. The government later approved the extension of the special subsidy program throughout 2022.
North Macedonia	Energy subsidies are granted to beneficiaries of social and permanent social assistance, amounting to MKD 1,000 or EUR 16 per month. In January 2022, the government expanded the coverage and the benefit of the energy poor program: from 600 to 800 MKD per month for around 7,500 households, depending on the size of the household.
Poland	A person or a family can receive Special Needs Allowance for housing-related costs, including utilities. In 2022, the allowance to help households struggling with energy bills was strengthened, to provide a maximum of €106 per person per year based on income, type of heating, and the number of people in the household (the largest of which can get up to €306 per year)
Romania	Various provision for low-income families such as Heating Energy Allowance, Natural Gas Allowance, Solid Fuel or Oil Allowance and Electricity Allowance. In October 2021, the government also introduced a temporary subsidy for households (covering about two thirds of households) that kicks in when retail prices go beyond a certain threshold.
Russian Federation	Accommodation costs and services are subsidized in accordance with income level and for certain categories of population. The government has introduced a 10 percent rise in pensions and minimum wage to mitigate the impact of inflation and major employers have also started raising their employees' salaries from July 2022.
Serbia	Electricity and natural gas bill discounts (up to 100 percent) for entitled families for electricity, gas, and DH bills, currently reaching around 0.5 percent of households. In Novi Sad, families with 3 or more children are entitled to a reduction in their monthly utility bills ranging from 30 to 50 percent, depending on the number of children. Socially vulnerable households (e.g., large families, households with disabled members) are entitled to a reduction in their monthly utility bills of up to 30 percent
Tajikistan	Aid of 9 dirams (SM 0.09) per kWh for households with per capita incomes of less than SM 35 per month per person for electricity and gas.
Türkiye	In 2022, the government decided to provide a 50 percent discount on natural gas bills and a 25 percent discount on electricity bills to more than 2.1 million households.
Ukraine	Reimbursement for cost of household heating (housing subsidies) is provided for low-income families to limit heating bill spending to not more than 20 percent of family income. Specific categories of vulnerable citizens (e.g., war veterans, disabled people) receive deductions on their utility bills.

Annex E: District Heating Survey Methodology

To perform the survey, a sample of countries was selected that had substantial use of DH, were representative of different sub-regions within the ECA region, and had readily available data.[152] Where possible, a mix of large, medium and smaller utilities was selected. The final list included 18 DH utilities, including five from Bulgaria, one from Kyrgyz Republic, nine from Poland, and three from Serbia.[153]

Next, a longlist of financial and operational indicators was developed based on data typically required for in-depth DH assessments. A shortlist was then developed based on data availability and judgements about which indicators would best represent utility performance. presents the shortlist of financial and operational indicators.

Table E.1: Shortlist of Financial and Operational Indicators for Rapid Assessment

Dimension	Indicator	Methodology
		Financial Indicators
Cost recovery	Operating and debt service cost recovery (with and without operational subsidies)	(Revenue [plus Operations Subsidies]) divided by [Operating Costs (Cost of Sales + Other Operating Expenses – Bad Debt Expense + Income Tax)] plus Debt Service (Interest Expense plus Repayment Component of Debt Servicing Cashflows)
	Average heating tariff and Average cost of heating supply	Average tariff: Heating revenue divided by kWh billed Average cost of heating supply: Cost of Supply [Operating Costs (Cost of Sales + Other Operating Expenses + Income Tax) plus Debt Service (Repayment of Borrowings + Interest Paid)] divided by kWh billed*
Liquidity	Collection rate	[Revenue minus Cashflow from Net Trade Receivables (Net Trade Receivables in Year T minus Net Trade Receivables in Year T-1) minus Bad Debt Expense plus (Deferred Income on Prepaid Sales in Year T minus Deferred Income on Prepaid Sales in Year T-1)] divided by Revenue
Profitability	Net profit margin	Profit/(Loss) for the Year divided by Revenue
		Operational Indicators
System efficiency	Heat production efficiency	Heat Produced divided by Primary Energy Used for DH
	Heat distribution efficiency	Heat Sold divided by Heat Produced
	Specific heat consumption	Heat Sold divided by Total Area Served
	Network water replacement rate	Water Losses divided by Network Water Volume
Network configuration	Heat demand density	Heat Sold divided by Network Trench Length
	Substation heat metering rate	Heated Area Behind Meters at Group Substation Level divided by Total Heated Area Served
	Building heat metering rate	Heated Area Behind Meters at Building Level divided by Total Heated Area Served

A questionnaire was then designed to collect data from utilities to calculate the indicators - see tables below.

[152] Data availability proved challenging for the survey. Much of the data had to be obtained through direct correspondence with the heating companies or through previous reports. Regular, public reporting of financial and operational performance was less common among DH companies than electric utilities, perhaps—in part—because DH companies are more often regulated at local government levels rather than at a national level.

[153] Kazakhstan and Uzbekistan were also included but insufficient data could be obtained from the surveyed district heating utilities.

Financial Data

Table E.2: Income Statement

Line Item	Unit	2017	2018	2019	2020	2021
Revenue (sum of DH revenue and other revenue)						
--DH revenue						
--Other revenue						
Cost of Sales						
Gross Profit (sum of revenue and cost of sales)						
Other operating expenses (sum of operating expenses and bad debt expense)						
--Operating expenses						
--Bad debt expense						
Other income (sum of other operating income and operations subsidies)						
--Other operating income						
--Operations subsidies						
EBITDA (sum of gross profit, other operating expenses, and other income)						
Depreciation and amortization						
Capital subsidies						
Operating profit/loss (sum of EBITDA, depreciation and amortization, and cap. subsidies)						
Interest expense/financing cost						
Other financing income/costs						
Profit/loss before tax (sum of operating profit, interest, and other finance income/costs)						
Income tax						
Other comprehensive income						
Profit/loss for the year (sum of profit/loss before tax, tax, and other comp. income)						

Note: Costs should be entered as negative values.

Table E.3: Balance Sheet

Line Item	Unit	2016	2017	2018	2019	2020	2021
Non-current assets							
Total non-current assets		[redacted]					
Current assets							
Trade receivables							
Doubtful debt provision							
Net trade receivables (trade receivables minus doubtful debt)							
Other current assets		[redacted]					
Total current assets (sum of net trade receivables and other current assets)		[redacted]					
Total assets (sum of total non-current assets and total current assets)		[redacted]					
Equity							
Total equity		[redacted]					
Non-current liabilities							
Long-term debt		[redacted]					
Other non-current liabilities		[redacted]					
Total non-current liabilities (sum of long-term debt and other non-current liab.)		[redacted]					
Current liabilities							
Deferred income on prepaid sales							
Current portion of long-term debt		[redacted]					
Short-term borrowing		[redacted]					
Bank overdraft		[redacted]					
Other current liabilities		[redacted]					
Total current liabilities (sum of the above five rows)		[redacted]					
Total liabilities (sum of total non-current liabilities and total current liabilities)		[redacted]					

Table E.4: Cashflow Statement

Line Item	Unit	2017	2018	2019	2020	2021
Cash flow from operating activities						
Net cash generated/(used in) operating activities						
Cash flow from investing activities						
Net cash used in investing activities						
Cash flow from financing activities						
Repayment of principal on borrowings						
Repayment of interest on borrowings						
Other cash flow from financing activities						
Net cash generated from financing activities (sum of the above three rows)						
Increase/(decrease) in cash and cash equivalents (sum of net cash flows from operating, investing, and financing activities)						
Cash and cash equivalents at the beginning of the year						
Cash and cash equivalents at the end of the year						

Operational Data

Table E.5: Heat Production and Fuel Usage

Fuel Type	Unit	2017	2018	2019	2020	2021
Amount of fuel used in heat production						
Coal						
Natural gas						
Fuel oil						
Other fuel (specify)						
Heat production by fuel type						
Coal						

Natural gas						
Fuel oil						
Other fuel (specify)						

Table E.6: Network

Fuel Type	2017	2018	2019	2020	2021
Total network trench length (m)					
Water losses (m^3)					
Network water volume (m^3)					

Table E.7: Heated Area

	2017	2018	2019	2020	2021
Heated area served by customer class and consumption-based billing status					
Residential, with CBB					
Residential, no CBB					
Commercial, with CBB					
Commercial, no CBB					
Industrial, with CBB					
Industrial, no CBB					
Public, with CBB					
Public, no CBB					
Other (please specify), with CBB					

Other (please specify), no CBB					
Heated area behind meters					
At group substation level					
At building level					
Heated area of disconnections and new connections					
Disconnections					
New connections					

Note: Data on heated area by customer class and consumption-based billing status, heated area behind meters at the group substation and building levels, and heated area of disconnections and new connections. All units are in m^2.

Table E.8: Sales

Customer Class	2017	2018	2019	2020	2021
Residential, with CBB					
Residential, no CBB					
Commercial, with CBB					
Commercial, no CBB					
Industrial, with CBB					
Industrial, no CBB					
Public, with CBB					
Public, no CBB					
Other (please specify), with CBB					
Other (please specify), no CBB					

The questionnaire requested data for the last five years of financial and operational data. A utility's performance on each indicator was scored on three equally weighted parameters:

- **Most recent year (MRY):** the utility's performance on the indicator in the most recent year of available data, giving a snapshot view of the utility's performance now.
- **Five-year trend (FYT):** the utility's performance on the indicator in the most recent year of available data are compared to its performance on the indicator five years ago, showing the utility's improvement (or lack thereof) over the period.
- **Stability (STA):** the utility's performance on the indicator over the last five years is examined for any substantial year-on-year declines in performance, an indication of the utility's consistency in performance over the 5-year period.[154]

The indicators were then compared to regional benchmarks. Scores for the parameters were based on a series of "yes/no" questions, each with an accompanying score: the utility receives the score for the first question answered "yes." Scores on each parameter are summed to get the score for the indicator. The maximum score for each parameter is 33.3; the maximum score on each indicator is therefore 100.[155] Table E.9 shows the scoring methodology for the collection rate as an example.

Table E.9: Parameter Scoring Methodology for Collection Rate Indicator

Parameter	Question	Score
Most Recent Year	Does the utility's collection rate meet or exceed the benchmark value of 95%?	33.33
	Is the utility's collection rate within 5% of the benchmark value?	25
	Is the utility's collection rate within 10% of the benchmark value?	10
	If none of the above	0
Five-Year Trend	Has the utility's collection rate improved from 5 years ago (ignoring years between), or has it worsened but its performance is still better than the benchmark?	33.33
	Has the utility's collection rate remained stable (within 5%) from 5 years ago (ignoring years between)?	25
	If none of the above	0
Stability	Has the utility's year-on-year collection rate decreased by more than 20% in any of the last 5 years?	0
	Has the utility's year-on-year collection rate decreased by 10 to 20% in any of the last 5 years?	10

[154] The assessment ignored declines in performance in 2020 to avoid penalizing utilities for poor performance associated with the COVID-19 pandemic.

[155] Because this study largely relied on publicly available data, the input data required to calculate some indicators were not always available. In these cases, the utility did not receive a score for that indicator, and the indicator was excluded from the overall scoring.

Parameter	Question	Score
	Has the utility's year-on-year collection rate decreased by 5 to 10% in any of the last 5 years?	20
	If none of the above	33.33

Because this is a pilot study that relies on publicly available data, leading to data gaps, the results should be considered indicative. Because of this, and some utilities expressed concerns over data confidentiality, all utility data and scores have been anonymized by randomly assigning each utility a letter ID between A and S.

District heating utilities selected

Bulgaria. Table E.10 provides an overview of the Bulgarian DH utilities included in the survey. All data were from 2020 unless otherwise noted.

Table E.10: Bulgarian District Heating Utilities

Utility	Location	Function	Heat Production Capacity (MW)	Network Trench Length (m)	Customers (# of metered buildings)	Fuel Mix
Toplofikatsiya Burgas AD	Burgas	Generation & Distribution of Heat & Electricity	93.04	124,876	31,016	93% Natural Gas, 7% Biomass
Toplofikatsiya Pernik AD	Pernik	Generation & Distribution of Heat & Electricity	244	67,511	19,959	91% Coal, 9% Natural Gas
EVN Bulgaria Toplofikatsiya EAD	Plovdiv	Generation & Distribution of Heat & Electricity	522	180,000	30,000 (2021)	100% Natural Gas (2019)
Toplofikatsiya Sofia EAD	Sofia	Generation & Distribution of Heat & Electricity	3,000 (2022)	950,000 (2022)	430,000 (2022)	99.98% Natural Gas, 0.02% Fuel Oil
Veolia Europe Varna EAD	Varna	Generation & Distribution of Heat & Electricity	46 (2019)	36,000 (2019)	12,743 (2019)	100% Natural Gas (2019)

Notes: Heat production capacity is the total capacity of heat production owned by the utility. The figures do not include heat purchased from private or other third-party CHPs. The number of customers is the number of metered buildings.

Kyrgyz Republic. Table E.11 provides an overview of the Kyrgyz DH utility included in this study. All data were from 2021 unless otherwise noted.

Table E.11: Kyrgyz District Heating Utilities

Utility	Location	Function	Heat Production Capacity (MW)	Network Trench Length (m)	Customers	Fuel Mix
JSC Bishkekteploset	Bishkek	Distribution of Heat	N/A	473,000	131,480	predominantly coal with gas as backup occasionally

Poland. Table E.12 provides an overview of the Polish DH utilities included in this study. All data were from 2021 unless otherwise noted.

Table E.12: Polish District Heating Utilities

Utility	Location	Function	Heat Production Capacity (MW)	Network Trench Length (m)	Customers	Fuel Mix
PEC Belchatowie	Bełchatów	Distribution of Heat	N/A	160,000	3,290	N/A
PEC Ciechanowie	Ciechanów	Generation & Distribution of Heat & Electricity	92.12	60,400	646	94% Coal, 6% Natural Gas
Miejskie PEC	Dębica	Generation & Distribution of Heat	47.68	35,712.5	261	93% Coal, 7% Natural Gas
Okregowe PEC	Gdynia	Generation & Distribution of Heat & Electricity	72.67	414,000	2,594	54% Natural Gas, 46% Coal
MPEC Kraków	Kraków	Generation & Distribution of Heat	28.11	929,400	6,000	75% Natural Gas, 25% Fuel Oil
Lubelskie PEC	Lublin	Distribution of Heat	N/A	467,260	1,687	N/A
PEC Mińsk Mazowieckim	Mińsk Mazowiecki	Generation & Distribution of Heat & Electricity	35.11	30,130	202	76% Natural Gas, 24% Coal
Energetyka Cieplna Opolszczyzny	Opole	Generation & Distribution of Heat & Electricity	542.6	318,200	2,330	82.53% Coal, 17.52% Natural Gas, 0.12% Fuel Oil, 0.01% LPG
PEC Radzyń Podlaski	Radzyń	Generation & Distribution of Heat	21.46	19,760	374	100% Coal

Serbia. Table E.13 provides an overview of the Serbian DH utilities included in this study. All data were from 2021 unless otherwise noted.

Table E.13: Serbian District Heating Utilities

Utility	Location	Function	Heat Production Capacity (MW)	Network Trench Length (m)	Customers	Fuel Mix
JKP "Gradska toplana" Niš	Niš	Generation & Distribution of Heat	266.23	107,000	28,077 (2019)	95% Natural Gas, 5% Fuel Oil
Novosadska Toplana	Novi Sad	Generation & Distribution of Heat	692.9	228,000	109,680	100% Natural Gas
JKP “Toplana-Šabac”	Šabac	Generation & Distribution of Heat	67.2 (2020)	22,000 (2020)	8,090	99.6% Natural Gas, 0.4% Biomass (2020)

Annex F: Multilateral Development Banks’ Experiences in Heating

1. 1World Bank Support for DH

The World Bank began developing investment operations in the heating sector in Poland in the late 1980s in four cities—Warsaw, Krakow, Gdansk, and Gdynia. Approved in June 1991, these projects all focused on DH upgrades and the reduction of heat losses. A similar loan to Katowice followed in 1993. Soon after the Soviet Union collapsed, governments across the region were requesting World Bank financing for improving their DH systems (tariff reforms, building connections, upgrading of heating boilers, DH networks, and some pilot renovations of MFBs)—starting with Estonia and Latvia in the mid-1990s, and Lithuania a few years later. In the late 1990s and the early 2000s, new DH loans were requested from Russia, Ukraine, Bulgaria and Croatia. Since 2010, about US$1.05 billion (US$810 million in ECA, US$240 million in the East Asia & Pacific region) was approved in new DH loans for Moldova, Belarus, Ukraine, Uzbekistan, the Kyrgyz Republic, China and Mongolia.

For DH projects, the World Bank did not have formal selection criteria, but investments that proceeded to the investment stage generally had: DH utilities that were considered more cost-effective at supplying space heating and domestic hot water than moving to individual heating systems, government commitment to supporting DH service improvements, DH management was willing to agree to certain institutional reforms (such as improved investment planning, greater energy efficiency, greater use of heat metering, improved O&M practices)—all designed to better ensure the sustainability of the investments. While each project developed a customized package of investments, the common legacy resulted in similar investments across many of the countries. These generally included:

- *Cleaner, efficient heating*. Replacement of old (coal, oil) heat boilers to combined-heat-and-power (CHP) using natural gas or biomass (mostly wood chips);
- *DH system upgrades and reduced technical losses*, through the replacement of pipes, components (valves, compensators), modernization of pumping stations (including variable flow pumps), temperature controls, metering;
- *Investments in multifamily apartments buildings*, including moving from open (direct) DH connections to closed (indirect) connections at the building-level substation, meters, thermostatic radiator valves, heat cost allocators, building envelope measures (wall/roof insulation, windows), etc.; and
- *Investments to support operational DH improvements*, such as upgraded billing and accounting systems, etc.

The DH projects were generally designed to improve energy efficiency by reducing thermal and water losses, improving the quality of heating services, extending the lifetime of DH systems, reducing environmental pollution (including CO_2 emissions), improving the operational efficiency and financial sustainability of DH companies both technically and financially, and improve cost recovery of heat tariffs. Therefore, in addition to the investment components, operations generally included institutional and policy reforms designed to support the sustainability of the sector. These included: (i) technical assistance and training for improved DH investment planning and O&M practices, (ii) more cost-reflective tariffs, including consumption-based metering and billing, (iii) rationalization of DH staffing, (iv) DH corporate reforms, (v) technical assistance and training on energy auditing, technical designs, measurement and verification, building certification, and (vi) support to assess, test and establish sustainable financing schemes for energy efficiency in buildings.

The Bank’s portfolio offered several lessons, including:

- **Government commitment.** DH projects were generally large and complex, with many different investment components and complementary reforms. Projects with strong demand and ownership by national and municipal governments were more likely to be implemented on time and according to the plans. Implementation issues, that inevitably arose, tended to be resolved in a timely manner.
- **Optimistic heat demand forecasts.** Many early DH projects had much higher projected demand than was realized. The introduction of cost-reflective tariffs, combined with equipment to measure and regulate

consumption at the building level resulted in customers changing their behaviors and reducing their demand, Subsequent investments in building-level insulation and other energy efficiency measures further reduced demand.

- **Rational tariff policies.** Appropriate tariff policies are important to maintain DH consumers and the financial viability of the DH systems. High prices often led to customer disconnections and erosion of the customer base and financial revenues to the DH company. Low prices, on the other hand, resulted in customers using more heating services than necessary which led to the deterioration of the financial standing of the utility and subsequently to reduced revenues for capital repairs and maintenance which results in a decline in efficiency and service quality. As DH systems are capital-intensive and thus have high fixed costs, a decline in demand increases the portion of fixed costs that the remaining customers would need to pay, making DH more expensive. A two-tiered tariff system thus allows for more transparent pricing of DH based on fixed and variable costs.
- **Sound business practices.** DH utilities should adopt sound business practices. This means ensuring customer satisfaction and high service quality, recruitment of new DH customers, assessing the potential to connect small, isolated heating systems to the larger network, and identifying and closing sections of the DH network that are uneconomic.
- **Reasonable project sizes.** It is important to consider the size and complexity of a project the DH utility can reasonably complete in the typical 5-6-year project duration. Similarly, the capacity for the coordinating agency to manage investments across too many cities/utilities. Successful DH projects are generally designed to be simple, with built-in flexibility to allow modifications during the implementation period.
- **Carbon dependency.** While environmental issues were considered during most of the investment projects, the focus was more on energy efficiency (reducing losses) and switching to cleaner fuels, such as natural gas. However, the ability of large, inflexible DH networks to decarbonize had not been fully evaluated. While there remains substantial demand for financing to convert remaining coal-based DH systems to gas (e.g., Kazakhstan, Kyrgyz Republic, Poland), more efforts are needed to identify and develop heating supplies based on RE, waste heat and electricity.

Sources: World Bank project documents; interviews with World Bank staff in 2022.

2. IFC's Experience in Financing Modernization of District Heating Utilities 2

The International Finance Corporation (IFC) has financed six DH projects totaling US$193.5m, including equity investments in two private DH companies, and sub-national loans to municipalities or municipal-owned DH companies in ECA, as well as the Baltics from 2009-14. These IFC projects financed the rehabilitation and modernization of urban DH systems, ultimately reducing their carbon footprint by increasing the efficiency of heat generation, and reducing heat and water losses in DH networks, as well as improving their reliability. Some of the typical technical solutions financed by IFC included upgrading heat-only boilers and CHP plants, changing the design of DH systems away from group heat substations (supply-driven DH) to individual heat substations (demand-driven DH), rehabilitating DH networks using pre-insulated pipes, upgrading network pumps and installing variable frequency drives, and upgrading heat metering, monitoring and control systems.

Two of IFC's sub-national projects in Romania were accompanied by advisory to help municipal-owned DH companies further decarbonize and improve the affordability of DH services, exploring additional technical solutions as well as non-technical measures (cost structure optimization) to reduce costs of providing DH services to residential customers. The rehabilitation of the DH system in Botoşani financed by IFC was provided as an example of international best practice in UNEP's flagship report "District Energy in Cities."

IFC's DH investment portfolio has performed well, with no defaults, but finding investible opportunities during recent years has been challenging. Several DH investment opportunities were pursued by IFC in Eastern and Southern Europe as well as in China, but did not materialize for reasons such as the non-creditworthiness of sponsors; guarantees from creditworthy municipal sponsors thus proved a key success factor. This is often linked to an inadequate DH tariff-setting regime, whereby DH utilities are unable to fully recover their total costs of heat supply and depend on subsidies which are not always provided in full and on time. In addition, only a few emerging economies have managed to establish adequate PPP frameworks promoting private sector participation in DH.

Looking forward, IFC is exploring Paris Agreement-aligned investment opportunities in DH, including RE, solar DH systems with seasonal thermal storage, sustainable biomass-based heat generation, heat pump-based DH systems, etc. In addition to DH, IFC is currently scoping for opportunities in the district cooling market, following IFC's first district cooling investment in India in 2021.

Source: *IFC project data and personal communication with Alexander Sharabaroff, MAS Climate* Advisory*, IFC.*

3. EBRD Experiences and Lessons Learned on Sustainable Heating

The European Bank for Reconstruction and Development (EBRD) focuses on municipal infrastructure and DH in ECA. EBRD engagement in the heating sector historically focused on modernizing existing DH systems and energy efficiency-focused retrofits of public buildings. EBRD has a large portfolio of successful DH projects, primarily focused on improving the operational performance and energy efficiency of utility operations, such as generation and network modernization, utility-controlled demand-side investments such as individual heating substations and heat metering at the building level.

Generation investments include best-in-class CHP and heat-only plant and the replacement of coal-fired capacity with cleaner fuels such as natural gas and biomass. EBRD's pipeline of investments for signing in 2022/23 now includes centralized solar thermal, geothermal and large-scale heat pumps; any future investments in natural gas generation will need to prove that they contribute to the long term decarbonization of the specific country or region. Network investments are focused on expanding DH supply to replace poor quality individual furnaces, improving control, introducing digital solutions and reducing operating temperatures to better prepare systems for RE- or waste heat-based supply.

Utility clients must meet minimum creditworthiness criteria (public sector projects are normally backed by a municipal or in some cases, a sovereign guarantee) and commit to reforms or improvements such as implementing cost-recovery tariffs or internationally recognized environmental management/ reporting systems. Alongside the well-documented regulatory barriers, lack of consumption based billing and low heat tariffs seen across the region, this "utility side" focus reflects another big challenge that the sector faces in ECA, which is the complexity and lack of incentives for the roll out of individual level demand-side measures and deep renovation of consumer buildings.

There are limited policies or regulations in ECA to support the need to decarbonize heating supply and reduce consumption. Nonetheless, EBRD has some recent successful heating projects covering both DH and individual systems that incorporated RE, demand-side measures and deep building renovation. In DH, commitment to implementing cost-recovery tariffs by government authorities alongside a recognition of the need to improve operations and consumer experience by public utilities in order to retain and attract new customers have been crucial. Projects focused on improving or replacing individual systems pose a greater challenge, given the need to engage with large numbers of private households. Here, demonstration projects focused on public buildings (including municipally owned residential buildings) where heating systems are replaced alongside energy efficient renovations are crucial for future private residential sector investments in green heating systems.

There is widespread acceptance of the need to decarbonize heating, but the region is overly reliant on fossil fuels and a large gap exists for actual policies or government actions. The lack of an appropriate carbon price or tax outside of EU Member States is an historic obstacle. In spite of these barriers and with the support of our donor partners, EBRD has had some notable success introducing RE to replace fossil fuels. Issues of air quality and the more recent energy crisis and associated energy security concerns have generated significant interest in RE- or waste heat-based solutions. Dedicated support facilities such as the EBRD's Renewable District Energy in the Western Balkans (ReDEWeB) Programme laid the groundwork with policymakers and utility companies and the Bank now has a promising pipeline of low carbon heating projects.

Some project examples include:

- Banja Luka Biomass Project (Bosnia & Herzegovina). Banja Luka suffered from very poor air quality in the winter months and heavy fuel oil plant was a major contributor. EBRD provided a loan to the city of Banja Luka to support a newly created majority privately-owned DH utility to support their equity investment in the utility, which partly financed the construction of a new biomass boiler plant to replace heavy fuel oil. Today, ~97% of DH supply in Banja Luka comes from RE-based fuels.
- Walbrzych Thermo-Modernization (Poland). Walbrzych had a chronic air pollution problem in the winter months, which is a direct result of the heavy reliance on rudimentary solid fuel stoves. So EBRD renovated 52 publicly owned multi-apartment buildings, including the replacement of individual coal stoves with building level heat pump systems.

Source*: EBRD project data and person communications with Greg Gebrail and Bojan Bogdanovic, Sustainable Infrastructure Group.*

4. KfW Experiences with Sustainable Heating4

KfW, as part of German development cooperation, has been engaged in sustainable heating in the Western Balkans for more than 20 years. This engagement comprises two main parts: DH and energy efficiency in buildings.

Existing DH systems. KfW has sought to focus on preserving and extending existing DH systems. The main part of KfW's DH portfolio has been in Serbia and Kosovo. During the first years of the cooperation, the focus lay on ensuring the functionality of existing systems, which had previously suffered from a lack of maintenance. One of the worst-performing systems at this time was in Pristina, with only 4-6 hours of heating provided by a heavy fuel oil boiler in a few weeks per winter. People turned to other ways of heating, such as individual stoves and electricity. This electricity mainly comes out of two aging lignite power plants. As a way to quickly improve the situation, the more modern power plant was retrofitted for co-generation. Even though leading to drastically reduced CO_2 emissions (80kt/year) and reliable 24/7 heating for 70,000 residents for the first time in 30 years. Subsequent projects focused on further expanding the network. A program for rehabilitating existing DH networks has also been implemented in Serbia since 2001, where KfW is by far the largest financier of DH.

Sustainable heating solutions. While rehabilitating and expanding existing systems remains a priority, a new focus lies in switching away from fossil fuels. There is no one size fits all approach for decarbonizing the supply side of heating. Individual heat pumps will play a role, but existing DH infrastructure will also need to be maintained and updated. KfW, therefore, continues to include this in its programs, even though the focus is shifting towards new, sustainable heating sources.

One example is a project in Serbia which is under advanced implementation. Three of four municipalities in the first phase of KfW's biomass program (co-financed by Switzerland's State Secretariat for Economic Affairs, SECO) are now using new boilers running on woodchips, with complementary measures to strengthen the DH network, including substations. In addition, KfW is also preparing solar DH projects in the region. This includes adding what would be one of Europe's largest solar thermal components to the DH system in Pristina. Feasibility studies for solar DH are also underway in Serbia.

Demand-side improvements. Demand-side investments are usually more cost-effective than heating supply investments, and in addition to having a positive impact on decarbonization, they significantly contribute to energy security, reducing consumers' energy expenditure, and thus reducing energy poverty and improving affordability overall. KfW promotes the energy-efficient refurbishment of public buildings in the educational, social and healthcare sectors, including the region's largest hospital in Belgrade. The KfW approach to retrofitting is holistic: interventions are not limited to energy efficiency but also encompass measures to improve the structure and enhance the comfort of public buildings. KfW projects thus usually also have social impacts such as improved learning atmospheres in schools, reduced health risks, as well as higher environmental awareness.

Overall, KfW has an active portfolio of almost half a billion euros in energy efficiency (including energy efficiency interventions in DH systems) in the Western Balkans. Currently, new support schemes are being prepared, the implementation of which will be supported by grants from the regional blending platform REEP (the regional energy efficiency program, supported by the EC, EBRD, KfW, Energy Community and GEFF).

Source*:* Authors' communications with Simon Martz and Matija Tadic.

Annex G: District Heating Experiences

1. Comprehensive District Heating Reform in Ukraine

A comprehensive reform plan for the DH sector was formulated in Ukraine in 2019. The plan covered legislative, regulatory, and financial reforms. The plan was developed with broad consultations with stakeholders such as DH utility managers, national line ministries, representatives of local governments, national regulators, legislators and consumer groups. Comprehensive reforms, rather than incremental changes, allowed the DH sector to modernize and adjust to a competitive environment more quickly, to overcome resistance to reform actions by ensuring that the reform plan brought benefits in addition to costs for stakeholders, and to simply the legislative process. Having a comprehensive reform plan also allowed for more buy-in and support from development partners.

The reform plan in Ukraine included:

- Modernization and simplification of technical norms applicable to the DH sector, which, for example, previously prevented procurement of efficient equipment widely available among international suppliers ;
- Alignment to technical requirements with international best practices;
- Reforms of DH economic regulations, including tariff methodology, tariff adjustment processes, and responsibility for tariff-making;
- Creation of an enabling environment for the modernization of DH infrastructure, operations, and management; and
- Support for financial recovery of the DH sector.

In 2020, Ukraine began implementation of the DH and energy sector reform, working to bring the electricity and natural gas sectors in line with the EU Third Energy Package. Reform progress on tariffs was delayed due to the COVID-19 pandemic, during which the Government prohibited the revision of heating tariffs until the end of the 2020/2021 heating season. While initially expected to expire in October 2021, the Government announced in November 2021 that tariffs would also be unchanged for the 2021/2022 heating season.

Sources: World Bank, Setting the Agenda for Further District Heating Reform in Ukraine (Washington, D.C.: The World Bank, 2019), available https://openknowledge.worldbank.org/bitstream/handle/10986/33473/Setting-the-Agenda-for-Further-District-Heating-Reform-in-Ukraine.pdf?sequence=1&isAllowed=y ;

USAID, White Paper on Transforming District Heating in Ukraine: Assessment and Recommendations (Washington, D.C.: USAID, 2020), available https://energysecurityua.org/wp-content/uploads/2021/04/050G-DH_White-Paper_for_DEC-2021-02-02-ENG.pdf ;

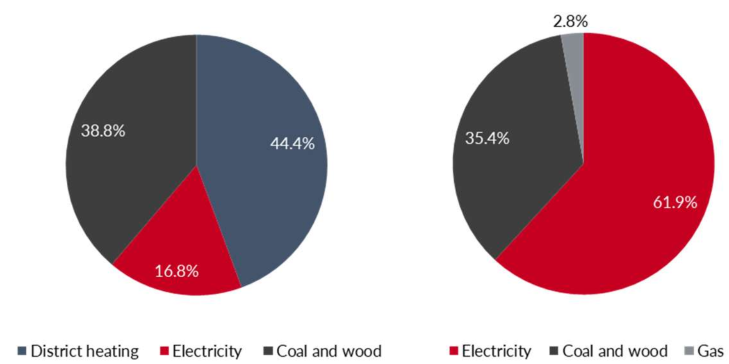
Government of Ukraine, "This heating season tariffs for the population will remain unchangeable, says Prime Minister.," 3 November 2021, available https://www.kmu.gov.ua/en/news/tarifi-dlya-naselennya-cogo-opalyuvalnogo-sezonu-zalishatsya-stabilnimi-premyer-ministr

2. Case Study of Failed District Heating in Shumen, Bulgaria1

The DH company in Shumen, Bulgaria ceased operation in 2011 due to accumulated large debts to the state gas supplier Bulgargaz EAD; it declared bankruptcy in 2014. Before 2011, the DH company in Shumen served more than 18,000 customers and provided heating to more than 40 percent of households in the city. In the years leading to its closure, its customer base steadily declined because of rising heat prices combined with low incomes, inefficient buildings, and a lack of trust in heating bills based on readings from heat cost allocators. By 2005, the number of customers had already declined by half and more than 250 subscriber stations had been shut down. Because of the large number of households that disconnected from DH, the bills of the remaining customers had to increase substantially, causing customers to look for alternative heating sources.

Both before and after the closure of the DH company there was a clear transition to heating with electricity. The city's integrated municipal development plan described the types of heating used by households in 2010. The types of heating used by households in 2010 are shown on the left in Figure G.1. The figure does not, however, include the share of households that were not heating their dwellings at all, estimated at 10 percent (and growing) in 2010. By 2017, six years after the closure of the DH company, the share of citizens in Shumen who used electricity for heating reached nearly 62 percent (as shown on the right in Figure G.1.), a 43 percent increase compared to 2010. Although the development of the city's gas distribution network began in 2004, by 2017 the share of households using gas for heating was only 2.8 percent.

Figure G.1: Household Heating Sources in Shumen, 2010 (Left) and 2017 (Right)



Source: Integrated Plan for Urban Reconstruction and Development in Shumen, 2014–2020; Program for Reduction of the Levels of Pollutants and Reaching the Established Norms for Fine Dust Particles (PM10) in the Atmospheric Air on the Territory of the Municipality of Shumen, 2018–2022; Program for Reduction of the Levels of Pollutants and Reaching the Established Norms for Fine Dust Particles (PM10) in the Atmospheric Air on the Territory of the Municipality of Shumen, 2018–2022; Aresgaz EAD, "Development Aresgaz EAD," available at aresgas.bg/за-компанията/развитие/.

The closure of the DH company in Shumen initially caused serious social upheavals and many households were left without heating, but gradually households have shifted to heating mainly with electricity. Given that Bulgaria's national grid emissions factor (543 tCO_2/MWh) is almost 2.7 times higher than the emission factor for natural gas (202 tCO_2/ MWh), emissions likely increased. If the majority of households used air-source heat pumps with an average seasonal coefficient of performance of 2.5–3.0, the carbon emissions associated with heating in Shumen could have remained at similar levels.

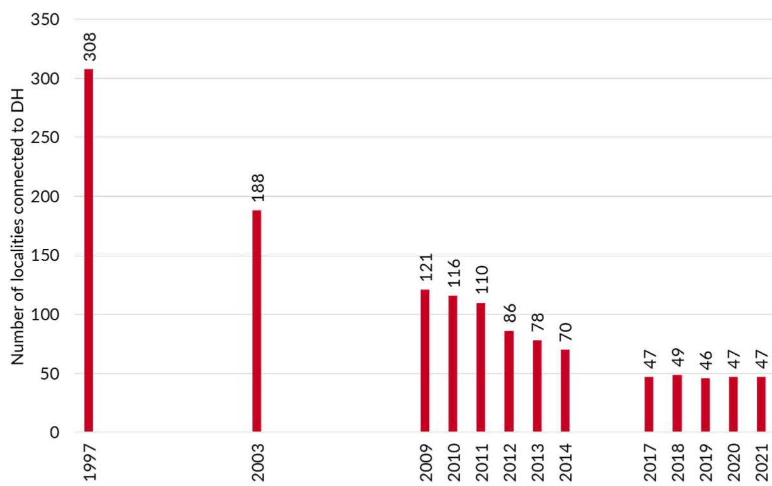
The mass electrification of heating in the city shows what could occur without a planned and managed phaseout of DH. When a DH utility fails, households typically have few options except to revert to dirtier, solid fuels or inefficient electric heating, neither of which are sustainable. Rather, measures need to be taken to support renovations of the housing stock and support for cleaner, individual heating options (e.g., community RE heating installations, efficient wood pellet or wood chip boilers or electric heat pumps). But this should be done gradually as the DH utility phases out, with incentives and financing to support households to transition to other options.

Sources: Written Response of the Minister of Energy Temenujka Petkova to Member of Parliament Ivan Ivanov, 18 December 2015; Bulgaria SEGA, "*13 times difference in the price of heating in neighbouring blocks in Shumen*," 10 October 2005; Integrated Plan for Urban Reconstruction and Development in Shumen, 2014–2020; Program for Reduction of the Levels of Pollutants and Reaching the Established Norms for Fine Dust Particles (PM10) in the Atmospheric Air on the Territory of the Municipality of Shumen, 2018–2022; Aresgaz EAD, "Development Aresgaz EAD," available aresgas.bg/за-компанията/развитие/; Ministry of Environment and Water, "Calculation and Forecast for Carbon Emissions Baseline Factor for Performance and the Development of the Bulgarian Electricity Sector for the Period 2017–2025," Sofia, 2020.

3. Failures of District Heating Romania2

District heating (DH) in Romania has been declining since the late 1990s. Retail gas prices for individuals (about 122 to 137 ROL/MWh in 2019) have been lower than the bulk heating price for DH companies (about 195 ROL/MWh in 2019). This has made it difficult for DH companies to compete with individual gas heating. The number of localities connected to DH has decreased from 308 in 1997 to just 47 in 2021, as shown in Figure G.2.

Figure G.2: Romanian Localities Connected to District Heating, Selected Years 1997–2021



Source: ANRE, *Report on the Status of the Public Service of Thermal Energy Supply in Centralized System*, 2019 and 2021 editions (Bucharest: ANRE, 2020 and 2022).

The cities of Slobozia and Baia Mare are two examples of where DH in Romania failed:

- **Slobozia**, in southern Romania, is an agro-industrial city with a population of nearly 46,000 and winter temperatures reaching -12°C. Its DH system included five DH plants but largely depended on an energy producer located inside a large chemical fertilizer plant which generated steam for its own manufacturing processes and hot water for 17 thermal substations (used to supply apartment blocks and public facilities). After 1990, the chemical plant was privatized, and its economic activity gradually declined until its complete closure. The remaining thermal network had heat losses of greater than 60 percent. After 1995, all of its customers gradually disconnected, due to low levels of thermal comfort and high prices, and mostly adopted individual gas-fired heaters.
- **Baia Mare**, in northern Romania, is a cultural, educational, and economic center in the region focused on small industry and tourism. Its population is about 130,000 and temperatures in winter reach -18°C. Its DH system consisted of gas-fired heat-only boilers and a cogeneration plant. Distribution

networks were poorly insulated, leading to losses of greater than 50 percent. The inefficiency of the system, combined with high prices and consumers' thermal discomfort, led to Baia Mare being one of the first Romanian cities where the DH system completely closed; all customers disconnected from DH over a short period beginning in 1995 (from 42,255 apartments to 1,200 apartments by 2001), during which DH was largely replaced with individual gas-fired units.

Sources: Romania National Energy Regulatory Authority (ANRE), *Annual Report 2019* (Bucharest: ANRE, 2020); Romania Ministry of Regional Development and Ministry of Energy, *Report on the Assessment of the National Potential to* Implement *High-Efficiency Cogeneration and Efficient District Heating* (Bucharest: MRDPA and MoE, 2015); Romania Ministry of Energy, *District Heating in Romania* (Bucharest: MoE, 2010); UNDP, *Improving Energy Efficiency in Low-Income Households and Communities in Romania* (Bucharest: UNDP, 2011), available at https://info.undp.org/docs/pdc/Documents/ROU/00061005_ProDoc_PIMS_4289_ROU_Energy_Efficiency_signed_July2011.pdf; Municipality of Iaşi, "Iaşi City Hall," available at http://www.primaria-iasi.ro; Energy & Resource Solutions, Inc., *Efficiency, Performance, and Social Issues for Eastern European District Heating* (ACEEE panel, 2002), available at https://www.aceee.org/files/proceedings/2002/data/papers/SS02_Panel3_Paper03.pdf.

4. Sustainable District Heating in Oradea, Romania3

Oradea, near the western border of Romania, is an important economic and tourist center with a population of 220,000 and winters with temperatures dropping to -12 °C. Its DH system supplies more than 70,000 customers. The system is operated by Termoficare Oradea S.A., which was founded in 2013 after the bankruptcy of the previous DH company.

The municipality has implemented several investment projects, including a 51 MW_t/45 MW_e gas-fired cogeneration plant, rehabilitation of 40 km of the network, modernization of 30 thermal substations, and extensions of the distribution network. Several substations are being decommissioned and will be replaced with transformer stations in which the pressure and temperature are reduced to meet the interior heating installations; they are mounted on the level of each housing block. In addition, Oradea was the first city in Romania to produce thermal energy from geothermal sources. While the heat produced using geothermal sources only accounts for only five percent of the total in the city, Oradea has served as an example for other cities in Romania to follow. Through these investments, thermal losses have decreased from 42 percent in 2014 to 26.7 percent in 2021, and CO_2 emissions have decreased from 1.156 tCO_2/Gcal to 0.355 tCO_2/Gcal over that period.

In 2021, the thermal energy tariff (about 336 to 373 ROL/Gcal) and subsidy (about 142 to 155 ROL/Gcal) in Oradea were the lowest in the country. The collection rate was nearly 100 percent, and there were no disconnections from the DH network between 2020 and 2021.

As a result of local policies and investment projects, the DH system in Oradea is efficient, performs well financially, and is increasingly environmentally sustainable. The number of customers has steadily increased; more than 5,300 customers since 2018. Real estate developments are required to connect to the heating system. Further investments are ongoing to rehabilitate the thermal network, extend the use of geothermal resources, and develop a solar PV park. Financing for investment has come from EU funds, the national budget, and the local budget.

Sources: Romania National Energy Regulatory Authority (ANRE), *Annual Report 2019* (Bucharest: ANRE, 2020); Romania Ministry of Regional Development and Ministry of Energy, *Report on the Assessment of the National Potential to Implement High-Efficiency Cogeneration and Efficient District Heating* (Bucharest: MRDPA and MoE, 2015); *Municipality of Oradea, "Oradea.ro—The Official Website of the Oradea City Hall," available https://www.oradea.ro/; Romanian Ministry of Energy, District Heating in Romania (Bucharest: MoE, 2010).*

Annex H: Support Schemes for District Heating and Combined Heat and Power Plants

Table H.1: Summary of Support Schemes for District Heating and Combined Heat and Power Plants

Country	Schemes
Austria	Subsidies for biomass CHP construction and emissions reductions; electricity FiTs for biogas CHPs
Croatia	Electricity market premia, guaranteed offtake, and FiT auctions for eligible highly efficient biogas/biomass CHPs
France	30 percent tax credit for connection to DH networks (will be converted to a bonus); reduced VAT for DH end-users; Heat Fund providing financing for heating networks, RE, and heat recovery; electricity FiT for biogas CHPs; bonus for electricity from biogas CHPs using livestock manure; electricity market premia (under competitive tenders) for biogas and biomass CHPs
Germany	Competitive tenders for electricity market premia for new, modernized, or innovative CHPs; coal replacement bonuses for electricity from CHPs
Netherlands	CHPs using natural gas are exempt from energy tax; Government tax scheme supporting investments in energy-saving equipment and sustainable energy; competitive premium FiT auctions for RE to compensate for the difference between the technology price and the market price of avoided CO_2
Romania	Bonuses for highly efficient CHPs per MWh delivered to the grid, to cover the differences between the combined revenue a qualifying CHP receives for selling heat at regulated prices and electricity at market prices and its total annual costs, with annual reconciliation process
Serbia	Subsidies for high-efficiency CHPs up to 10 MW; electricity FiTs for CHPs up to 500 kW; competitive auctions for electricity market premia to supplement the price obtained on the market for CHPs 500 kW to 10 MW
Poland	Competitive auctions for electricity market premia covering the difference between generation costs and the electricity market price
Denmark	Electricity market premia for biomass CHPs for the additional costs incurred compared to using coal
Estonia	Subsidies for electricity from (1) biomass CHPs; (2) efficient CHPs fueled by waste, peat, or oil shale gas; and (3) efficient CHPs with generating capacity less than 10 MW
Finland	Electricity FiT for biogas and biomass CHPs equal to the difference between EUR 83.5 per MWh and actual market price of electricity in NordPool; subsidies for biogas heating
Sweden	Heat production covered by EU emissions trading scheme is exempt from CO2 tax; green certificate system for electricity produced by RE or peat-fueled CHPs, with certificates then sold on open market to consumers to generate additional revenue for electricity production

Annex I: Methodology and Detailed Analysis for Assessing the Economics of Sustainable Heating

1) Methodology for Assessing Economics of Sustainable Heating

Data collection

A survey instrument was created to gather inputs for the building energy modeling for one rural and one urban location in each country in order to compare and contrast results of building typologies within the regional residential building stock. The survey instrument asked for information on three types of residences—single-family homes, multi-apartment buildings, and townhomes—and outlined the building features and heating systems for which data was needed. The completed survey instruments were reviewed and translated into representative architectural house layouts in AutoCAD software and related modeling assumptions in Microsoft PowerPoint format. Representative locations with weather files available in the simulation software were also identified for each urban and rural location.

Energy modeling

Energy modeling of residential buildings was performed using DesignBuilder software, a software tool for simulating building energy, carbon, lighting, and comfort performance. DesignBuilder combines three-dimensional building modeling with dynamic energy simulations. EnergyPlus is tested according to American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Standard 140 methodology.

EnergyPlus implemented detailed building physics for air, moisture, and heat transfer including treating radiative and convective heat transfer separately to support modeling of radiant systems and calculation of thermal comfort metrics. It calculates lighting, shading, and visual comfort metrics; supports flexible, component-level configuration of heating, ventilation and air conditioning (HVAC), plant, and refrigeration systems; and includes a large set of HVAC and plant component modules.

This software is an integrated suite of applications (e.g., shading analysis, thermal analysis, or heating systems analysis) based on a three-dimensional geometric model of the building. All of the inputs are linked to the same geometric model and the model performs an integrated simulation to produce the set of results (e.g., the characteristics of windows are provided as an input to the thermal analysis, which impacts the heating system analysis).

In each of the target countries, the representative residential building stock was modeled in cold regions of the country for one rural and one urban location each, using an 80-20 approach to select layouts to create prototypes to represent a majority of the building stock (i.e., if a building model represented less than 20 percent of the building stock, it was typically not considered representative and therefore not selected for modeling). For example, in countries where rural multi-apartment buildings represented less than 20 percent of the building stock, they were left out of the analysis. Architectural layouts vetted by the local consultants in each country were translated into three-dimensional BEM models in DesignBuilder. These models defined the basic geometry of the building, including floor area, floor-to-ceiling height, number of floors, roof type (flat or sloped), and the ratio of glazing to wall area. With the geometry defined, the envelope characteristics—such as the thermal transmittance of all constructions (wall, roof, floor, ceiling, windows, and doors) and the solar heat gain coefficient (SHGC) of windows—were entered. In addition to defining the envelope, the model also described all substantial internal heat gains, such as occupancy, lighting, equipment, and plug loads, as well as their daily use profile based on the data provided for each country type.

Results showing annual heating energy use consumption and peak loads were tabulated and compared to the appropriate base case scenarios. Hourly (8,760) results were also generated and plotted against the hourly dry-bulb temperatures in the climate files as a final check. Climate and meteorological data used for the energy calculations is the typical meteorological year of each location over the period 2007 to 2021, obtained from OneBuilding, a recognized library of weather data for building energy performance simulations. These files were created using the TMY/ISO 15927-4:2005 methodology.

Levelized cost of heating

The cost-effectiveness of each heating option was evaluated using the levelized cost of heating (LCOH), which is the cost of a unit of heat supplied (e.g., USD per MWh of thermal energy delivered), discounted over the life of the supply option. The LCOH analysis considers all capital, operating, maintenance, asset disposal, and other costs; the economic LCOH also includes environmental- and health-related costs. Table I.1 shows which of these variables are included in the economic and financial assessments. The economic analysis includes the cost of environmental externalities (the cost of global and local pollutants), excludes transfers between actors in a country (taxes), and uses a discount rate which reflect a country's social opportunity cost of capital rather than the private sector's opportunity cost of capital.

Simplifications were made in differentiating the financial analysis from the economic analysis:

- Explicit subsidies (for example, subsidies to electricity or fuel prices) are included in both the financial and economic analysis. These would normally be excluded from economic analysis, but the scope of the study and the availability of data did not allow for the uniform quantification of subsidies across countries.
- Implicit subsidies were also not possible to identify in detail, and thus are also included in the economic and financial analysis. For DH, or technologies that rely on existing gas or electricity networks, such subsidies are often seen in the form of utility under-spending on O&M, or under-investing. Economic analysis would normally consider the full economic cost of O&M, as well as the long-run average incremental cost of capital expenditure. Instead, this report uses DH, electricity, or gas tariff as the cost of fuel, with the assumptions that these tariffs are set at full cost recovery levels (where such cost recovery includes capital expenditure costs). The result is that DH, or technologies using electricity or gas, may be underpriced in the economic analysis relative to other technologies (such as wood or coal burning technologies) that do not rely on the existence of infrastructure networks.
- Shadow pricing was not used for the economic analysis. Such pricing is often used in economic cost-benefit analysis where market prices differ from prices that would exist in the absence of government intervention (for example, currency controls or regulation of goods and services) or market failures. The absence of shadow pricing may affect results in countries like Uzbekistan, where the use of currency controls can drive a wedge between official prices and market prices.
- Many environmental externalities were likely not captured as they are not easily quantifiable. Prominent among them are the economic cost of wood fuel in countries (such as Armenia) with a

long history of severe deforestation challenges. In such cases, even the official price of wood fuel is likely to substantially understate the economic cost.[156] The potential global warming impact of natural gas use is also likely understated. Combusted natural gas (CH_4) contributes low CO_2 emissions relative to other hydrocarbon fuels, but uncombusted methane (through gas flaring or gas pipeline leaks released into the atmosphere) eventually has a potentially profound impact on global warning that is not captured in this analysis.

Table I.1: Variables Included in Economic and Financial LCOH Assessment

Variable	Economic LCOH	Financial LCOH
Capital expenditure (CAPEX)	Y	Y
Fuel cost	Y	Y
Maintenance cost	Y	Y
Carbon emissions cost	Y	
Health cost (due to emissions $PM_{2.5}$, SO_2, NO_X)	Y	
Economic discount rate	Y	
Financial discount rate		Y
Taxes		Y

It is important to consider these caveats when interpreting the results of this exercise, and to note that LCOH is just a single indicator of the appropriateness of any heating option and thus indicative at best. As described in Box I.1, a multi-criteria analysis is important in deciding which options are most appropriate for each of the country contexts.

Box I.1 The Importance of Multi-Criteria Analysis

Levelized cost is only one indicator in assessing the appropriateness of a heating option for a particular country or location. Other factors are important to consider in evaluating which technology is the most viable. Other important factors in considering cleaner heating options are:

• **Market maturity/immaturity**. The extent to which the technology is used or the resource is already exploited in each country, access to competitively priced equipment, access to spare parts and able technicians or there is financing already available from other entities

• **Potential for job-creation**. The extent to which use of a technology or exploitation of a resource creates jobs

• **Effect on existing energy system stability**. The extent to which certain technologies had a negative or positive impact on system operation and dispatch of heat, electricity or gas networks

• **Social acceptability and familiarity**. Some technologies may be more attractive to consumers in certain circumstances (for example, more efficient woodstoves in rural areas), and hence may be better positioned for quicker uptake than other, less familiar technologies. Many may hesitate to invest in new technologies with which they are unfamiliar

• **Sunk costs**. Consumers may not use LCOH to evaluate potential investments. The lower cost of the alternatives may, in some cases, be enough to convince shoppers to opt for the cleaner technology option, but many customers will often not want to purchase an alternative until their existing heating solution fails and needs to be replaced

• **Institutional realities**. Implementing common, cleaner heating solutions in MFBs has proven difficult in the region. Many of these challenges relate to the predominance of Homeowners Associations (HoAs) in the ECA region, and their legacy of organization and management. Collective ownership in multifamily residential buildings and weak homeowners' associations (HOAs) are key challenges to upgrades of collective heating solutions. If decision-making structures for investments and mechanisms for financing more capital-intensive upgrades are not well established, it can be very difficult in multifamily residential buildings to reach consensus about upgrading/switching to collective heating solutions or implementing building-level energy efficiency measures

[156] Informal (black market) wood fuel prices were used for the financial analysis, where available.

• **Sustainability**. Heating options may not be viable if they cannot be implemented sustainable and scalable through business models that allow for proper maintenance, operation, and replacement of equipment over time.

These are just some of the non-economic and non-financial criteria that policymakers may wish to consider as they evaluate cleaner heating options.

Source: Authors

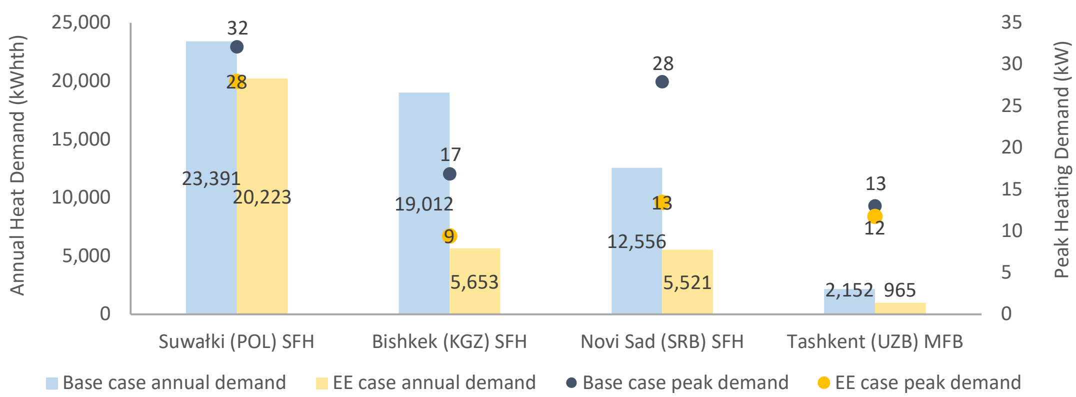
2) *Sensitivity and scenario analysis*

The LCOH results vary considerably with changes in assumptions about demand, fuel costs, and CAPEX costs. The analysis below presents (i) case studies of how investments in energy efficiency would impact the results of the modeling in four locations; (ii) the extent to which changes in fuel and CAPEX costs affect the results (switch value analysis); (iii) potential impact of changes in all variables (demand, fuel price, and CAPEX cost) on the modeling results and heat system rankings.

1) Energy Efficiency

Buildings in four locations were selected as case studies and were modeled to include energy efficiency investments—with more insulated walls and more efficient windows—alongside the heating upgrades to assess the impacts. Figure I.1 below shows the base case annual heat demand (in kWh_{th}) and peak heating demand (in kW) for each of the four selected case studies, a description of each energy efficiency investment modeled, and the annual heat demand and peak demand that would be achieved after the energy efficiency investment.

Figure I.1: Energy Efficiency Interventions and Annual Heat Demand (kWhth) and Peak Heating Demand (kW) [157]



Sources: *World Bank reports and expert estimates.*

While thermal renovations do allow for lower capacity heating systems to be installed and can substantially reduce overall energy use (and thus energy bills), the high investment cost for energy efficiency measures can have an adverse impact on the overall payback period. For example, in the case of a Bishkek SFH, the payback improves when energy efficiency is combined with switching from a coal boiler to more sustainable options (e.g., biomass, air-to-air heat pump). The very low price of coal results

[157] Bishkek (KGZ) SFH: Walls: Wall U-value improved from 1.001 to 0.149 W/m²K ; Windows: N/A (windows already efficient)
Suwałki (POL) SFH: Wall U-value improved from 1.0 to 0.149 W/m²K; N/A (windows already efficient
Novi Sad (SRB) SFH: Wall U-value improved from 1.457 to 0.156 W/m²K; U-value improved from 3.5 to 1.7 W/m²K
Tashkent (UZB) MFB: Wall U-value improved from 1.12 to 0.157 W/m²K; N/A (windows already efficient)

in almost all the sustainable alternatives (except air-to-water heat pumps) being unable to payback; so, combining the heating investment with energy efficiency improves the payback period. However, when assessing the replacement of a gas boiler with more sustainable options the payback period with energy efficiency measures increases considerably, due to the high investment cost for energy efficiency and low electricity prices. Therefore, reforms to better reflect actual fuel costs is critical to improve the payback periods of combining energy efficiency with sustainable heating replacements while helping the transition to be for affordable to households.

Table I.2: Base Case and Energy Efficiency Case Payback Periods for Single-Family Homes in Bishkek

Conventional technology and fuel consumption (kWh_{fuel})	Sustainable alternative and scenario	Payback period without EE (years)	Payback period with EE (years)	Change in payback period with EE
Coal boiler (38,024.66 kWh_{fuel})	Condensing gas boiler	n/a	147	↑
	Eco-design wood boiler	n/a	161	↑
	Wood pellet boiler	n/a	350	↑
	Air-to-water heat pump	18	93	↓
Existing gas boiler (24,066.24 kWh_{fuel})	Condensing gas boiler	18	63	↓
	Air-to-water heat pump	9	52	↓
Electric heater (19,012.33 kWh_{fuel})	Air-to-air heat pump	18	467	↓

Sources: *World Bank reports and expert estimates.*

Analyses show that energy efficiency investments impact the overall rankings of sustainable heating systems, system size (which lowers CAPEX), monthly energy bills and payback periods. Investments in energy efficiency reduce payback periods in roughly a third of the 83 possible switches customers could make from conventional to cleaner heating options. Table I.3 compares the number of clean energy investments with positive payback periods with and without energy efficiency measures. Investments in energy efficiency reduce the median payback periods by nearly 60 years and the average payback period by nearly 250 years.[158]

Table I.3: Number of Clean Energy Investments with Positive Payback Periods—with and without Investments in Energy Efficiency in Buildings

Number of Investments with Positive Payback Periods				
Country	Financial		Economic	
	Without Energy Efficiency Investment	**With Energy Efficiency Investment**	**Without Energy Efficiency Investment**	**With Energy Efficiency Investment**
Armenia	5	9	10	10
Kyrgyz Republic	9	17	15	17
Poland	9	12	10	12

[158] On a financial basis, considering only those investments in which payback periods are reduced when combined with investments in energy efficiency.

Serbia	17	18	18	18
Türkiye	8	9	6	13
Uzbekistan	5	6	5	8

Sources: *World Bank reports and expert estimates.*

Only some of the investments counted in Table I.4 will have low enough payback periods to be attractive to consumers; payback periods differ substantially by country, type of building and technology. Poland and Serbia have the lowest average payback periods—when measured on a financial basis—after investments in energy efficiency; the Kyrgyz Republic has the highest repayment periods, pointing to energy pricing as a key factor.[159]

Table I.4: Average, Maximum, and Minimum Payback Periods by Country (financial basis)

Country	Average	Maximum	Minimum
Armenia	56	90	19
Kyrgyz Republic	271	2216	35
Poland	19	52	4
Serbia	39	124	11
Türkiye	134	495	16
Uzbekistan	445	1713	6

Sources: *World Bank reports and expert estimates.*

Investments in urban MFBs show the lowest payback periods overall when combined with energy efficiency investments; investments in energy efficiency reduce the average payback period for urban MFBs by an average of 20 years, although some investments still remain unviable (i.e., payback period over 20 years). Investments in rural SFH have the highest payback periods with an average of 271 years.

When analyzed from an economic perspective, payback periods are substantially lower (on average 114 days) than financial payback periods. The very few exceptions are when for potential switching between a relatively clean conventional energy service, such as DH, to one with higher emissions, such as air-air or air-water heat pumps in countries with a relatively high grid emissions factor (e.g., Poland, Serbia).

2) Switching Values

Switching values refer to the value an input variable would need to take for a proposed investment to switch from one recommended option to another option. The analysis was undertaken to look at results based on changes in fuel and CAPEX costs. The analysis looks only at changes in costs that would make a given technology become least-cost or lose its least-cost ranking.

The country-by-country modeling analysis shows some common themes as described below:

- District heating is relatively insensitive to fuel price increases; its position as a least-cost option is robust. Wherever it is the least-cost option, it can sustain large increases in fuel prices without being displaced by another. This may be the result of its use of very low-cost fuels (e.g., natural gas in Uzbekistan, geothermal in Türkiye). It could also be a symptom of below cost pricing of DH, or the fact that the CAPEX costs are assumed to have been amortized into the heating tariff. The exception to the above statement can be found in urban MFBs in Uzbekistan, where an 8 percent increase in DH tariffs would make condensing gas boilers lower cost.

[159] Negative payback periods (in which there is no savings from switching) were ignored.

- The results for technologies using electricity are also robust, remaining least-cost with even quite large increases in the electricity price. Electric heaters and air-air heat pumps can sustain substantial increases in electricity tariffs before losing their least-cost ranking.
- Condensing gas and existing gas boilers are relatively sensitive to changes in CAPEX costs (more so than to fuel costs), with moderate increases in CAPEX cost making existing gas boilers lower cost.

3) Scenario Analysis

Scenario analyses examine the impact of changes in multiple input variables on the modeling results. As shown in the sections above, changes in demand, fuel costs, or CAPEX costs can all affect the LCOH ranking of technologies.

A scenario analysis was undertaken for cases in which the least-cost technology was not a cleaner technology, the intent being to understand what market factors might drive a re-ranking of the options, and to inform thinking on what policymakers might do to influence consumer choices. Table I.5 summarizes the results of the analysis.

Table I.5: Fuel and CAPEX Cost Changes that would Change LCOH Ranking

Country	Location	Building type	Least cost (financial)	Changes required to encourage cleaner options
Kyrgyz Republic	Rural	SFH	Electric heater	A 100% increase in electricity prices combined with a 61% decrease in CAPEX for air-to-air heat pumps would make the heat pumps least-cost.
Kyrgyz Republic	Rural	SFH	Coal boiler	A 50% increase in coal prices would make Eco-design wood boilers least-cost. Combining the coal price increase with a 50% reduction in condensing gas boiler CAPEX would make condensing gas boilers least-cost. Combining the coal price increase with a 42% reduction in air-to-water heat pump CAPEX would make air-to-water heat pumps least-cost.
Kyrgyz Republic	Urban	SFH	Electric heater	A 100% increase in electricity prices combined with a 74% decrease in CAPEX for air-to-air heat pumps would make the heat pumps least-cost.
Kyrgyz Republic	Urban	SFH	Coal boiler	A 50% increase in coal prices would make Eco-design wood boilers least-cost. Combining the coal price increase with a 50% reduction in condensing gas boiler CAPEX would make condensing gas boilers least-cost. Combining the coal price increase with a 43% reduction in air-to-water heat pump CAPEX would make air-to-water heat pumps least-cost.
Kyrgyz Republic	Urban	MFB	Electric heater	A 100% increase in electricity prices combined with a 78% decrease in CAPEX for air-to-air heat pumps would make the heat pumps least-cost.
Serbia	Rural	SFH	Existing wood stove	If market prices for firewood were used instead of the informal market price (a 405% increase in prices), electric heaters and air-to-air heat pumps would be lower cost than wood stoves; a 54% decrease in air-to-air heat pumps would make them lower cost than electric heaters.
Serbia	Urban	MFB	Electric heater	A 100% increase in electricity prices combined with a 73% decrease in CAPEX for air-to-air heat pumps would make the heat pumps least-cost.
Türkiye	Rural	SFH	Coal stove	A 75% increase in coal prices plus a 49% decrease in CAPEX for Eco-design wood stoves would make the Eco-design stoves least-cost. Combining the coal price increase with a 75% decrease in air-to-air heat pump CAPEX would make the heat pumps least-cost.

Sources: *World Bank reports and expert estimates.*

Where electric heaters are least-cost, air-to-air heat pumps can become least-cost with a combination of electricity price increases (100 percent increase) and a CAPEX subsidy (61-78 percent) for the heat pumps. Where coal boilers or coal stoves are least-cost, increasing the coal price by 50-75 percent can make Eco-design wood stoves or boilers least-cost instead because coal prices are low and Eco-design boilers and stoves are more efficient. Condensing gas boilers, air-to-air, and air-to-water heat pumps can also become least-cost when coal prices are increased, and appropriate CAPEX subsidies are applied to the gas boilers and heat pumps. In rural Serbia, existing wood stoves are least-cost because of the prevalence of unregistered or informal logging. If firewood is set at the market price (i.e., a 405 percent increase), electric heaters and air-to-air heat pumps would be lowest cost; a 54 percent CAPEX subsidy would be needed to make the heat pumps lower cost than electric heaters.

Annex J: Sustainable Heating Roadmaps: A Case Study of Romania

Under the sEEnergies project, supported by the EC, a case study of sustainable heating in Romania was conducted using the sustainable heating roadmap (SHR) methodology. Romania currently has 19.9 million inhabitants, and the population is expected to decrease to around 16.3 million people in 2050[160]. The existing energy system for Romania is dominated by fossil fuels with an overall share of around 70 percent in the primary energy supply out of a total of 372 TWh in 2019.[161]

For the heat demand in buildings, the heat is mostly produced by individual boiler systems with a DH share of around 15 percent. The individual boilers are mostly oil and gas-based, and individual heat pumps only register a small share of the overall heat supply i.e., 1.2 percent. Figure J.1 shows a breakdown of the heat supply in buildings in Romania in 2015.

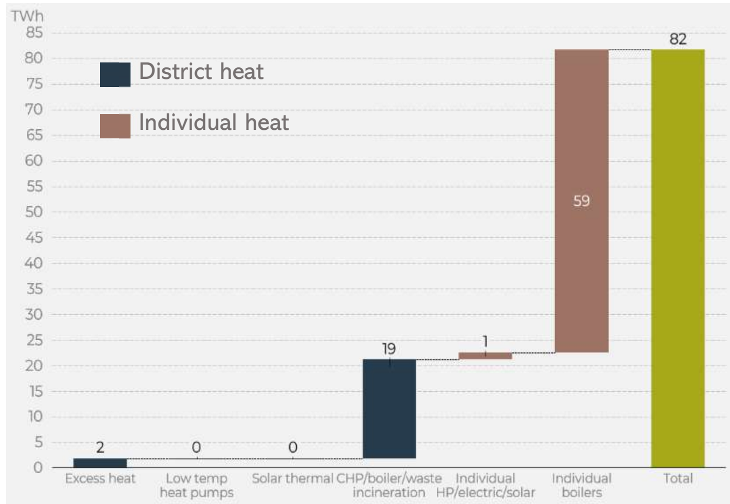


Figure J.1: Heat supply for buildings in Romania (2015)

Source: Djørup S, Bertelsen N, Mathiesen BV, Schneider NCA. Definition & experiences of strategic heat planning: Handbook I. 2019.

The existing heat demand for buildings in Romania was mapped for the reference year 2015 as shown in Figure J.2 for example, the city of Bucharest in Romania. The spatial assessment of heat demand densities allows us to study the suitability of two important parameters: heat demand saving potentials and DH grid expansion costs. This is because when the heat demand densities are too low, individual heating appliances (e.g., heat pumps) will be the preferred solution.

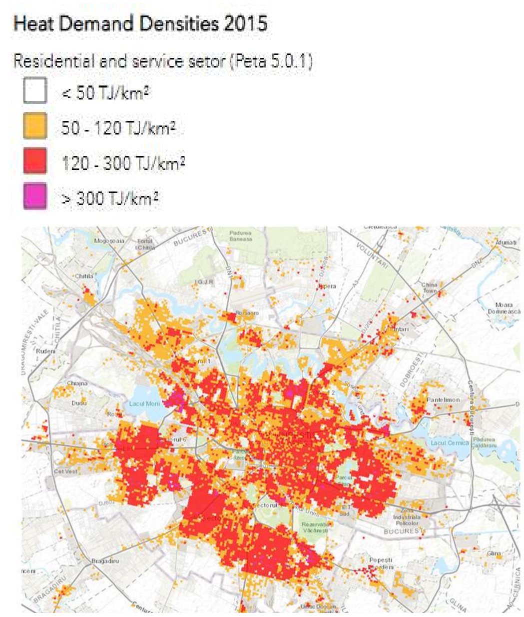


Figure J.2: Heat demand density for a city in Romania (2015)

Source: Peta5 | sEEnergies n.d. https://www.seenergies.eu/peta5/ (accessed September 5, 2022).

These heat demand levels are projected in the future for an evolving building stock, population growth (de-growth), renovation rates, etc. Different cost curves for the shares of heat savings are developed. These heat savings costs are estimated using the Forecasting Energy Consumption Analysis and Simulation Tool (FORECAST) tool. Along with the spatial assessment of heat demand densities, RE resources like excess heat from industries, and

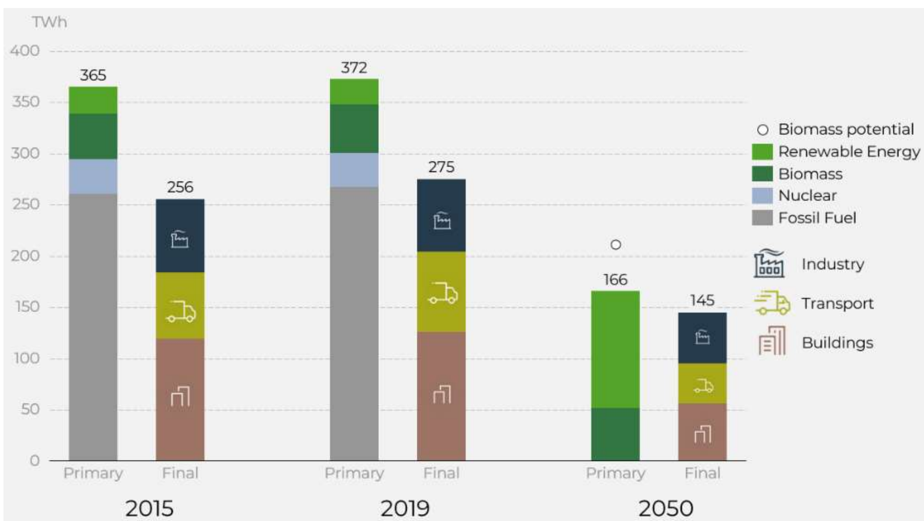
[160] Romania Population (2022) - Worldometer n.d. https://www.worldometers.info/world-population/romania-population/ (accessed September 5, 2022).
[161] Database - Eurostat 2020. https://ec.europa.eu/eurostat/web/transport/data/database (accessed September 4, 2020).

geothermal heat is also mapped. The spatial assessment of heat demand densities along with the identification of nearby resources allows the DH distribution capital costs to be estimated.

Once the cost curves are constructed for the heat demand savings and DH grid costs, different energy systems scenarios are formulated with varying levels of DH level and heat demand savings level for the future Romanian system in 2050.[162] The analysis for the identification of appropriate heat savings levels in buildings and DH share is performed similarly using the EnergyPLAN simulation tool.[163] The available potential for RE, e.g., PV, and other resources such as biomass were estimated using the EU's Joint Research Council figures. In the case of Romania, this analysis was combined with an integrated energy systems assessment covering industry and transport to identify synergies with other sectors and the impact of one sector on another to design an overall energy-efficiency, smart energy system.

The results of the analysis showed that Romania could reduce its total heat demand cost-effectively by 44 percent by 2050 in the residential and service building sector at a cost of about €20 billion. As seen in Figure J.3 the 2050 sEEnergies system has a much lower difference between primary and final energy demand indicating lower losses and an efficient energy system.

Figure J.3: Primary and Final Energy Demand for Romania in a Scenario Modelling A Smart Energy System



Source: Djørup S, Bertelsen N, Mathiesen BV, Schneider NCA. *Definition & experiences of strategic heat planning: Handbook I*. 2019.

The highest costs are for the renovation of the building stock i.e., heat demand savings. However, these high investment costs for heat demand savings can be largely offset by savings in fuel costs and an overall reduction in energy demand. In terms of the heat supply for buildings, the analysis found that almost 45 percent of the heat supply could be supplied cost-effectively by DH, with half of it being sourced from excess heat and low-temperature sources. Individual heat pumps are an energy-efficient option for heat supply to areas with insufficient heat demand densities and more remote rural areas. This is made possible due to a massive increase in RE capacities to almost 50 GW, which is almost double the existing overall installed capacity.

[162] Future Heat Demand, Efficiency Potentials and Supply n.d. https://storymaps.arcgis.com/stories/5aee81e1408b4410887011818bcac80f (accessed September 5, 2022).
[163] See https://www.energyplan.eu.

Once the reductions in heat demand through energy efficiency and RE/clean energy resources are mapped against heat demand, DH can substantially increase its share of coverage without significant increases in heat supply as shown in Figure J.4 with some densification and extension of the network. The DH system also switches to cleaner and a more diversified fuel mix by 2050, incorporating waste incineration, excess or waste heat, low temperature heat pumps and solar thermal (Figure J.5). For buildings not connected to DH, the overwhelming number of them would switch to heat pumps with some residual homes using mostly biomass boilers.[164]

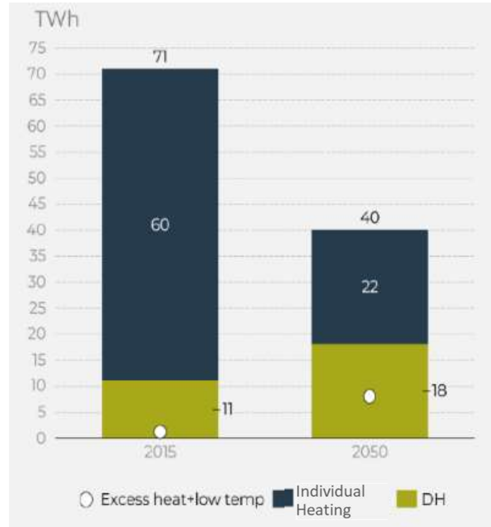
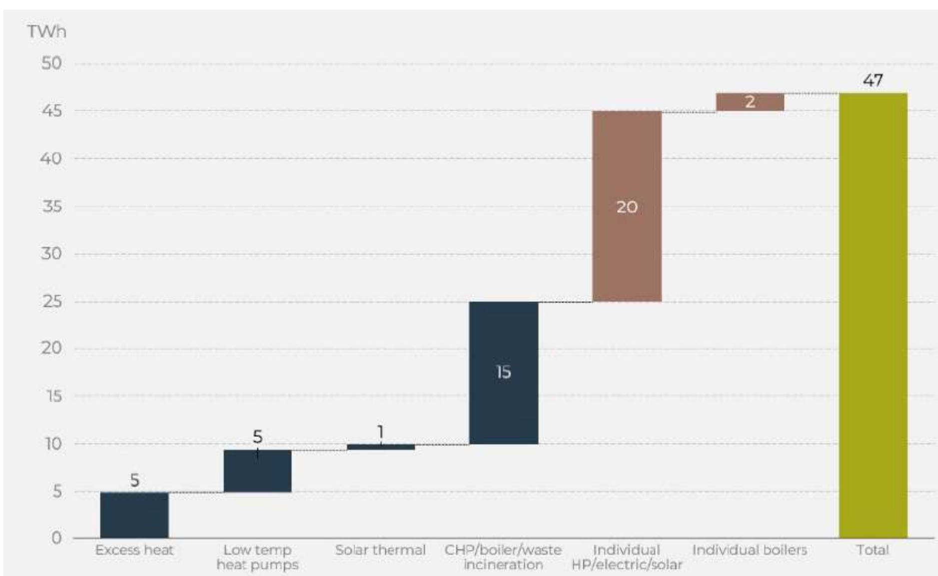


Figure J.4: Share of Individual Heat and District Heat in Romania

Source: Energy Efficiency 2050 Roadmap: Romania — Aalborg Universitets forskningsportal n.d. https://vbn.aau.dk/da/publications/energy-efficiency-2050-roadmap-romania (accessed September 5, 2022).

Figure J.5: Heat Supply for Buildings in Romania (2050)



Source: Djørup S, Bertelsen N, Mathiesen BV, Schneider NCA. Definition & experiences of strategic heat planning: Handbook I. 2019.

[164] For more information, see Energy Efficiency 2050 Roadmap: Romania — Aalborg Universitets forskningsportal n.d. https://vbn.aau.dk/da/publications/energy-efficiency-2050-roadmap-romania (accessed September 5, 2022).

Annex K: International Examples of Programs Supporting Sustainable Heating Systems

- **Table K.1: International Examples of Programs Supporting Air-Source Heat Pumps**[165]

Country	Program description	Incentives	Results/Expected Results
Greener Homes Initiative—Canada	Launched in June 2021 to reduce GHG emissions from residential heating. Eligible beneficiaries include existing single and semi-detached houses; row homes and town homes; mobile homes on permanent foundations; permanently moored floating homes; residential portions of mixed-use buildings; small multi-unit residential buildings	Grants for energy use evaluations and retrofitting homes to be more energy efficient, including installation of ASHPs	30,000 applications in first week after launch
Renewable Heat Initiative (RHI)—United Kingdom	Launched in April 2014 to promote heating and cooling systems using RE, including solar water heating and heat pumps (biomass boilers excluded)	Grants	Government aims to encourage 600,000 heat pump installations annually by 2028; 14,000 applications submitted between 4/2019 and 3/2020
Two-Part Assistance Programs—Scotland and Wales	Programs intended to overcome aversion of homeowners to initial expense of ASHP adoption and operating costs once installed	Grants or no-interest loans; tariff designed for ASHPs to reduce heating costs to consumers over time	N/A
Superbonus—Italy	Program to encourage the use of all types of renewable and more efficient energy sources, including ASHPs. Eligible beneficiaries include condominiums; individuals; housing cooperatives; non-profit, social promotion, and voluntary organizations; amateur sports associations and clubs	Tax rebate of 110 percent of the purchase price of an ASHP	Building renovations have increased by 500 percent since the program has been in force
Finland	Government introduced policies directed at energy efficiency and emissions mitigation	Tax deductions for building renovations and heat pump installations; higher taxes on fossil fuels	Finnish households are adopting ASHPs at a rate of 5,000/year; Finland has developed manufacturing capacity for ASHPs and technical skills to install and maintain them
Myclimate Support Program—Switzerland	Program provides funding for replacement of old oil and natural gas heating in rented residential properties; Government enacted limits on CO2 emissions in both new and existing buildings	Grants and tax incentives for switching to geothermal-, water-, and air-source heat pumps	By mid-200s, ASHPs accounted for 75 percent of systems installed in new homes
China	Government committed to subsidize adoption of ASHPs in its latest Five- Year Plan	Direct grants to reduce upfront installation and equipment costs	674,000 households expected to be eligible over 5 years; ASHPs expected to provide about 25 percent of Norther China's heating needs in 2035

- **Table K.2: International Examples of Programs Supporting Sustainable Biomass Stoves**

Country	Program description	Incentives	Results/Expected Results
Canada	Federal and Provincial governments support households in switching to more advanced stoves	Rebates	A program in British Columbia resulted in exchange of 50,000 old, inefficient stoves for newer, certified appliances with advanced combustion technologies
Renewable Heat Initiative (RHI)—United Kingdom	Government program to incentivize homeowners to adopt pellet stoves	Grants	Installations went from near zero in 2/2014 to nearly 1,300 systems in 12/2016
Italy	Government program to support purchase of pellet stoves and certification of wood pellet quality	Tax deductions and feed-in tariffs for heating and cooling	N/A
Germany	Program to replace existing heating systems with pellet stoves; Federal Office for Economic Affairs and Export Control promotes efficient technologies that provide buildings with RE-based heating or cooling	Subsidies	12,500 applications to the program in the first half of 2019

[165] Air-source heat pump (ASHP) works by absorbing heat from the outside air and then transfer it directly into your home via a fan system to heat a room.

Annex L: Case Studies of Sustainable Heating Programs

a. Clean Air Priority Program (CAPP)—Poland

The Polish residential sector is a major contributor to the country's poor air quality, with almost 47 percent of $PM_{2.5}$ generated outside industry. This is a consequence of the many Polish homes that rely on solid fuels for heat, and poor thermal insulation in buildings. By 2016, 5.4 million homes were without connections to the gas/heating network, while 4.5 million buildings (80 percent of all homes) used solid fuels for heat.[166]

Program Description

Poland's Clean Air Priority Program (CAPP) is intended to encourage the adoption of clean energy heating systems, and thermo-modernization by households in Poland. Established within the European Commission's "Clean Air Policy Package for Europe," CAPP began accepting applications by Polish homeowners in September 2018. The program is expected to spend a total of PLN 103 billion on grants, loans, and tax rebates through September 2029.[167] The primary targets are existing single-family residential buildings[168] and buildings planned or under development.[169] For existing homes, program funds may be used for: (*1) replacing old inefficient coal heating sources with modern heating boilers fueled by coal or biomass; (2) electric heating systems; (3) condensing gas boilers and heating pumps; (4) building thermo-modernization; and (5) utilization of renewable sources for electricity and heat generation (solar collectors and photovoltaic micro-installations)*.[170] Ultimately, this program is expected to assist Poland in meeting the EU clean air criterion which sets limits on particulates and various gases including carbon monoxide, sulfur dioxides, and nitrous oxides. It is anticipated that roughly three million Polish homes will be modernized under the program.

Results

As of December 2, 2022, 531,459 applications had been received by the CAPP for a total grant request of 9.9 billion PLN. In September of 2020 a non-technical evaluation of CAPP[171] revealed three areas of concern that imposed limits on CAPP's success. First, the application process was found to be cumbersome, with long processing times owing to inefficient administration. Applicants had an especially difficult time providing technical and cost details of the proposed work and its outcomes. Second, the income thresholds for applicants were found to be unrealistically low; relaxing this criterion could yield a higher participation rate. Finally, funding channels are confusing.

b. Energy Efficiency and Renewable Sources Fund (EERSF)—Bulgaria

In 2004, the Government of Bulgaria enacted the Energy Efficiency Act (EEA), which aimed to promote energy efficiency following the Government's policy on sustainable development and the country's low energy efficiency: Bulgaria's energy intensity was twice the average of EU countries by 2005.[172] The EEA mandated the National Energy Efficiency Action Plans to set energy savings and energy efficiency targets through 2020. The EEA also created the Energy Efficiency and Renewable Sources Fund (EERSF) to help achieve these targets.

Program Description

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[166] Anna Sakson-Boulet, "The Clean Air Priority Programme – Evaluation and Perspectives," *Środkowoeuropejskie Studia Polityczne*, March 15, 2020, 171–92, https://doi.org/10.14746/ssp.2020.1.9.
[167] Ibid.
[168] Cool Products, "Analysis of Existing Incentives in Europe for Heating Powered by Fossil Fuels and Renewable Sources," December, 2020, https://www.coolproducts.eu/policy/analysis-of-incentives-for-fossil-fuel-heating-across-the-eu/.
[169] International Trade Administration, "Poland Launches 'Clean Air' Program," accessed September 7, 2021, http://www.trade.gov/market-intelligence/poland-launches-clean-air-program.
[170] Ibid.
[171] Ibid.
[172] Institute for Industrial Productivity, "Energy Efficiency and Renewable Sources Fund — Fact Sheet," 2012, https://www.ase.org/sites/ase.org/files/iip-financefactsheet-4-eersf.pdf.

Initiated in 2004, the EERSF combines funding (loans), credit guarantees, and technical consulting to encourage investment in energy efficient technologies.[173] The main objectives of the fund are reducing greenhouse gases (GHGs) emissions and improving the country's energy intensity.[174] The EERSF was capitalized with USD 13.8 million[175] in grant financing to provide soft loans, credit guarantees for ESCOs, and technical assistance for rehabilitation and energy efficiency improvements in buildings of all sectors. Interest rates range from 3.5 to 7 percent for municipalities, companies and individuals.[176] Funding is principally from the Global Environment Facility (GEF) through the IBRD (USD 10 million), the Government of Austria (EUR 1.5 million), and the Government of Bulgaria (EUR 1.5 million).[177]

The EERSF website describes it as "*…an independent public legal entity, separate from any governmental agency or institution. It performs its activity in accordance with the EEA, Energy from Renewable Sources Act (ERSA), current legislation framework, and the agreements with the major donors*."[178] EERSF is designed to be self-sustaining as a public-private partnership (PPP) and is operated by a private fund manager. Its participants are primarily municipal and corporate buildings. Residential participants (both multifamily and single-family dwellings) are only a small percentage of the total client base. The breakdown of client types as of June 2018 is as follows:[179]

- *Municipalities: 52 percent of total portfolio. Types of projects: energy efficient reconstruction of public buildings such as schools, kindergartens, administrative buildings; reconstruction and improvement of street lighting*
- *Corporate clients: 36 percent of total portfolio. Types of projects: energy efficient reconstruction of industrial premises; replacement of equipment with new, more energy-efficient*
- *Others, including universities, hospitals, residential buildings: 12 percent of the total portfolio. Types of projects: energy efficient reconstruction of educational, hospital and residential premises.*

RESULTS

The Institute for Industrial Productivity (IIP), a non-profit organization concerned with reducing carbon emissions in China, India, the US, and the EU, found that the EERSF had provided 85 loans with a total loan value of USD 16 million and a total investment of USD 24 million by March 2010. In addition, it had helped secure 31 guarantee deals of about USD 2 million with a total investment of USD 15 million.[180] Energy savings over the lifetime of these loans and deals were 0.11 Mtoe, while GHG savings were estimated at 1 $MtCO_2e$.[181] The EERSF became a revolving fund with a ratio of operating income over operating cost of 133 percent.[182]

Moreover, the implementation of the EERSF drew two key lessons on the leverage impact of the program's different products. First, co-financing for small energy efficiency projects was not attractive to local banks. About USD 0.45 was leveraged from private financing sources for each dollar that the EERSF provided through is loan product. Second, the partial credit guarantee program had a greater leverage impact, attracting five dollars of private finance for each dollar from the EERSF.[183]

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[173] "About Us," Energy Efficiency and Renewable Sources Fund, accessed September 8, 2021, https://www.bgeef.com/en/about-us/.
[174] Ibid.
[175] Institute for Industrial Productivity, "Energy Efficiency and Renewable Sources Fund — Fact Sheet," 2012, https://www.ase.org/sites/ase.org/files/iip-financefactsheet-4-eersf.pdf.
[176] Cool Products, "Analysis of Existing Incentives in Europe for Heating Powered by Fossil Fuels and Renewable Sources," December, 2020, https://www.coolproducts.eu/wp-content/uploads/2020/12/Analysis-of-Fossil-Fuel-Incentives-in-Europe_FINAL_.pdf.
[177] "Donors," Energy Efficiency and Renewable Sources Fund, accessed September 8, 2021, https://www.bgeef.com/en/about-us/donors/.
[178] "History," Energy Efficiency and Renewable Sources Fund, accessed September 8, 2021, https://www.bgeef.com/en/about-us/history/.
[179] "Energy Efficiency and Renewable Sources Fund – Financial and Technical Partner for Energy Efficiency Improvement Projects," European Commission, accessed September 8, 2021, https://ec.europa.eu/energy/sites/ener/files/documents/017_3a_asen_charliyski_seif_sofia_28-06-18.pdf
[180] Institute for Industrial Productivity, "Energy Efficiency and Renewable Sources Fund — Fact Sheet," 2012, https://www.ase.org/sites/ase.org/files/iip-financefactsheet-4-eersf.pdf.
[181] Ibid.
[182] Ibid.
[183] Ibid.

c. Efficient Home Program—Romania

Like much of Southeast Europe, most homes in Romania lack sufficient insulation and are therefore not energy efficient. In urban areas of Romania, most residential buildings were built before 1980 with little regard for energy efficiency. In rural areas, where 46 percent of the Romanian population resides, single-family homes are constructed with poor quality adobe or timber frames and require four times the energy needed than a properly insulated home.[184]

Program Description

Starting in late 2020, the "Efficient Home Program" allows single-family dwellings to recover, via cash payments, up to 60 percent of costs associated with improvements in energy efficiency.[185] The program is run by the Environment Fund Administration (AFM), a department within the Ministry of the Environment, Waters and Forests of the Romanian Government. Improvements can include windows replacement, thermal insulation, installation of solar panels or other RE sources, installation of ventilation systems, LED lighting, motion sensors, and new valves and pipes. Funds are provided by the Romanian Government. To qualify, participants must arrange for energy audits of their dwelling before and after the improvement and then apply for reimbursement of part of the expenditures. If the investment results in energy savings, families can receive grants or refunds of up to EUR 15,000 each out of a total fund of EUR 88.5 million earmarked for the program.

Results

Information on the results of the program was not available at the time of writing—likely due to the short period since the launch of the program (late 2020). However, it is estimated that 9,000 families will eventually participate in the program.[186]

d. Out of Oil and Gas Campaign—Austria

As of 2016, fossil fuels were the main energy source for residential heating in Austria, with a share of 48 percent.[187] However, demand for coal and oil for residential heating was declining, while more sustainable sources of heating such as biogenic fuels, DH heat pumps, and solar thermal were gaining momentum.[188] The Austrian Government aims to phase out gas boilers by 2025 and oil heating by 2035.[189]

Program Description

The "Out of Oil and Gas Campaign" (the "Campaign") is just one of many Austrian Government programs meant to reduce greenhouse gas emissions. The Campaign provides grants to owners of single-family and multi-story homes for energy improvements. The program "…*promotes the replacement of fossil fuel-fired heating systems with sustainable heating systems through a one-off grant (which also covers planning costs with a maximum of 10 percent of all eligible costs). The interventions promoted are the connection to a district heating system or, where not possible, the transition to centralized wood heating or to a heat pump is financed.*"[190]

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[184] The World Bank, "Housing in Romania — Towards a National Housing Strategy," August, 2015, https://documents1.worldbank.org/curated/en/552171468585744221/pdf/106856-REVISED-WP-RomaniaHousingRASOutputFinalHousingAssessment-PUBLIC.pdf.

[185] "Romanians Who Want Energy-Efficient Homes Can Apply for EUR 15,000 Grants," Romania Insider, accessed September 9, 2021, http://www.romania-insider.com/grants-ro-energy-efficient-homes-sept-2020.

[186] "Romania to Grant up to EUR 15,000 per House for Energy Refurbishment," Balkan Green Energy News, accessed September 9, 2021, https://balkangreenenergynews.com/romania-to-grant-up-to-eur-15000-per-house-for-energy-refurbishment/.

[187] International Energy Agency, "Country Report: Austria — HPP Annex 43," December, 2016, https://nachhaltigwirtschaften.at/resources/iea_pdf/hpt-annex-43-country_report_austria-2016.pdf

[188] Ibid.

[189] Cool Products, "Analysis of the Existing Incentives in Europa for Heating Powered by Fossil Fuels and Renewables Sources," July, 2021, https://www.coolproducts.eu/wp-content/uploads/2021/07/coolproducts-heating-subsidies-report-web.pdf.

[190] Ibid.

Grants amount to up to EUR 5,000 for single-family dwellings, while multi-story buildings can receive up to EUR 10,000 plus EUR 1,500 per living unit. In both cases, the maximum grant cannot exceed 35 percent of the eligible costs.[191]

RESULTS

The Campaign appears to have been successful. In 2018, 7,678 applications were approved, resulting in CO_2 savings of 61,000 tonnes per year.[192] Moreover, the demand for the grants has increased in recent years, leading to an extension of the program in 2019. An additional EUR 20 million were added to the Campaign's original budget of EUR 42.6 million—a 47 percent increase.[193] Around 13,000 projects are expected to receive grants in 2019, which would result in CO_2 savings of approximately 96,000 tonnes per year. This is expected to bring about an annual energy savings of approximately 113 GWh.[194]

e. REDUCED VAT FOR ENERGY EFFICIENCY—FRANCE

Seventy percent of France's ENERGY demand is provided by nuclear power, but carbon emissions have remained high. To meet its commitment to the 2015 Paris Accord, the French Government passed a law that commits the country to achieving carbon neutrality by 2050. The law mandates a 40 percent reduction in the use of fossil fuels by 2030 and includes measures to accelerate the development of low-carbon energies and renewable hydrogen. The housing sector will play a key role in meeting these requirements. As of 2019, the French housing sector was responsible for approximately 45 percent of the country's energy use and a quarter of its GHG emissions.[195]

PROGRAM DESCRIPTION

France offers a lower VAT for purchasers of energy-efficient investments. Known as the "Law on Reduced VAT for Residential Renewable Energy Equipment", this policy aims to encourage the use of RE in the residential heating sector by reducing the costs of its required equipment. The reduced VAT rate for these commodities is 5.5 percent (the standard VAT rate in France is 20 percent).[196]

RESULTS

France's GHG emissions have declined since 2000,[197] but the role of the Law on Reduced VAT for Residential Renewable Energy Equipment on this reduction is questionable. Several studies suggest that VAT policy is not an effective way to combat climate change.[198] Stakeholders are not obligated to pass on a rate reduction to their final customers and the rate difference may not be large enough to affect consumption decisions. While VAT reduction proposals targeting energy efficiency are frequently introduced in the French parliament, many do not comply with EU tax policy. Although the effects on purchase of such central heating boilers, refrigerators, freezers, and washing

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[191] Ibid.
[192] Replace, "Policy Framework Conditions Assessment and Outlook for Sustainable Heating and Cooling in Selected European Regions", February, 2020, http://replace-project.eu/wp-content/uploads/2020/05/D2.1_Policy-Framework-Conditions-Assessment-and-Outlook-for-RHC.pdf.
[193] Ibid.
[194] Ibid.
[195] "France Sets 2050 Carbon-Neutral Target with New Law," *Reuters*, June 27, 2019, sec. Environment, https://www.reuters.com/article/us-france-energy-idUSKCN1TS30B.
[196] Cool Products, "Analysis of the Existing Incentives in Europa for Heating Powered by Fossil Fuels and Renewables Sources," July, 2021, https://www.coolproducts.eu/wp-content/uploads/2021/07/coolproducts-heating-subsidies-report-web.pdf.
[197] "France Greenhouse Gas Emissions Decreased by 16.9% From 1990 Levels," Climate Scorecard, accessed September 9, 2021, https://www.climatescorecard.org/2020/12/france-greenhouse-gas-emissions-decreased-by-16-9-from-1990-levels/.
[198] See OECD (2018), Consumption Tax Trends 2018: VAT/GST and Excise Rates, Trends and Policy Issues, Consumption Tax Trends, OECD Publishing, Paris; European Commission (DG Environment, 2018), Final Report, The use of differential VAT rates to promote changes in consumption and innovation, Institute for Environmental Studies, Amsterdam; Copenhagen Economics (2008), Final Report, Reduced VAT for Environmentally Friendly Products, Copenhagen, Copenhagen Economics (2007), Final Report, Study on reduced VAT applied to goods and services in the Member States of the European Union, Copenhagen.

machines is positive, the possibility of higher administrative and compliance costs, along with reduced tax revenue and increased incentives for tax evasion, could also lead to welfare-reducing economic distortions.[199]

f. Programs from the Massachusetts Clean Energy Center—United States

The Massachusetts Clean Energy Center (MassCEC) was established in 2009 as a quasi-public agency. The mission of MassCEC is to accelerate the adoption of clean energy across the Commonwealth of Massachusetts, with particular attention to lower income households, while simultaneously contributing to economic development.

Program Description

MassCEC offers several programs, including tax rebates, loans, grants, and other financing such as aggregating buying power amongst households, to encourage the residential sector to invest in energy-efficient technologies. Specifically, MassCEC promotes efficient wood stove technology, solar heating and cooling, weatherization, air- and ground-source heat pumps, and others. It also seeks to develop "community micro-grids" to tilt buying power in favor of households. MassCEC's programs are funded by electric bill surcharges and the State's Renewable Energy Trust Fund.[200] Some of MassCEC's current and past residential programs are presented below:[201]

- **Clean Heating and Cooling**—This program offered rebates to promote the installation of renewable heating, hot water, and cooling technologies. MassCEC invested USD 48 million through this program. Funding for this program is no longer available.
- **HeatSmart**—This program supports the adoption of small-scale clean heating and cooling technologies in participating communities. This program helps create a competitive solicitation process by aggregating homeowner buying power to lower installation prices for participants.
- **Solarize Massachusetts**—This program aims to increase the uptake of small-scale solar electricity through aggregated solicitation processes, as described above for the HeatSmart program.
- **Woodstove Replacement**—This program provides homeowners who install efficient woodstoves (with a thermal efficiency of at least 75 percent per the higher heating value) with federal tax credits ranging from 22 to 26 percent.

Results

The programs implemented by MassCEC have been successful. In 2020, the American Council for an Energy-Efficient Economy (ACEEE) ranked Massachusetts as the second most energy-efficient state in the United States.[202] The following are some of the results by program:

- **HeatSmart**—Since 2018, the program has reached 15 communities across Massachusetts enabling 462 contracts in air- and ground-source heat pumps, automated wood heating, and solar how water.[203]
- **Solarize Massachusetts**—Since 2011, the program has reached 85 communities and secured 3,759 contracts in small scale solar electric systems. The contracted capacity installed amounts to 25,661 kW.[204]

g. New Czech Green Savings Program—Czech Republic

[199] "INSIGHT: Using VAT as a Tool to Fight Climate Change?," Bloomberg Tax, accessed September 9, 2021, https://news.bloombergtax.com/daily-tax-report-international/insight-using-vat-as-a-tool-to-fight-climate-change.
[200] "About MassCEC," MassCEC, accessed September 9, 2021, https://www.masscec.com/about-masscec.
[201] "Residential," MassCEC, accessed September 9, 2021, https://www.masscec.com/get-clean-energy/www.masscec.com.
[202] "The State Energy Efficiency Scorecard," American Council for an Energy-Efficient Economy, accessed September 9, 2021, https://www.aceee.org/state-policy/scorecard.
[203] "HeatSmart Massachusetts Program Results," MassCEC, accessed September 9, 2021, https://www.masscec.com/heatsmart-massachusetts-program-results.
[204] "Solarize Mass Program Results," MassCEC, accessed September 9, 2021, https://www.masscec.com/solarize-mass-program-results.

Although the Czech Republic's CO_2 emissions decreased substantially from 1990 to 2000, in the early 2000s they plateaued, hovering at around 12 metric tons per capita between 2000 and 2007.[205] By 2008, the country's CO_2 emissions per capita were 56 percent higher than the EU's average, with most of the country's GHGs emitted by the electricity and heating sectors.[206] Against this backdrop and aiming to reduce GHG emissions, the Government of the Czech Republic launched the Green Savings Program, which was operational between 2009 and 2011. The New Green Savings Program, launched in 2013, is an updated version of the original Green Savings Program.

Program Description

With the objective of reducing GHG emissions, especially CO_2, the New Green Savings Program awards grants to eligible participants who undertake investments in household energy efficiency. In general, it *"…supports the reduction of the energy intensity of residential buildings (complex or partial thermal insulation), construction of houses with very low energy intensity, environmentally friendly and efficient use of energy sources and renewable sources of energy*."[207] Eligible participants are owners or builders of single-family homes and apartment buildings, including individuals and legal entities. The maximum grant varies according to the technology adopted. The New Green Savings Program supports the following technologies:

- Thermal insulation of single-family homes and apartment buildings
- Construction of passive single-family homes and apartment buildings
- Solar thermal and PV systems
- Green roofs
- Heat from wastewater
- Controlled ventilation systems with heat recovery
- Replacement of heat sources for heat pumps and biomass boilers.

The program is funded with revenues from the sale of EUA (European Union Allowance) and EUAA (European Union Aviation Allowance) units. The original Green Savings Program (2009–2011) was financed by revenues from the sale of tradable units under the Kyoto Protocol.

Results

The original Green Savings Program awarded grants to 73,000 projects and achieved emission reductions of approximately 710 $KtCO_2$ per year—60 percent of reductions are accounted for by energy savings and 40 percent by the use of RE sources.[208] From 2015 to 2021, the New Green Savings Program will have disbursed grants for a total of CZK 27 billion (EUR 1 billion).[209]

h. Eco Fund—Slovenia

The government of Slovenia passed an Environmental Protection Act in 1993 to detail the responsibilities of environmental protection required of the State and Local Public Services. The Act established the Environmental Development Fund, later called the Environmental Public Fund, and now commonly known as the Eco Fund to promote investment in environmental activities.

Program Description

[205] "CO2 Emissions (Metric Tons per Capita) - Czech Republic," The World Bank, accessed September 9, 2021, https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?locations=CZ.

[206] Ibid.

[207] "New Green Savings Programme," State Environmental Fund of the Czech Republic, accessed September 9, 2021, https://www.sfzp.cz/en/administered-programmes/new-green-savings-programme/.

[208] "Green Savings and New Green Savings – Governmental Subsidy Schemes," *INHERIT*, accessed September 9, https://www.inherit.eu/green-savings-and-new-green-savings/.

[209] "New Green Savings Programme – Policies," IEA, accessed September 9, 2021, https://www.iea.org/policies/12478-new-green-savings-programme.

Since 1995, Slovenia has been providing grants and soft loans through the state-owned Eco Fund to encourage the implementation of several environmental investment projects, including sustainable heating systems in the public and private sectors. Heating technologies supported by the Eco Fund include heat pumps, biomass and condensing gas boilers, micro cogeneration, and DH.[210] Households (including single-family dwellings), companies, and municipalities are eligible. The Eco Fund's main functions are:[211]

- Issuing soft loans with favorable interest rates
- Issuing non-repayable subsidies (grants)
- Financing and coordination of Energy Advisory Network (ENSVET)
- Financing of awareness-raising activities in the field of environmental protection.

The Eco Fund's approach is holistic. Financing, technical assistance and public outreach each play a role in the overall effort.

RESULTS

The Eco Fund reports that, "*from 1995–2015 there was a total of 56 published public calls for households which resulted in 17,300 granted loans in the amount of over 451 million EUR and 78,400 granted non-repayable subsidies in the amount of over 141 million EUR.*"[212]

[210] Cool Products, "Analysis of the Existing Incentives in Europa for Heating Powered by Fossil Fuels and Renewables Sources," July, 2021, https://www.coolproducts.eu/wp-content/uploads/2021/07/coolproducts-heating-subsidies-report-web.pdf.
[211] "Eco Fund, Slovenian Environmental Public Fund," Interreg Europe, accessed September 9, 2021, https://www.interregeurope.eu/policylearning/good-practices/item/3365/joint-developement-of-wind-farm-projects/.
[212] Ibid.

Annex M: Investment Costs per Scenario (Disaggregated)

- Table M.1: Scenario 1 Investments Costs

Countries	Retrofit Costs (90€ / m2)	Residential Buildings				Commercial and Public Buildings				Total Investment Cost per country - Only Heating Systems	Total Investment Cost per country (Heating Technologies + Envelope) in billions
		Individual Heating Unsustainable Heating Peak Demand (kW)	Individual Heating Investment Cost (€)	DH Unsustainable Heating Peak Demand (kW)	DH Investment Cost (€)	Individual Heating Unsustainable Heating Peak Demand (kW)	Individual Heating Investment Cost (€)	DH Unsustainable Heating Peak Demand (kW)	DH Investment Cost (€)		
Albania	$7,110,000,000	773,400	$405,461,285	0	$0	548,535	$291,464,909	0	$0	$696,926,194	$8
Armenia	$10,552,596,032	2,360,908	$1,217,557,026	1,671	$2,445,216	220,556	$117,054,907	0	$0	$1,337,057,149	$12
Azerbaijan	$15,057,532,469	7,028,503	$3,645,368,198	189,479	$277,216,984	2,137,754	$1,128,496,370	60,499	$88,512,964	$5,139,594,515	$20
Belarus	$27,919,291,228	6,878,720	$3,582,333,902	4,845,348	$7,088,984,419	1,902,741	$1,001,363,954	3,431,182	$5,019,989,912	$16,692,672,187	$45
Bosnia and Herzegovina	$16,384,531,410	5,358,627	$2,714,184,163	253,721	$371,206,383	884,302	$463,274,256	74,257	$108,641,449	$3,657,306,252	$20
Bulgaria	$31,098,413,970	4,725,167	$2,413,372,485	521,101	$762,396,565	1,652,813	$864,983,383	303,519	$444,063,503	$4,484,815,936	$36
Croatia	$18,397,640,970	5,765,043	$2,942,564,921	255,436	$373,714,857	1,327,853	$702,794,570	134,220	$196,370,570	$4,215,444,917	$23
Georgia	$11,519,822,589	2,636,862	$1,371,581,703	0	$0	854,271	$451,345,019	0	$0	$1,822,926,722	$13
Kazakhstan	$44,580,406,147	52,244,883	$28,063,519,363	10,068,590	$14,730,846,716	11,003,752	$5,896,472,500	7,741,610	$11,326,358,947	$60,017,197,525	$105
Kosovo	$5,922,037,080	1,701,274	$868,824,103	42,964	$62,858,318	431,214	$229,862,348	13,444	$19,669,463	$1,181,214,233	$7
Kyrgyzstan	$11,109,519,641	4,815,660	$2,576,190,195	432,005	$632,045,437	838,992	$449,690,600	315,373	$461,405,999	$4,119,332,231	$15
Moldova	$9,063,074,340	3,085,137	$1,571,160,766	246,200	$360,203,327	470,938	$248,865,867	98,288	$143,800,738	$2,324,030,698	$11
Montenegro	$2,238,591,690	672,633	$342,419,180	0	$0	189,820	$100,269,547	0	$0	$442,688,726	$3
North Macedonia	$8,545,792,910	1,359,686	$698,140,424	94,594	$138,395,718	460,241	$245,722,428	28,683	$41,964,398	$1,124,222,968	$10
Poland	$128,344,500,000	44,137,031	$23,369,616,478	6,316,703	$9,241,650,489	13,270,667	$7,036,269,000	2,735,906	$4,002,766,471	$43,650,302,438	$172
Romania	$48,925,800,000	16,240,056	$8,291,923,506	1,834,278	$2,683,640,150	3,693,111	$1,947,898,608	381,853	$558,669,394	$13,482,131,658	$62
Russian Federation	$413,730,000,000	149,625,526	$77,579,825,170	189,667,527	$277,493,004,984	51,900,083	$27,439,906,407	58,558,474	$85,673,954,122	$468,186,690,683	$882
Serbia	$24,189,896,857	8,322,902	$4,276,535,324	1,098,691	$1,607,440,091	1,506,903	$798,723,631	283,915	$415,381,119	$7,098,080,166	$31
Tajikistan	$10,594,713,670	3,168,769	$1,666,736,031	15,503	$22,681,343	376,211	$199,327,657	0	$0	$1,888,745,030	$12
Türkiye	$261,000,000,000	40,214,765	$21,212,224,979	0	$0	34,479,380	$18,409,075,840	0	$0	$39,621,300,819	$301
Turkmenistan	$12,075,789,968	1,583,660	$847,288,431	0	$0	16,101,787	$8,511,340,766	0	$0	$9,358,629,196	$21
Ukraine	$112,739,597,366	25,861,857	$13,448,334,888	3,836,581	$5,613,107,844	8,263,383	$4,394,398,116	4,612,383	$6,748,145,299	$30,203,986,147	$143
Uzbekistan	$79,283,950,470	36,824,160	$19,500,259,495	1,680,334	$2,458,412,716	7,968,901	$4,221,511,289	3,715,478	$5,435,928,564	$31,616,112,063	$111
ECA Retrofit Cost	$ 1,310,383,498,806								**ECA Investment Cost**	$752,361,408,455	$2,063

Source: Authors.

- Table M.2: Scenario 2 Investment Costs

Countries	Retrofit Costs (120€ / m2)	Residential Buildings				Commercial and Public Buildings				Total Investment Cost per country - Only Heating Systems	Total Investment Cost per country (Heating Technologies + Envelope) in billions
		Individual Heating Unsustainable Heating Peak Demand (kW)	Individual Heating Investment Cost (€)	DH Unsustainable Heating Peak Demand (kW)	DH Investment Cost (€)	Individual Heating Unsustainable Heating Peak Demand (kW)	Individual Heating Investment Cost (€)	DH Unsustainable Heating Peak Demand (kW)	DH Investment Cost (€)		
Albania	$9,480,000,000	580,050	$304,095,964	0	$0	411,401	$218,598,681	0	$-	$522,694,645	$10
Armenia	$14,070,128,043	1,770,681	$913,167,769	1,253	$1,833,912	165,417	$87,791,180	0	$-	$1,002,792,862	$15
Azerbaijan	$20,076,709,958	5,271,377	$2,734,026,148	142,109	$207,912,738	1,603,316	$846,372,278	45,374	$66,384,722.85	$3,854,695,886	$24
Belarus	$37,225,721,637	5,159,040	$2,686,750,427	3,634,011	$5,316,738,314	1,427,056	$751,022,966	2,573,387	$3,764,992,433.79	$12,519,504,141	$50
Bosnia and Herzegovina	$21,846,041,880	4,018,970	$2,035,638,123	190,291	$278,404,787	663,226	$347,455,692	55,693	$81,481,087.11	$2,742,979,689	$25
Bulgaria	$41,464,551,960	3,543,875	$1,810,029,364	390,826	$571,797,424	1,239,610	$648,737,537	227,639	$333,047,627.62	$3,363,611,952	$45
Croatia	$24,530,187,960	4,323,783	$2,206,923,691	191,577	$280,286,142	995,890	$527,095,927	100,665	$147,277,927.26	$3,161,583,688	$28
Georgia	$15,359,763,452	1,977,647	$1,028,686,277	0	$0	640,703	$338,508,765	0	$-	$1,367,195,042	$17
Kazakhstan	$59,440,541,530	39,183,662	$21,047,639,522	7,551,442	$11,048,135,037	8,252,814	$4,422,354,375	5,806,207	$8,494,769,210.06	$45,012,898,144	$104
Kosovo	$7,896,049,440	1,275,956	$651,618,077	32,223	$47,143,738	323,411	$172,396,761	10,083	$14,752,097.56	$885,910,675	$9
Kyrgyzstan	$14,812,692,854	3,611,745	$1,932,142,646	324,004	$474,034,078	629,244	$337,267,950	236,530	$346,054,499.15	$3,089,499,173	$18
Moldova	$12,084,099,120	2,313,853	$1,178,370,574	184,650	$270,152,495	353,203	$186,649,400	73,716	$107,850,553.74	$1,743,023,023	$14
Montenegro	$2,984,788,920	504,474	$256,814,385	0	$0	142,365	$75,202,160	0	$-	$332,016,545	$3
North Macedonia	$11,394,390,547	1,019,765	$523,605,318	70,946	$103,796,788	345,181	$184,291,821	21,512	$31,473,298.46	$843,167,226	$12
Poland	$171,126,000,000	33,102,773	$17,527,212,359	4,737,528	$6,931,237,867	9,953,000	$5,277,201,750	2,051,930	$3,002,074,853.26	$32,737,726,829	$204
Romania	$65,234,400,000	12,180,042	$6,218,942,629	1,375,709	$2,012,730,112	2,769,834	$1,460,923,956	286,389	$419,002,045.55	$10,111,598,743	$75
Russian Federation	$551,640,000,000	112,219,145	$58,184,868,878	142,250,646	$208,119,753,738	38,925,062	$20,579,929,805	43,918,856	$64,255,465,591.43	$351,140,018,012	$903
Serbia	$32,253,195,809	6,242,177	$3,207,401,493	824,019	$1,205,580,069	1,130,178	$599,042,723	212,936	$311,535,839.53	$5,323,560,125	$38
Tajikistan	$14,126,284,893	2,376,577	$1,250,052,023	11,627	$17,011,007	282,158	$149,495,743	0	$-	$1,416,558,773	$16
Türkiye	$348,000,000,000	30,161,074	$15,909,168,734	0	$0	25,859,535	$13,806,806,880	0	$-	$29,715,975,614	$378
Turkmenistan	$16,101,053,290	1,187,745	$635,466,323	0	$0	12,076,340	$6,383,505,574	0	$-	$7,018,971,897	$23
Ukraine	$150,319,463,155	19,396,393	$10,086,251,166	2,877,435	$4,209,830,883	6,197,537	$3,295,798,587	3,459,287	$5,061,108,974.33	$22,652,989,610	$173
Uzbekistan	$105,711,933,960	27,618,120	$14,625,194,621	1,260,251	$1,843,809,537	5,976,676	$3,166,133,467	2,786,608	$4,076,946,422.65	$23,712,084,047	$129
ECA Retrofit Cost	$ 1,747,177,998,408								**ECA Investment Cost**	$564,271,056,341	$2,311

Source: Authors.

- Table M.3: Scenario 3 Investment Costs

Countries	Retrofit Costs (150€ / m2)	Residential Buildings				Commercial and Public Buildings				Total Investment Cost per country - Only Heating Systems	Total Investment Cost per country (Heating Technologies + Envelope)
		Individual Heating Unsustainable Heating Peak Demand (kW)	Individual Heating Investment Cost (€)	DH Unsustainable Heating Peak Demand (kW)	DH Investment Cost (€)	Individual Heating Unsustainable Heating Peak Demand (kW)	Individual Heating Investment Cost (€)	DH Unsustainable Heating Peak Demand (kW)	DH Investment Cost (€)		
Albania	$11,850,000,000	386,700	$202,730,643	0	$0	274,267	$145,732,454	0	$0	$348,463,097	$12
Armenia	$17,587,660,054	1,180,454	$608,778,513	836	$1,222,608	110,278	$58,527,454	0	$0	$668,528,575	$18
Azerbaijan	$25,095,887,448	3,514,251	$1,822,684,099	94,739	$138,608,492	1,068,877	$564,248,185	30,249	$44,256,482	$2,569,797,258	$28
Belarus	$46,532,152,047	3,439,360	$1,791,166,951	2,422,674	$3,544,492,210	951,370	$500,681,977	1,715,591	$2,509,994,956	$8,346,336,094	$55
Bosnia and Herzegovina	$27,307,552,350	2,679,313	$1,357,092,082	126,860	$185,603,191	442,151	$231,637,128	37,128	$54,320,725	$1,828,653,126	$29
Bulgaria	$51,830,689,950	2,362,583	$1,206,686,242	260,550	$381,198,283	826,407	$432,491,692	151,760	$222,031,752	$2,242,407,968	$54
Croatia	$30,662,734,950	2,882,522	$1,471,282,461	127,718	$186,857,428	663,927	$351,397,285	67,110	$98,185,285	$2,107,722,459	$33
Georgia	$19,199,704,314	1,318,431	$685,790,851	0	$0	427,136	$225,672,510	0	$0	$911,463,361	$20
Kazakhstan	$74,300,676,912	26,122,441	$14,031,759,681	5,034,295	$7,365,423,358	5,501,876	$2,948,236,250	3,870,805	$5,663,179,473	$30,008,598,763	$104
Kosovo	$9,870,061,800	850,637	$434,412,052	21,482	$31,429,159	215,607	$114,931,174	6,722	$9,834,732	$590,607,116	$10
Kyrgyzstan	$18,515,866,068	2,407,830	$1,288,095,098	216,003	$316,022,718	419,496	$224,845,300	157,686	$230,702,999	$2,059,666,115	$21
Moldova	$15,105,123,900	1,542,568	$785,580,383	123,100	$180,101,663	235,469	$124,432,933	49,144	$71,900,369	$1,162,015,349	$16
Montenegro	$3,730,986,150	336,316	$171,209,590	0	$0	94,910	$50,134,773	0	$0	$221,344,363	$4
North Macedonia	$14,242,988,183	679,843	$349,070,212	47,297	$69,197,859	230,121	$122,861,214	14,341	$20,982,199	$562,111,484	$15
Poland	$213,907,500,000	22,068,515	$11,684,808,239	3,158,352	$4,620,825,244	6,635,333	$3,518,134,500	1,367,953	$2,001,383,236	$21,825,151,219	$236
Romania	$81,543,000,000	8,120,028	$4,145,961,753	917,139	$1,341,820,075	1,846,556	$973,949,304	190,926	$279,334,697	$6,741,065,829	$88
Russian Federation	$689,550,000,000	74,812,763	$38,789,912,585	94,833,764	$138,746,502,492	25,950,042	$13,719,953,203	29,279,237	$42,836,977,061	$234,093,345,342	$924
Serbia	$40,316,494,762	4,161,451	$2,138,267,662	549,346	$803,720,046	753,452	$399,361,816	141,957	$207,690,560	$3,549,040,083	$44
Tajikistan	$17,657,856,116	1,584,385	$833,368,016	7,751	$11,340,671	188,105	$99,663,828	0	$0	$944,372,515	$19
Türkiye	$435,000,000,000	20,107,382	$10,606,112,489	0	$0	17,239,690	$9,204,537,920	0	$0	$19,810,650,409	$455
Turkmenistan	$20,126,316,613	791,830	$423,644,215	0	$0	8,050,893	$4,255,670,383	0	$0	$4,679,314,598	$25
Ukraine	$187,899,328,944	12,930,928	$6,724,167,444	1,918,290	$2,806,553,922	4,131,692	$2,197,199,058	2,306,192	$3,374,072,650	$15,101,993,074	$203
Uzbekistan	$132,139,917,450	18,412,080	$9,750,129,747	840,167	$1,229,206,358	3,984,450	$2,110,755,645	1,857,739	$2,717,964,282	$15,808,056,032	$148
ECA Retrofit Cost	$ 2,183,972,498,010								**ECA Investment Cost**	$376,180,704,227	$2,560

Source: Authors.