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DEVELOPMENT OF HEATING AND COOLING SYSTEMS IN LATVIA

VPP-EM-EE-2018/1-0002

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DEVELOPMENT OF HEAT SUPPLY AND COOLING SYSTEMS IN LATVIA
LATVIJAS SILTUMAPGĀDES UN DZESĒŠANAS SISTĒMU ATTĪSTĪBA

ENERGY

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Introduction

Heating is currently supplied to consumers in Latvia via district heating systems, local heating and individual heating. The heating and cooling components of Latvia's energy sector should be viewed as a system comprised of three main elements – a source, networks and a consumer. The way this system operates and whether it works efficiently depends on the energy efficiency (EE) of the system's elements. A low level of EE poses risks both to energy security and resource sustainability and competitiveness. Raising the level of EE within the system as a whole or within individual elements of the system will contribute to the growth of the energy sector while fostering economic growth.
heating and cooling systems, (2) demand for heating and cooling, (3) objectives, strategies and policies, (4) analysis of the economic potential for efficiency in heating and cooling and (5) potential new strategies and policy measures, (6) recommendations.

The first part of the deliverable represents an overview of the heating and cooling systems in Latvia. The report is based on data available from the Central Statistical Bureau (CSB) for assessing the current situation with regard to heating in Latvia. This chapter uses CSB statistical data and provides a data analysis.

Chapter 2 provides an analysis of heating and cooling demand determined by the estimated useful energy and quantified in terms of final energy consumption by sectors. The data used were mainly those from the CSB, along with the project stakeholder assumptions necessary to assess the current situation. This chapter was drawn up on the basis of a request for data on heat produced and heat supplied to subscribers within the administrative territory of Latvia. The CSB of the Republic of Latvia compiled data on the heat balance in the cities and municipalities of Latvia in compliance with confidentiality provisions. Mathematical calculations and regression analysis were used to complete the task and achieve the set goal. To assess the potential of the technologies used, a multi-criteria analysis was employed, with the criterion weights for TOPSIS analysis determined through the analytical hierarchy process (AHP). Data from implemented EU-funded projects was analysed to determine what share the technologies and resources employed accounted for in the industrial and household sectors. To obtain an overall visual overview of the current situation and assess future potential, mapping was carried out using data (statistical data, assumptions, projects data and mathematical calculations) from the research performed.

Chapter 3 provides an overview of the role of efficient heating and cooling systems in the long-term reduction of GHG emissions and an overview of current policies. This chapter is based on an analysis of current laws, regulations, policies and strategies.

Chapter 4 contains a comprehensive methodology developed for the economic analysis of the potential to increase the efficiency of the heating and cooling system, and it may be applied for the assessment of different technological alternatives. The methodology's output module is based on raw data from documentation analysis, statistical data and assumptions. Regression analysis is used to obtain results for data processing, and assumptions are based on engineering calculations. In turn, the demand forecast is based on system dynamic modelling.

Chapter 5 of the first project development module is based on a review and analysis of potentially new strategies and policy measures, while using multi-criteria analysis for policies prioritisation.

The final chapter provides recommendations related to the research carried out.

DETERMINATION OF HEATING AND COOLING EFFICIENCY POTENTIAL IN LATVIA UNDER DIRECTIVE 2012/27EU ON ENERGY EFFICIENCY

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ABBREVIATIONS

4GHS – 4th Generation Heating System

RES – Renewable Energy Sources

AHP – Analytical Hierarchy Process

DCS – District Cooling System

CFCA – Central Finance and Contracting Agency

COP – Coefficient of Performance

DH – District Heating

CSB – Central Statistical Bureau

NRT – Natural Resources Tax

EE – Energy Efficiency

EED – Energy Efficiency Directive

EEF – Energy Efficiency Fund

EU – European Union

ETS – Emissions Trading Scheme

LCSE – Levelised Cost of Saved Energy

LH – Local Heating

LEGMC – Environment, Geology and Meteorology Centre of Latvia

NDP – National Development Plan

non-ETS – Emissions Trading Scheme Excluded Activities

NECP – National Energy and Climate Plan

NRERIS – National Real Estate Register Information System

MP – Mandatory Procurement

MPC – Mandatory Procurement Component

LCD – Low Carbon Development

R&D – Research and Development

GHG – Greenhouse gases

ESETP – European Strategic Energy Technology Plan

GC RES – Green certificates for sale of a specific amount of electric power produced from RES

1. HEATING AND COOLING SYSTEMS OVERVIEW

The overview of the current heating and cooling systems is based on the methodology whose algorithm is presented in Figure 1.

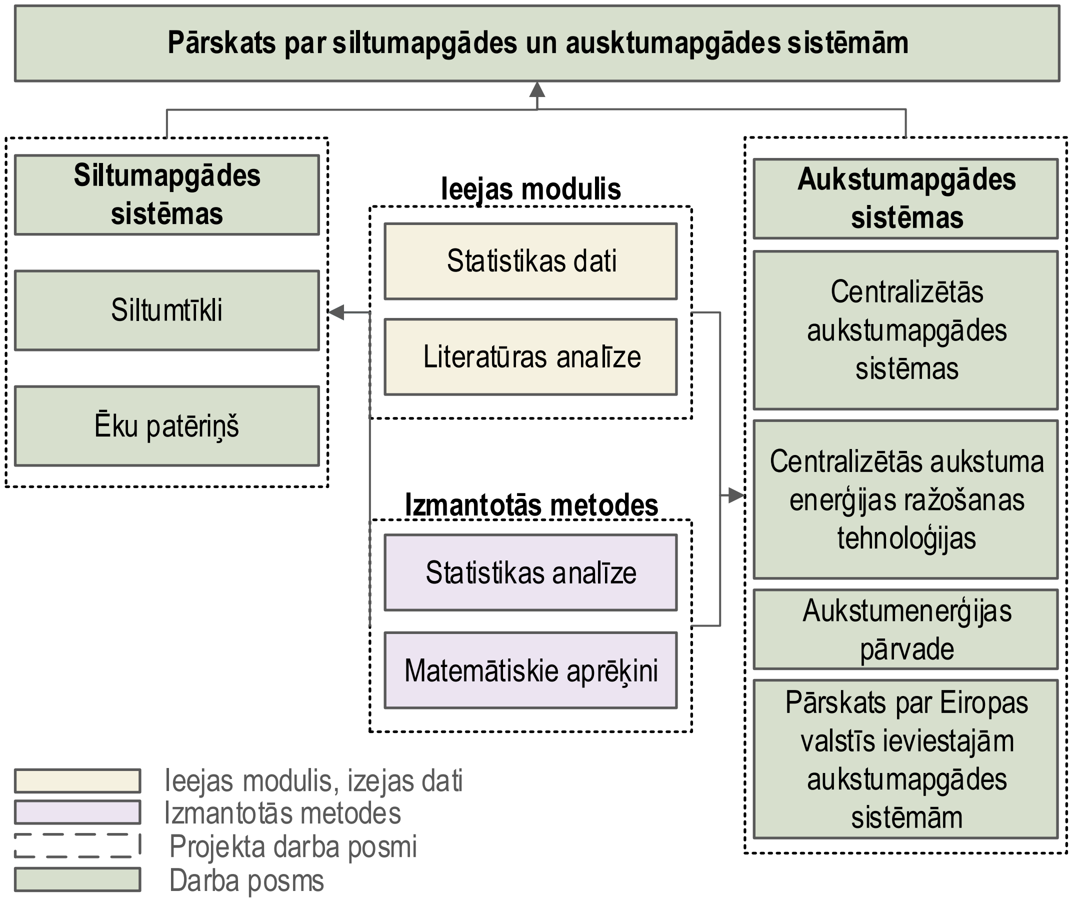


Figure 1. Algorithm for assessment of the current situation [*for translation, see (1) in accompanying document*]

The overview of heating and cooling systems includes an analysis of heating and cooling systems. CSB and scientific publications data were used to compile the overview. The heating systems overview includes an analysis of data on existing boiler houses and CHP plants, the energy resources used and the amount of heat produced. The components characterising the heating system are heating networks and heat consumption in buildings; hence, these chapters provide an overview of the importance of heating networks and building heat consumption and their interrelations. The overview of cooling systems includes an analysis of district cooling energy generation technologies and cooling energy transmission, providing examples of cooling systems implemented in European countries.

1.1. Heating systems

Heating is supplied to consumers in Latvia via district heating (DH) systems, as well as local and individual heating. In Latvia, heat is produced by boiler houses and CHP plants, along with electricity. The distribution of heat produced by boiler houses and CHP plants has changed significantly over the past 10 years. In 2008, 48 CHP plants produced 51 % (3.99 GWh), and 682 boiler houses produced 49 % (3.86 GWh), of the total heat produced, while in 2018 the share of heat produced by 175 CHP plants rose by 20 %, reaching 71 % or 5.89 GWh (see Figure 1.1).

Figure 1.1. Changes in the breakdown of heat production over a 10-year period [Data from the Central Statistical Bureau]

Katlu mājas - Boiler houses; Koģenerācijas stacijas - CHP plants

According to an analysis of the heat produced in 2018 by type of production technology (see Figure 1.2), most of the heat was produced by general-use CHP plants (70 % or 5 754 GWh); moreover, there has been a tendency towards the growth of heat produced by CHP plants in recent years. Approximately 24 % or 1 994 GWh of the total heat was produced by general purpose boiler houses. 2 % or 138 GWh of the total heat was produced by company-owned CHP plants and about 4 % (360 GWh) was produced by boiler houses.

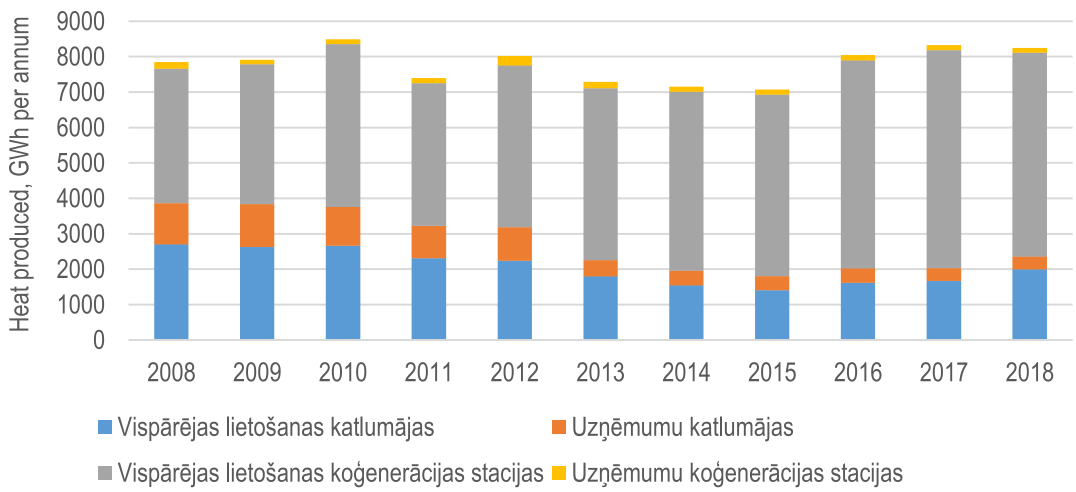


Figure 1.2. Heat produced by type of generation technology [Data from the Central Statistical Bureau]

Vispārējās lietošanas katlumājas - Public use boiler houses; Vispārējās lietošanas koģenerācijas stacijas - Public use CHP plants; Uzņēmumu kaltumājas - Company-owned boiler houses; Uzņēmumu koģenerācijas stacijas - Company-owned CHP plants

In 2018, there were 175 CHP plants operating in Latvia. 71 of them used natural gas as the primary fuel. Other CHP plants used biogas (54 plants), fuel chips (47 plants), wood pellets (1 plant), coal (1 plant) and a combination of fuel chips and peat (1 plant).

An analysis of the CHP plants by the installed electric output and the amount of heat produced shows that four CHP plants with an installed electric output exceeding 20 MW account for 83 % of the total installed electric output and produce the largest portion (47 % or 2 776 GWh) of heat. All of these CHP plants use natural gas as the primary fuel. Since 2019, a reconstruction project has been implemented at the CHP plant Siltumcentrāle Imanta, a replacement of natural gas CHP units with 48 MW biomass water heater and flue gas economizer. The project is co-financed by European Union funds.

Alternatively, in an analysis of the number of CHP plants by the installed electric output, for the majority of them, i.e. 66 CHP plants, this ranges from 0.5 MW to 1 MW (see Figure 1.3).

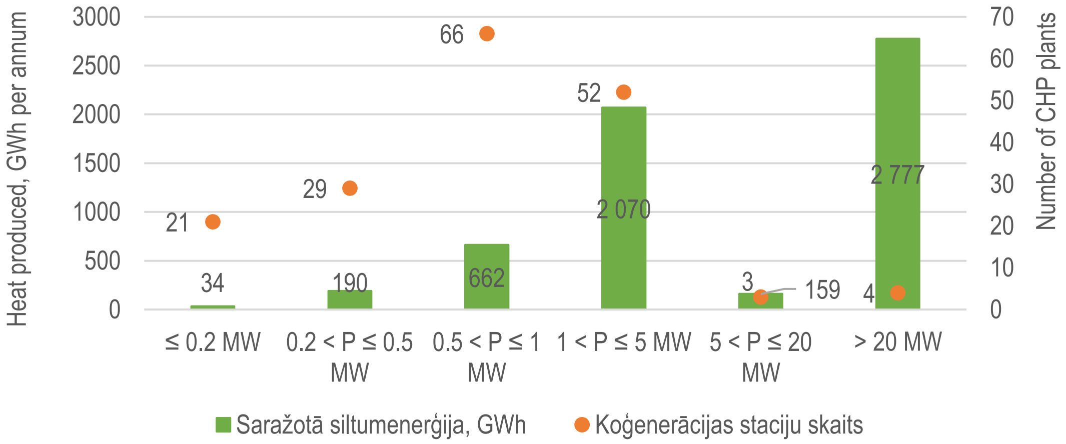


Figure 1.3. Breakdown of CHP plants by installed electric output and heat produced in 2017 [Data from the Central Statistical Bureau]

Saražotā siltumenerģija - Heat produced; Koģenerācijas staciju skaits - Number of CHP plants

The increasing number of CHP plants (see Figure 1.4) comes with two significant jumps in the installed electric output in 2008/2009 and 2012/2013. Over the 10-year period considered (2008-2018), the installed electric output of CHP plants has increased from 587 MW (2008) to 1 269 MW (2018), thus the installed electric output has increased by 54 %. In turn, the electricity produced by stations in the period from 2008 (2 103 GWh) to 2018 (4 170 GWh) has increased by 49 %, but the heat produced increased by 32 %, as it was 3 990 GWh in 2008 and 5 892 GWh in 2018. It can therefore be concluded that the installed output of CHP plants is not fully used.

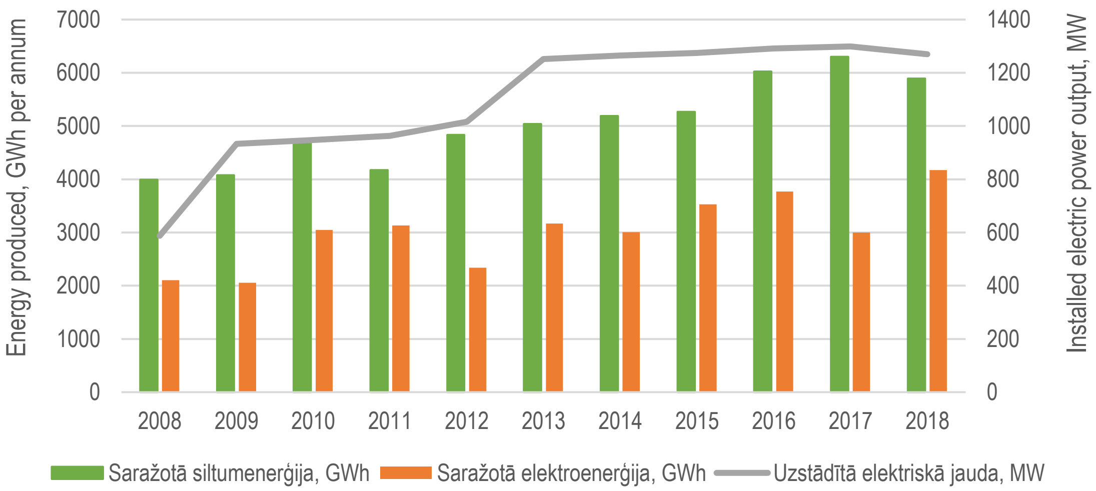


Figure 1.4. Development of CHP plants for the period 2008-2018 [Data from the Central Statistical Bureau]

Saražotā siltumenerģija - Heat produced; Saražotā elektroenerģija - Energy produced; Uzstādītā elektriskā jauda - Installed electric power output

It appears that the amount of heat produced was increasing over the period 2008-2017, but starting from 2015, it has experienced a significant rise resulting from CHP plant operation in condensation mode. One of the reasons for the reduction of electricity and heat produced in 2018 was the increased monitoring of CHP plants and changes in the costs of the mandatory procurement component due to the prevention of unjustified funding of CHP.

In Latvia, there were 619 boiler houses in 2016, 615 in 2017 and 633 boiler houses in 2018, of which 354 were general purpose boiler houses and 279 company-owned boiler houses.

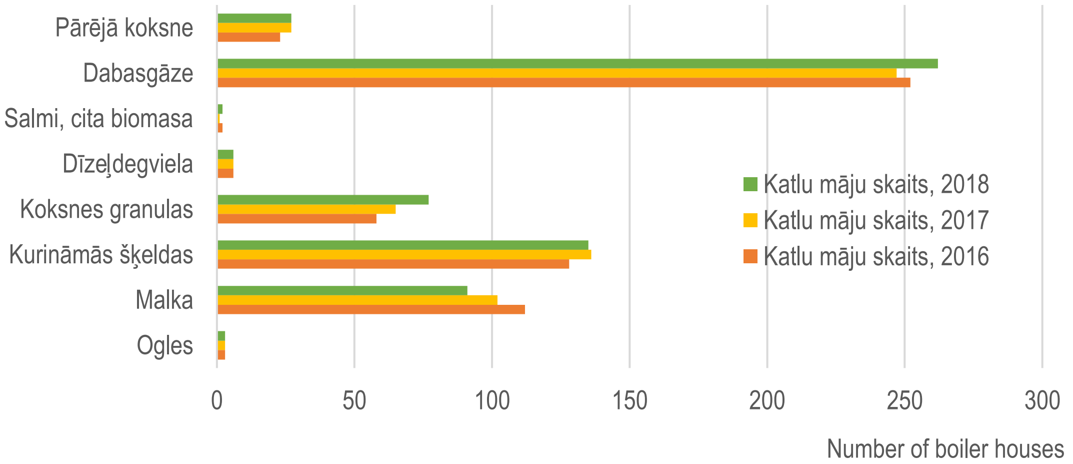


Figure 1.5. Number of boiler houses in Latvia by fuel type over the period 2016-2018 [Data from the Central Statistical Bureau]

Pārējā koksne - Other wood; Dabasgāze - Natural gas; Salmi, cita biomasa - Straw, other biomass; Dīzeļdegviela - Diesel fuel; Koksnes granulas - Wood pellets; Kurināmās šķeldas - Fuel chips; Malka - Firewood; Ogles – Coal; Katlu māju skaits - Number of boiler houses

Figure 1.5 shows the number of boiler houses in Latvia by fuel type (most commonly used) over the period 2016-2018. As it appears, the most commonly used fuel types in boiler houses are natural gas, chips, firewood, wood pellets and other wood (woodfuel, wood briquettes, wood waste). It is remarkable that the proportion of local and renewable energy is increasing year on year. The use of natural gas in boiler houses varied over the last three years. Natural gas was used in 252 boiler houses in 2016, in 247 boiler houses in 2017, while in 2018, the number of boiler houses using natural gas as fuel (262 boiler houses) slightly increased.

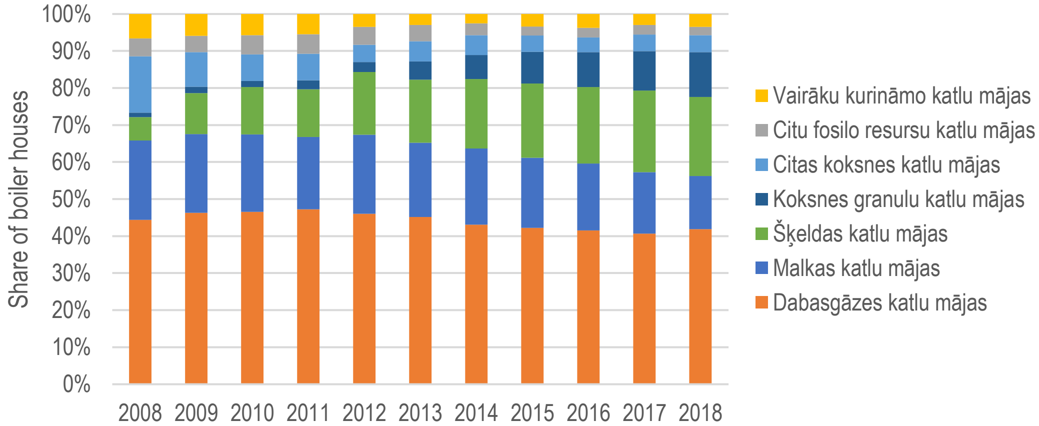


Figure 1.6. Breakdown of boiler houses using the most common fuel types for the period 2008-2018 [Data from the Central Statistical Bureau]

Vairāku kurināmo kaltu mājas - Multi-fuel boiler houses; Citu fosilo resursu katlu mājas - Other fossil resources boiler houses; Citas koksnes katlu mājas - Other wood boiler houses; Koksnes granulu katlu mājas - Wood pellet boiler houses; Šķeldas katlu mājas - Wood chips boiler houses; Malkas katlu mājas - Wood boiler houses; Dabasgāzes katlu mājas - Natural gas boiler houses

According to Figure 1.6, the number of boiler houses using natural gas has decreased by 14 % since 2008, but the number of boiler houses using wood chips has more than tripled and the number of those using wood pellet has increased by more than 11 times. Analysing the breakdown of boiler houses in 2018, it can be seen that 43 % of boiler houses use natural gas as fuel, 22 % use chips, 15 % use firewood, 13 % use wood pellets, 4 % use woodfuel (as wood waste, wood briquettes), and 2 % use woodfuel and natural gas.

In 2018, there were 633 operating boiler houses in Latvia, with a total installed heat output reaching 2 360.2 MW. A total of 2 355 GWh of heat was produced by boiler houses. Of these boiler houses, 354 are general purpose boiler houses with an installed output of 1 745.9 MW, while 279 are company-owned boiler houses with a total installed heat output of 614.3 MW. Heat production in general purpose boiler houses depends on the heat load of consumers, while the majority of heat produced by company-owned boiler houses is used for own consumption at the establishment.
The installed heat output of most boiler houses ranges from 1 MW to 5 MW; 228 boiler houses produce 590 GWh per annum. Within this output range, there are 118 general purpose boiler houses having produced 407 GWh of heat and 110 companies boiler houses having produced 182 GWh of heat, representing 25 % of all heat. In total, the installed output of 14 boiler houses exceeds 20 MW, and they produce 23 % or 538 GWh of all heat. Most of the heat, i.e. 36 % or 860 GWh, is produced by boiler houses with an installed heat output of 5 MW to 20 MW.

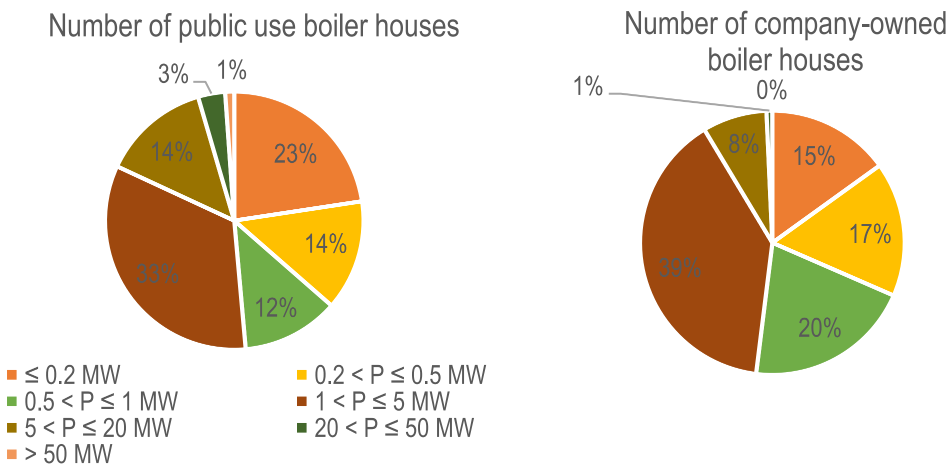


Figure 1.7. Breakdown of boiler houses by installed heat output in 2018 [Data from the Central Statistical Bureau]

According to the CSB data, the fuel consumed for heat and electricity production in the transformation sector amounted to 16.1 thousand GWh. The figure (see Figure 1.8) indicates that natural gas was the primary fuel in these energy sources (57.8 % or 9 313 GWh), while 41.8 % or 6 736 GWh of the consumed fuel accounted for wood (firewood, chips, pellets, etc.).

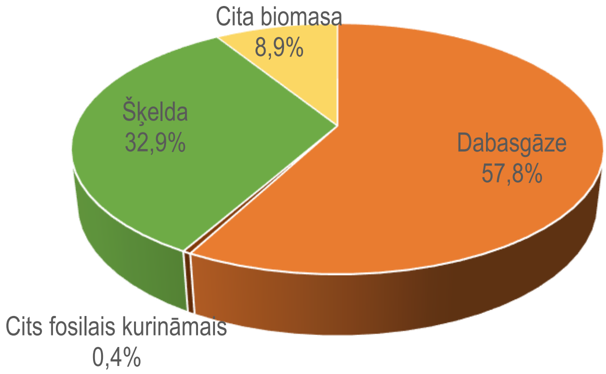


Figure 1.8. Fuel consumed by the transformation sector for heat and electricity production, 2018 [Data from the Central Statistical Bureau]

Cita biomasa - Other biomass; Šķelda - Chips; Dabasgāze - Natural gas; Cits fosilais kurināmais - Other fossil fuel

The share of wood used for heat production has increased over the period 2012-2018 (see Figure 1.9). For example, the share of chips amounted to 11 % or 1 556 GWh of the energy consumed in the transformation sector in 2009/2010, compared to ~32 % (5 297 GWh) in 2018. The increased usage of chips and other biomass can be explained by the launch of a capital investments co-financing programme in 2014 to facilitate EE and the use of local renewable energy sources (RES) in heating.

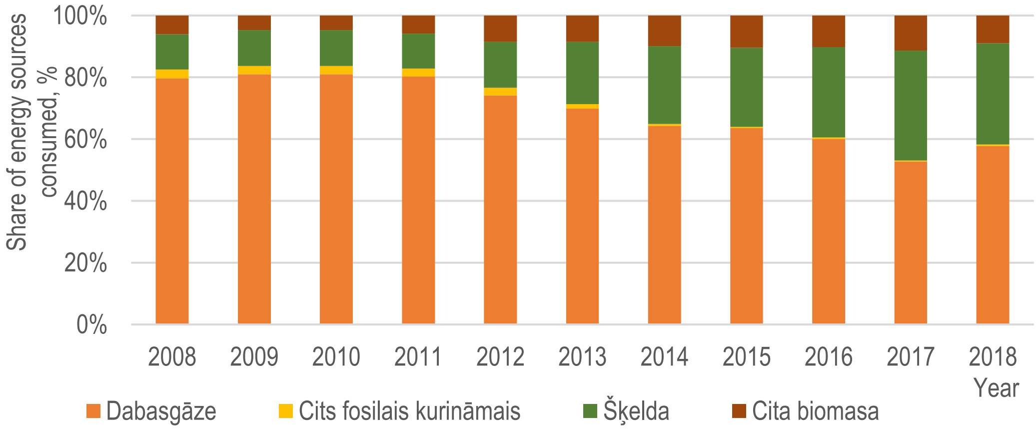


Figure 1.9. Share of energy consumed by transformation sector [Data from the Central Statistical Bureau]

Cita biomasa - Other biomass; Šķelda - Chips; Dabasgāze - Natural gas; Cits fosilais kurināmais - Other fossil fuel

In 2017, most heat (64 % or 3 998 GWh) was produced by CHP plants using natural gas (see Figure 1.10). The diagram also represents changes in the average temperature during the heating season in recent years. For a detailed overview of changes in climatic conditions influencing the amount of heat see Annex 1. The increase in the share of wood used by CHP plants is slower, still, in 2017, wood CHP plants produced 2 004 GWh of heat or 10 times more than in 2012 when they produced only 225 GWh. The share of natural gas tends to decrease at the expense of the wood used. Although wood is increasingly being used as a resource for heat generation, a rise in wood prices is expected over the next few years as the result of higher wood usage in the bioeconomy for the production of high value-added products. Thus, we have to think about another and more promising resource to be used instead of wood in the coming decades.

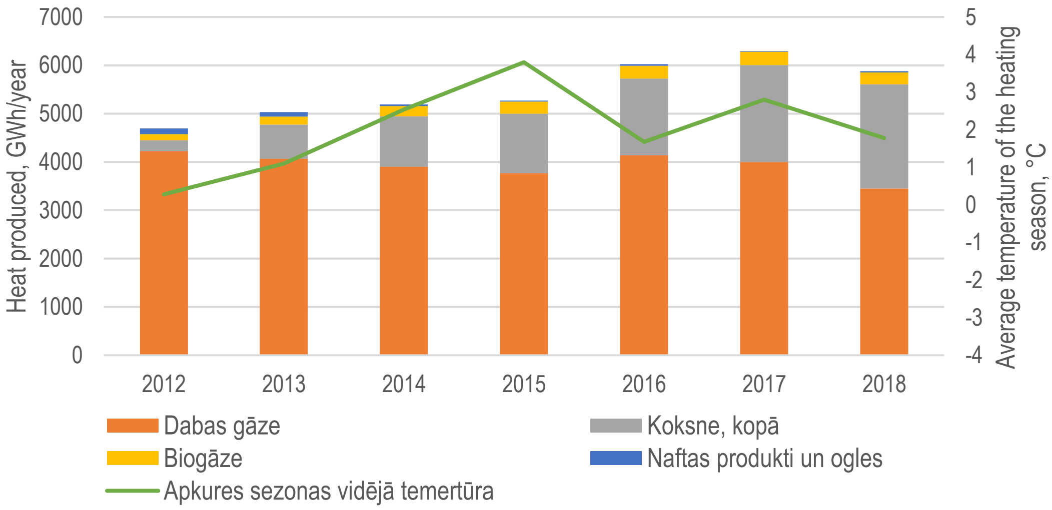


Figure 1.10. CHP plant-produced heat by consumed fuel [Data from the Central Statistical Bureau]

Dabas gaze - Natural gas; Biogāze - Biogas; Koksne, kopā - Wood total; Naftas produkti un ogles - Petroleum products and coal; Apkures sezonas vidējā temertūra - Average temperature of the heating season

A summary of the heat produced by both boiler houses and CHP plants shows that boiler houses mainly use woodfuel (63 %), while CHP plants mainly use natural gas (73 %). Natural gas is the most common type of fuel used by both boiler houses and CHP plants. In total, 66.2 % of DH system heat is produced using this fuel.

Boiler houses and CHP plants using woodfuel generate 30.1 % of the total heat produced within DH. Other fuel types (diesel fuel, heavy fuel oil, coal, straw and liquefied petroleum gas) are used to produce only 3.7 % of DH heat. As CHP plants also use biogas, unlike boiler houses, the share derived from this fuel is very small, and the heat produced using biogas amounts only to 3 % of total DH heat.
Figure 1.11 shows final heat consumption in various sectors for the period 2008-2018. The main heat consumers are households. In 2018, final heat consumption amounted to 6 998 GWh. Of the total final consumption of DH heat, the household sector consumed 4 315 GWh, the commercial and public sector consumed 1 501 GWh, the industrial and construction sector consumed 1 050 GWh and the agriculture sector consumed 132 GWh. According to the data available on final heat consumption, since 2014 heat consumption in the industrial sector has increased as a result of the development of industrial production and the registration of new companies. The structure of DH consumers in the household sector has not changed over the last 10 years, with direct heating accounting for 65-70 % and hot water supply for 30-35 %. A detailed analysis of final consumption is provided in Chapter 2.1.

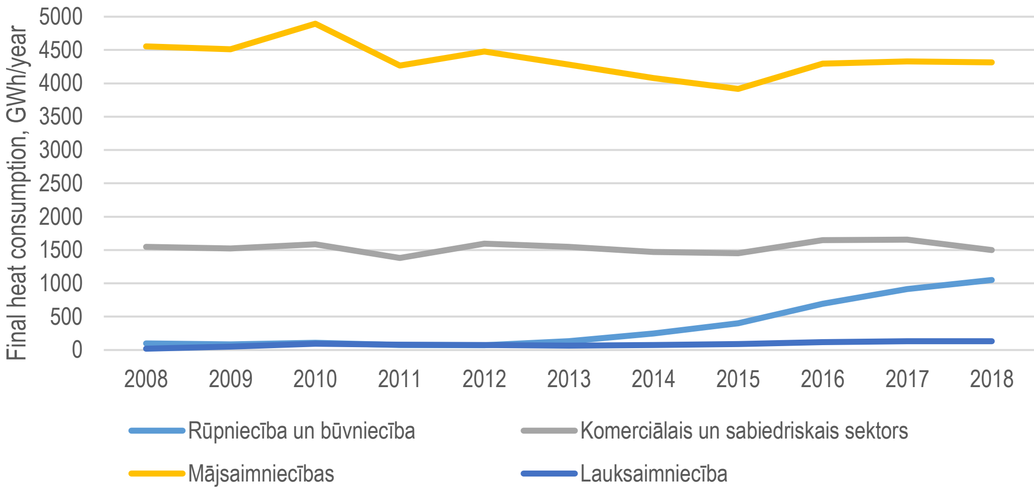


Figure 1.11. Changes in final heat consumption for the period 2008-2018 [Data from the Central Statistical Bureau]

Rūpniecība un būvniecība - Industry and construction; Mājsaimniecība - Households; Komerciālais un sabiedriskais sektors - Commercial and public sector; Lauksaimniecība - Agriculture

Although the share derived from fossil resources is higher than the share derived from RES, depending on the technology used to supply heat under certain headings, the energy sector still has the potential to become energy independent. Also, one of the development dimensions of the National Energy and Climate Plan 2030 (NECP) is 'energy supply security'. It aims to facilitate the creation of an independent system striving for climate neutrality in the long term.

Heating networks

The total length of heating networks in Latvia is about 2 000 km, and most (approx. 56 %) of the heating mains are more than 25 years old, but 60 km will be renovated by 2020 ([1]). At present, the share of heat loss in Latvia's DH system ranges from 10 % to more than 30 % of the heat supplied. According to Figure 1.12, total heat losses have tended to decrease by around 5 % since 2009 resulting from the increase and optimisation of heating networks' EE. The average heat loss as a percentage of the produced heat amounted to 12 % in 2018.

([1]) Ministry of Economics. Overview of heating and cooling. 2019 Available online: https://www.em.gov.lv/sites/em/files/siltum_apgade1_0.docx

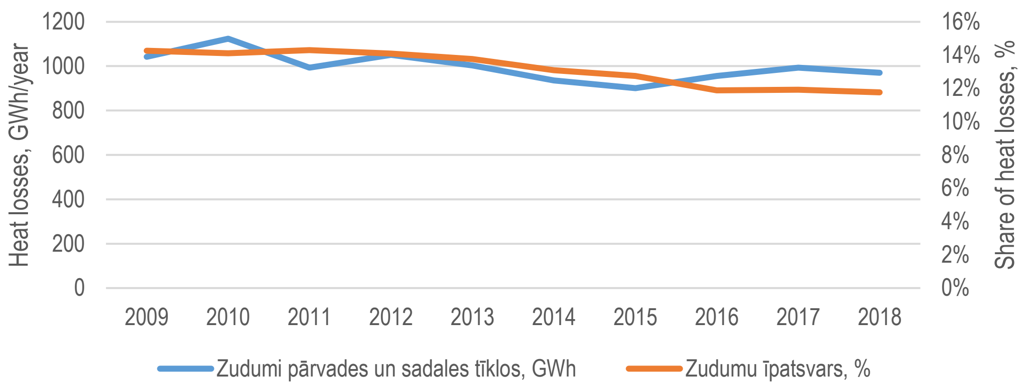


Figure 1.12. Decreasing trend of heat losses [Data from the Central Statistical Bureau]

Zudumi pārvades un sadales tīklos - Losses in transmission and distribution networks; Zudumu īpatsvars - Share of losses

Figure 1.13 presents a comparison of the total length of the heating networks and specific heat losses by region in Latvia. The lengths of old and new heating networks were determined on the basis of a survey (2015) of district heating companies ([2]), publicly available data on heating network reconstruction projects in 2017-2020 and approximate calculations of heating networks. Heat losses are lower in the Riga, Pierīga and Zemgale Regions as a result of the wide-ranging reconstruction of heating networks, in contrast to higher losses in the Vidzeme and Latgale Regions. The highest share of reconstructed heating networks is in the Kurzeme Region. The reduction in heat loss is influenced, inter alia, by the reconstruction of heating networks, heating line materials and changes in the length of the heating networks; however, the forecast of loss reduction assumes that the low specific level of heat loss depends on the heat carrier temperature in the networks being the most important factor. Annex 2 provides an overview of the total length of heating networks and the share of heating networks reconstructed in the largest cities in Latvia.

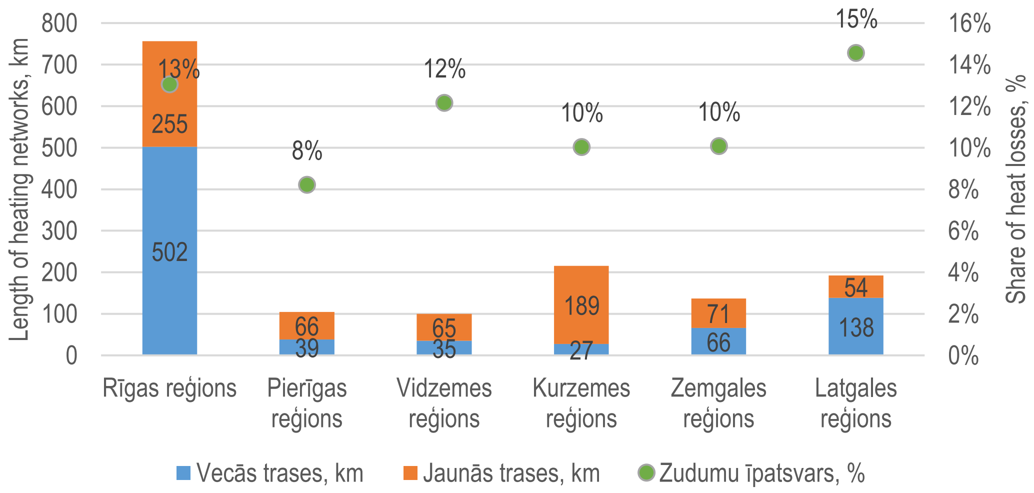


Figure 1.13. Comparison of total heating network length and specific heat losses in different regions of Latvia, 2018 [Data from the Central Statistical Bureau]

([2]) Ekodoma SIA Collection and analysis of data necessary for heating planning. Long-term trends in district heating up to 2030. Available online: http://petijumi.mk.gov.lv/sites/default/files/file/pielikums_petijums_EM_2015_par_siltumapgades_datu_ieguvi_anal_un_rokasgramat_sagat_pasval_energoplan.pdf

Rīgas regions - Riga Region; Pierīgas regions - Pierīga Region; Vidzemes regions - Vidzeme Region; Kurzemes regions - Kurzeme Region; Zemgales regions - Zemgale Region; Latgales regions - Latgale Region; Vecās trases - Old mains; Jaunās trases - New mains; Zudumu īpatsvars - Share of losses

There are two types of controls for heating network parameters in Latvia: qualitative and qualitatively quantitative. In the qualitative control system, the network water temperature is changed while the water flow remains constant. This ensures the hydraulic stability of the system. With qualitatively quantitative control, both the temperature and flow are changed. This results in the ability to reduce the electricity consumption while pumping the heat carrier. The majority of Latvia's largest DH system in Riga is equipped with automatic heating substations providing heating and hot water. The flow of the heat carrier used to be constant in the heating main, only the temperature of the heat carrier was changed. Thus, there has been a shift from qualitative to quantitative regulation, resulting in ability to combine both methods into a qualitatively quantitative regulatory system.
The temperature difference between outlet and return flows influences the amount of heat transferred to the consumer to a greater extent than outlet temperature. Increasing attention has been recently paid to the return temperature, especially where condensing economisers or flue gas condensers are installed. Figure 1.14 shows the temperature of the return water network in a biomass boiler house with a flue gas economiser installed.

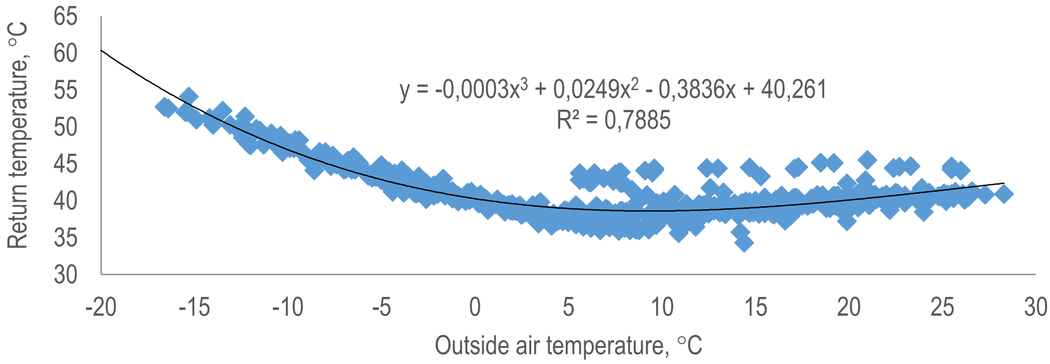


Figure 1.14. An example of a return water temperature

Figure 1.14 clearly demonstrates that temperatures in heating networks with installed condensers or condensing economisers commonly tend to be lower than in the standard diagram. The temperature difference (ΔT) between the outlet and return flows increases resulting in the use of latent heat in the condensing economizer to a fuller extent. It is apparent that there is a close correlation between the temperature of the return water and the outdoor air temperature below +5 °C at the moment when the heating is turned off and the flow in the system is connected to the hot water. Then, the temperature in the system rises, thus signalling necessary additional measures to be considered, such as temperature regulation or flow regulation (reduces flow rate).
Subchapter 4.2 provides an in-depth overview and analysis of heating networks.

Building consumption

Based on the data available in *Odyssee Mure*, one of the largest databases of energy efficiency indicators, the 2018 average heat consumption of household buildings in Latvia was around 179 kWh/m^2, which is well above the level established in the laws and regulations of Latvia. Figure 1.15 shows a decrease in the average specific heat consumption of buildings for heating purposes from 239 kWh/m^2 in 2008 to 163 kWh/m^2 in 2016 and a slight increase thereof in 2017 and 2018. This reduction occurred as a result of the renovation of buildings and the construction of new energy efficient buildings. According to the data gathered by the State Construction Control Bureau from the issued certificates, the average annual consumption of households (single-family and multi-apartment residential buildings) amounted to 159 kWh/m^2 in 2018. Such differences in the data can be explained by the fact that a different approach has been used in the determination of specific indicators.

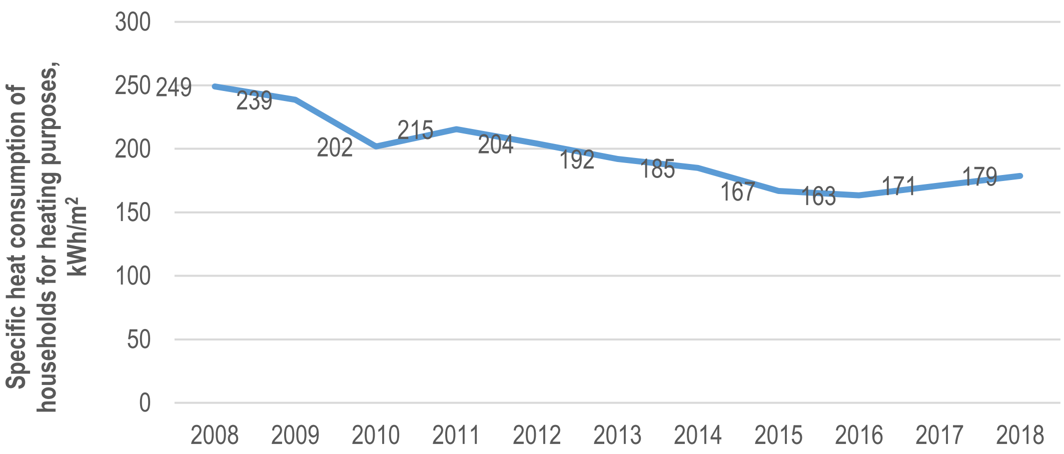


Figure 1.15. Trends in the average heat consumption of household buildings for heating purposes in Latvia (3)

The most important factor determining the development trends of buildings in Latvia is their age structure (see Figure 1.16). According to the CSB data for 2017, the majority of buildings in Latvia (63 % or 634 522) were built during the Soviet period: from 1941 to 1992. Approximately 26 % (261 866) of the buildings in Latvia were built prior to 1940 and about 11 % (110 790) were built after 1993. This factor should be considered while setting the heating system development trends, since most buildings from the Soviet era are connected to the DH system. In the coming years, these buildings should be renovated to ensure a considerable reduction in the heat consumption, and hence the demand for heat.

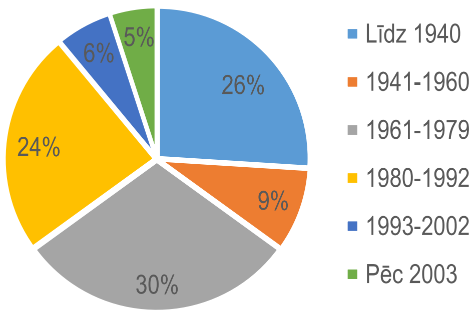


Figure 1.16. Age of buildings in Latvia, 2017 (4)

līdz – until; pēc - after

The Cabinet regulation on Latvia's construction standard LBN 002-19 provides reference values of thermal engineering factors for the external building envelopes of newly constructed, reconstructed and renovated buildings. To comply with the regulation requirements, the heat consumption of the building must amount to 70-80 kWh/m^2 per annum.

Acknowledging the high operating costs of buildings, the heat consumption of new buildings being designed and built in Latvia is well below the required level set out in regulatory enactments. Figure 1.17 represents an indicative comparison of heat consumption by different types of buildings. The concepts of and performance indicators for low-energy buildings and passive buildings are currently not defined in the laws and regulations in Latvia. The concept of a near zero-energy building is mentioned in the Cabinet regulation on the energy certification of buildings in reference to a building whose annual heat consumption is less than 30 kWh/m^2, while, in accordance with the building rating scale, buildings belong to Class A if they consume less than 40 kWh/m^2 per annum.

(3) ODYSEE indicators database. Available online: http://www.odysseemure.eu/project.html.
(4) Ministry of Economics. Long-term strategy for building renovation. Riga, 2017

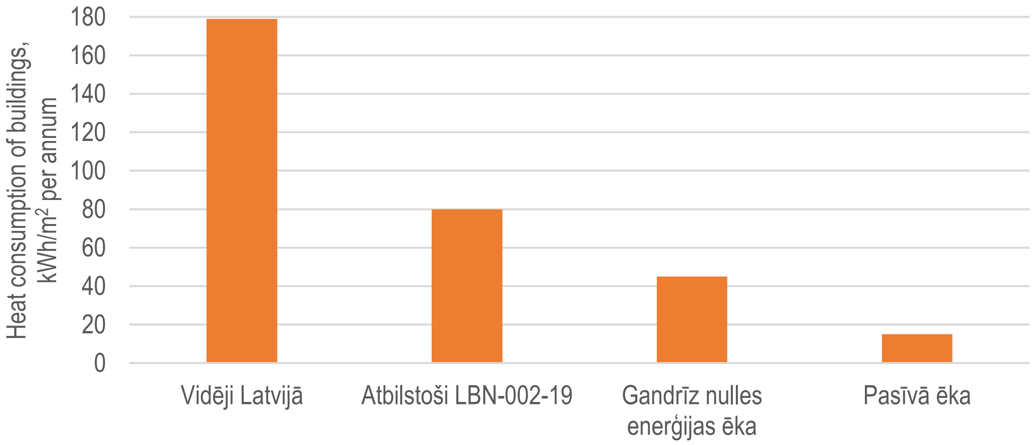


Figure 1.17. Indicative consumption of heat in Latvia by type of buildings (4), (5)

Vidēji Latvijā - Average in Latvia; Atbilstoši LBN-002-19 - Pursuant to LBN-002-19; Gandrīz nulles enerģijas ēkas - Near zero-energy building; Pasīvā ēka - Passive building

Various technical solutions and EE measures are applied to achieve low heat consumption by buildings. A thicker thermal insulation layer, reduced air permeability of the building, a low heat permeability factor of the windows and doors, and an efficient ventilation system of the building aim to reduce heat loss through the building envelope. At the design stage of passive buildings, the main focus is on their shape and location – the building has to be as compact as possible to reduce heat losses and has to take full advantage of solar heat. Particular attention is also being paid to reducing the amount of energy required for building ventilation. Various passive and active types of shading are used to regulate the solar gain to the building.

In passive buildings, innovative solutions are possible. If the thermal resistance of walls and windows is high enough, installation of heat emitters close to external structures can be avoided by designing the emitters with pipes that are as short as practicable. In low-energy and passive buildings, floor heating is more frequently used. In such buildings, the main heat source used is individual heating derived from alternative energy sources: biomass, solar energy and heat pumps.

1.2. Cooling systems

Due to climate change, the global mean temperature of the air is constantly rising. Over the last decade, the average air temperature in Latvia has risen by 1.4 °C (6). Due to these changes, there has been an increase in the demand for cooling, which in Latvia is provided to each building individually. At present, district cooling systems (DCS) are largely unknown in Latvia, whereas nearby European countries including, inter alia, Estonia, already make use of such systems; for example, the Tartu DCS pipeline is 2.9 km long. Based on available resources, Latvia also has the potential to slowly transition to a higher-efficiency DCS, because air is currently cooled by individual refrigerating appliances filled with fluorinated gas, which increases GHG emissions. The implementation of DCS is planned by 2030, as this currently does not exist, but is increasingly necessary for adaptation to climate change and the reduction of environmental pollution. (7)

1.2.1. District cooling systems

There are different solutions for cold load provision – individual solutions for premises or buildings, a set of buildings, or a neighbourhood unit. Customised solutions are usually split air conditioning systems, or rather, air-to-air heat pumps. To meet the requirements for building cooling, the coefficient of performance (COP)

(5) Cabinet Regulation No 280 of 25 June 2019 on Latvia's building code LBN 002-19 'Thermal Engineering of Building Envelopes'. Latvijas Vēstnesis, 135, 05.07.2019. https://likumi.lv/ta/id/307966
(6) Climate change scenarios for Latvia. Riga, 2017. Available online: https://www4.meteo.lv/klimatariks/files/zinojums.pdf
(7) National Energy and Climate Plan. Available online: https://em.gov.lv/lv/nozares_politika/nacionalais_energetikas_un_klimata_plans/. [Viewed: 17.10.2019].

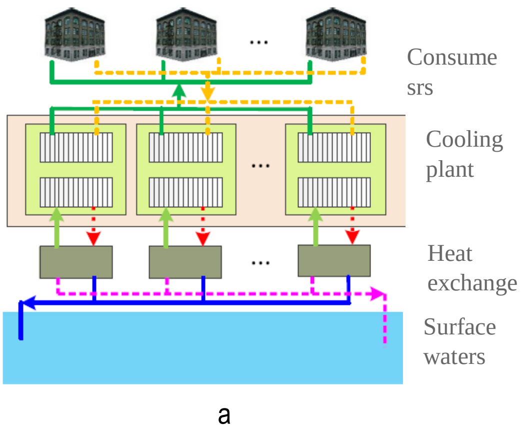
ranges from 2.5 to 3.25 for individual air conditioning units, from 3.5 to 5 for electrical refrigerating appliances, and from 6 to 10 for electrical refrigerating appliances with wet cooling towers ([8]), ([9]), ([10]). Absorption or electrical refrigerating appliances can reach much higher efficiency than individual air cooling systems.

1.2.2. Direct cooling generation technologies

There are various resources and technologies used for the production of cold: natural cooling energy (water bodies, geothermal energy) or cooling energy remaining from industrial processes through heat exchangers, waste heat used for the operation of absorption refrigerating appliances (with or without heat recovery), and cooling energy storage.

In contrast to district heating, renewable energy sources (RES) such as solar energy, biomass, or geothermal energy are not widely used in cooling. One of the main reasons for this is the high efficiency of heat production from the energy sources listed above. But for the purpose of cooling energy production, these resources must initially be converted into heat and then electricity or cooling energy through an absorption chiller. This results in relatively higher energy losses.

The cooling energy of rivers, lakes and marine waters is widely used in various DCS projects, resulting in low production costs, energy savings and environmental benefits compared to other conventional technologies. When the water temperature is low enough, it can be used directly for cooling purposes without refrigerating appliances, thus resulting in significant energy savings. ([7])



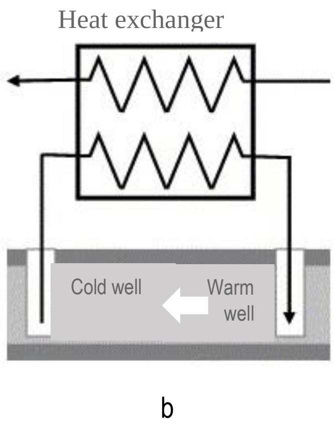


Figure 1.18. Indirect production of cooling energy from surface water (a) and direct abstraction from groundwater (b) ([11]), ([12])

Geothermal energy as another important resource for the cooling energy production enables significant funds to be saved in energy production. The groundwater cooling system requires an aquifer with access to cold water to be abstracted through a well. This principle is demonstrated in Figure 1.18. Cold water is abstracted from a certain part of the aquifer ('cold' well) (usually at 6-12 °C, depending on the aquifer and location) and is supplied via a heat exchanger to cool the building. The resulting water is then transferred into aquifers in another location ('hot' well). In areas with rising water levels, a second well is not required for many appliances and abstracted groundwater can often be reused as technical (drinkable) or released into sewage.

([8]) Dominković F., Bin Abdul Rashid K.A., Romagnoli A., Pedersen A.S., Leong K.C., Krajačić G., Duić N. Potential of district cooling in hot and humid climates, Applied Energy, 208; 2017; 49-61

([9]) Ecoheatcool Work package 2. The European Cold Market. Final report. 2006 Available online: https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/ecoheatcool_the_european_cold_market_final_report.pdf

([10]) M.A.D. Larsen, S. Petrović, A.M. Radoszynski, R. McKenna, O. Balyk, Climate change impacts on trends and extremes in future heating and cooling demands over Europe, Energy and Buildings 226, 2020, 110397

([11]) Gang W., Wang S., Xiao F., Gao D. District cooling systems: Technology integration, system optimization, challenges and opportunities for applications. Renewable and Sustainable Energy Reviews 53; 2016; 253–264

([12]) Ampofo F., Maidment G.G., Missenden J.F. Review of groundwater cooling systems in London, Applied Thermal Engineering, 26; 2006; 2055-2062

Absorption refrigerating appliances and trigeneration

The absorption chiller uses waste heat at about 90-95 °C, while electricity is only required to pump the working fluid. Consequently, there is the potential to achieve a common COP of 15-25, while the heat efficiency of certain absorption equipment usually amounts to 0.7. The continuous availability of unused heat flows is the key determinant for absorption chillers to be economically more advantageous compared to electric chillers. Despite the development of electrically operated chillers, absorption chillers have been proven to be more cost-effective in CO_2 emissions reduction, given the availability of cheaper waste heat.
One of the options for central cold load provision is the use of trigeneration, namely the combined production of electricity, heat and cold leading to a significant reduction of the overall energy loss in the system. Figure 1.19 provides a comparison of the trigeneration power supply system to other energy supply options. Conventional energy supply is a standard option for electricity, heat and cold – electricity is provided by electricity grids, and heat and cold are generated individually by boilers and compression or absorption type chillers. Direct energy supply is an alternative to the conventional option, as the combination of heat and cold production facilities results in an overall increase in production capacity and efficiency.

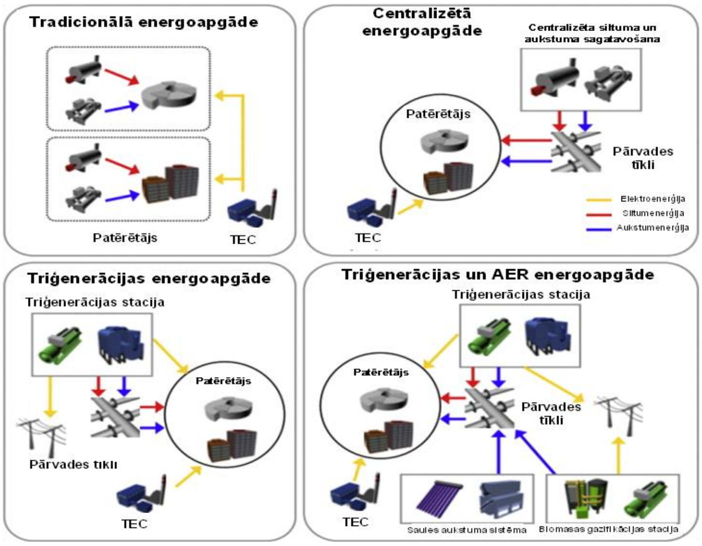


Figure 1.19. Comparison of different energy supply solutions (RES) ([13]) [*for translation, please see (2) in accompanying document*]

A plant equipped with three cogeneration engines, a conventional absorption chiller, a double absorption chiller and spare elements (boiler and compression chiller) constitutes the basis for the trigeneration power supply. The operation of cogeneration engines results in generation of electricity, heat and exhaust gases. Heat recovered from engines can be used for both heat production and cooling through a conventional absorption chiller or a double absorption chiller using exhaust gases.
Renewable energy sources can be integrated into the conventional trigeneration energy supply system. Figure 1.19 represents a scenario with trigeneration supplemented by a solar cooling system and a biomass gasification plant. Assistant Professor at the Institute of Environmental Protection and Heating Systems of Riga Technical University, Dz. Jaunzems has also analysed the use of solar energy in the cooling supply of buildings and concluded that even under the climatic conditions of Latvia, there is enough solar energy to provide a significant part of the heat energy necessary for the refrigerating appliances ([14]).

Solar cooling systems

([13]) Cers A., Options for the application of trigeneration technology for energy efficiency improvement. 2009. Available online: http://www.rea.riga.lv/files/Aivars_Cers_16_10_2009_VE2009.pdf
([14]) Jaunzems Dz. Study on the use of solar energy in the cooling supply of buildings. Doctoral thesis. 2011 Available online: https://ortus.rtu.lv/science/lv/publications/10783/summary

The main purpose of the solar cooling system is the use of solar energy for the cooling of premises. Studies show that in 2014, there were around 1 200 solar cooling systems installed worldwide. Figure 1.20 demonstrates that solar energy for cooling can be used either through electricity or heat generating processes. A high efficiency steam compression chiller is an extensively used solar electricity cooling technology. The technology is relatively simple and not associated with high maintenance costs. ([15])

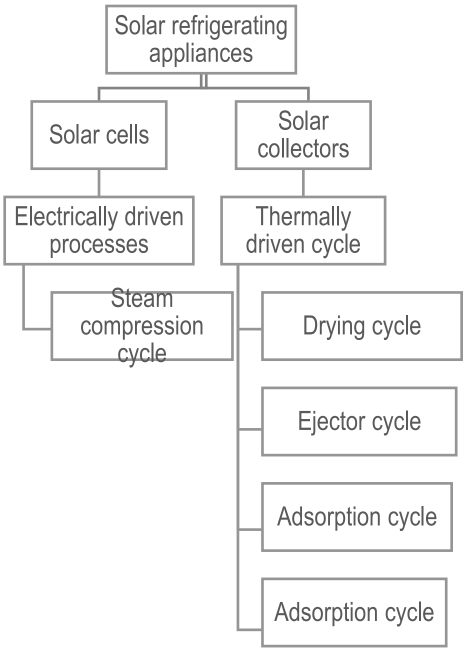


Figure 1.20. Different types of solar cooling systems ([13])

There are several technological solutions related to the use of solar energy for cooling. Compared to electricity-powered equipment, heat-operating equipment has a lower COP but higher collector efficiency. The main advantage of the heating systems is the simpler integration of the heat accumulation system, as well as low vibration and noise levels. Consequently, most solar cooling systems operate using solar energy.

Use of residual cooling energy

Cold energy unused in industrial processes can be integrated into district cooling. Cooling energy is generated, for example, at a natural gas liquefaction plant, where liquefied natural gas is converted back into a gaseous state before its transmission to consumers. Modern liquefaction process requires about 2 900 kJ/kg of energy: 2 070 kJ/kg is dispersed as heat and 830 kJ/kg is stored in liquefied gas as cold energy. However, due to the cryogenic temperature of liquefied gas, the cold emitted is also suitable for other processes, such as the freezing of materials, production, and the cooling of dry ice in the chemical industry. As the literature suggests, liquefied gas cold energy generated from the regasification process can be used for the production of electricity, freezers and dry ice, as well as in a district cooling system. The cascade process at the Osaka terminal is an example of very successful practices in which the cold energy generated during the gasification of liquefied natural gas is used. To use resources effectively, there is a combination of the ethylene plant, air separation, carbon dioxide liquefaction, water cooling and expansion turbine resulting in 52 % of efficiency. ([16])

Cold accumulation system

To reduce production costs and improve operational efficiency, the cooling system contains accumulation systems allowing the cold energy to be stored during low consumption periods. Due to the low cost and thermal properties, water is the principal accumulator of the cold energy. The temperature of the water storage system

([15]) Shirazia A., Taylora R.A., Morrisona G.A., Whitec S.D. Solar-powered absorption chillers: A comprehensive and critical review. Energy Conversion and Management 171; 2018; 59-81.

is compatible with the evaporation temperature of the conventional chiller, making it readily connectable to the district cooling. Conventional water storage tanks stratify at a water temperature of 4 °C with a maximum water density.

1.2.3. Cooling energy transmission

In cooling energy transmission, the temperature difference between the outlet and return flows is small. Hence, the diameter of the cooling pipes is usually much larger than in the heating network at the same energy input level. Cold energy losses in European systems are very low, since the ground temperature is close to the outlet temperature. Cooling energy supply is ensured through an individual substations un/equipped with a heat exchanger. Since the temperature difference is small, heat exchangers of a larger surface area are used to avoid the reduction of the transmission capacity in the cooling networks. ([16])

1.2.4. Overview of cooling systems in European countries

Sweden

The first Swedish cooling system was implemented in Västerås in 1992. This implementation was prompted by the ban of chlorofluorocarbon refrigerants and the need to replace current cooling equipment. The main Swedish cooling systems are in Stockholm, Göteborg, Linköping, Solna-Sundbyberg, Lund and Uppsala. In 2014, there were 40 populated areas with district cooling registered. The average cooling development rate is about 8 % per annum. In 2016, the amount of cold energy supplied amounted to 1 TWh or 3.6 PJ.([17]) The amount of cold energy supplied in Sweden is expected to reach around 7-8 PJ in 2020 and around 10-12 PJ in 2030. ([18])
Stockholm has one of the largest cooling systems with heat pumps delivering cold seawater for cold energy generation. By 2009, this system provided cooling to about 600 buildings, including offices, hospitals, universities and other types of buildings. In addition, two-stage compressors with heat recovery technology have been installed to produce cold energy from the CHP plant's heat. In the rocks, there is an installed storage facility for the accumulation of cold. According to 2015 data, Stockholm had a 260 km long cooling network, and generated 361 GWh of cold energy delivered to 300 customers. ([17])
Göteborg's DCS is still expanding. Cooling was provided to 100 different delivery points in 2010, including commercial buildings and hospitals that have to follow certain microclimate requirements. Customers are either connected to a large district cooling network or a small local cooling network. In the district network, the cooling temperature is 6 °C, but some customers obtain water cooled to variable temperatures up to 12 °C. During the winter season, the district cooling system has access to a free cold source in the nearby river. Cooling through cooling towers is available for local production facilities. ([19])

France

France has a well-developed DCS. In 2017, there were 22 DC systems operating in France with a total network length of 200 km. And total cold energy supplied to consumers amounted to 1 TWh ([20]).
The largest DC system in France is located in densely populated Paris. Here, cold energy is generated from cold water of the Seine River. Seven cold plants are integrated into the district heating, with four of them using cold towers and three using resources of the Seine River. Its water is used directly if the water temperature is below 8 °C. ([3]) Cold accumulation systems using both water and ice as an accumulating substance are also integrated into the cooling system. Three accumulation units are used, with two of them being ice units and one being a chilled water storage system. Their total output amounts to 140 MWh.

([16]) Werner S. Review International review of district heating and cooling. Energy. Vol. 137., 2017., pp. 617-631.
([17]) Heat Pumps in District Heating and Cooling Systems. 2018. Available online:
https://heatpumpingtechnologies.org/annex47/wp-content/uploads/sites/54/2018/12/task1reportsweden.pdf
([18]) Werner S. District heating and cooling in Sweden, Energy. Vol. 126. 2017., pp. 419-429.
([19]) Elsa Fahlén, Louise Trygg, Erik O. Ahlgren Assessment of absorption cooling as a district heating system strategy – A case study Energy Conversion and Management 60 (2012) 115–124.
([20]) District cooling statistics in France. 2017. Available online: https://www.fedene.fr/wp-content/uploads/sites/2/2017/10/Septembre-2017_SNCU_Reseaux-de-froid-OK.docx

Finland

DCSs are established in seven Finnish cities: Helsinki (1998), Turku (2000), Lahti (2000), Vierumäki (2002), Tamper (2012), Pori (2012) and Espoo (2013) ([21]). According to 2019 data, 281 GWh were produced in Finland with DCS continuing to expand, as the number of consumers has increased by 11 % and the load consumed, by 15 %. ([17]) According to Figure 1.21, the *Finish Energy* cooling company applies various cold production technologies. The selection of the most appropriate technology depends on the specific climate conditions of the site concerned, the available resources and other factors. The absorption refrigerating appliance uses heat or waste heat unused in industrial processes at CHP plants when heat consumption is low.

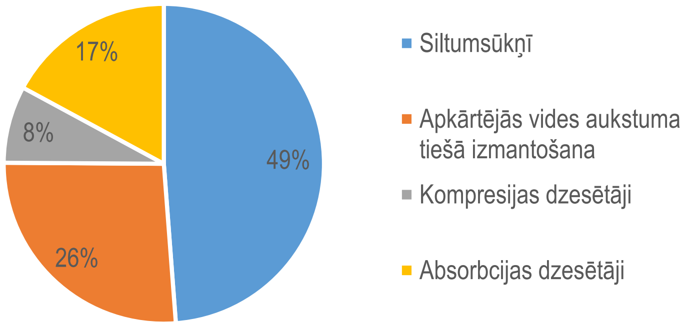


Figure 1.21. Breakdown of cold production technologies applied ([16])

Siltumsūkņi - Heat pumps; Apkārtējās vides aukstuma tiešā izmantošana - Direct use of ambient cold; Kompresijas dzesētāji - Compression chillers; Absorbcijas dzesētāji - Absorption chillers

The Helsinki DCS is the third largest and evolving system. It is connected to about 300 buildings and providing total cooling output at 154 MW. One of the largest cooling plants is the Katri Vala heat pump taking heat from sewage and seawater. The total output of the heat pump amounts to 90 MW for heating and 60 MW for cooling. A cold accumulation system is also integrated into the system.

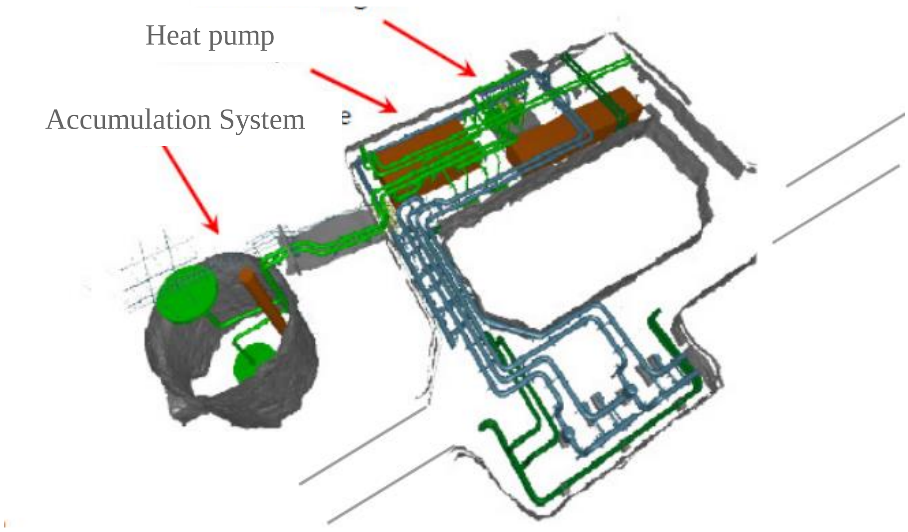


Figure 1.22. Heat pump and accumulation system diagram ([16])

([21]) Riipinen M., Eklund T. District cooling in Finland. 2014. Available online: http://basrec.net/wp-content/uploads/2014/05/District%20Cooling%20in%20Finland.pdf

The Netherlands. Amsterdam

The Amsterdam DCS was implemented in 2003 ([22]). The installed output amounts to 60 MW. The total length of cooling networks is 5.5 km (maximum pipeline diameter 700 mm). The outlet temperature is 5-6 °C, the return temperature is -16 °C. Deepwater from a nearby lake is the source of cold energy with additional compressors used for peak load provision. ([9])

([22]) Dutch cooling system. Available online: https://www.logstor.com/district-cooling/cases/amsterdam-the-netherlands

2. HEATING AND COOLING DEMAND

The heating and cooling demand analysis is based on the algorithm presented in Figure 2.

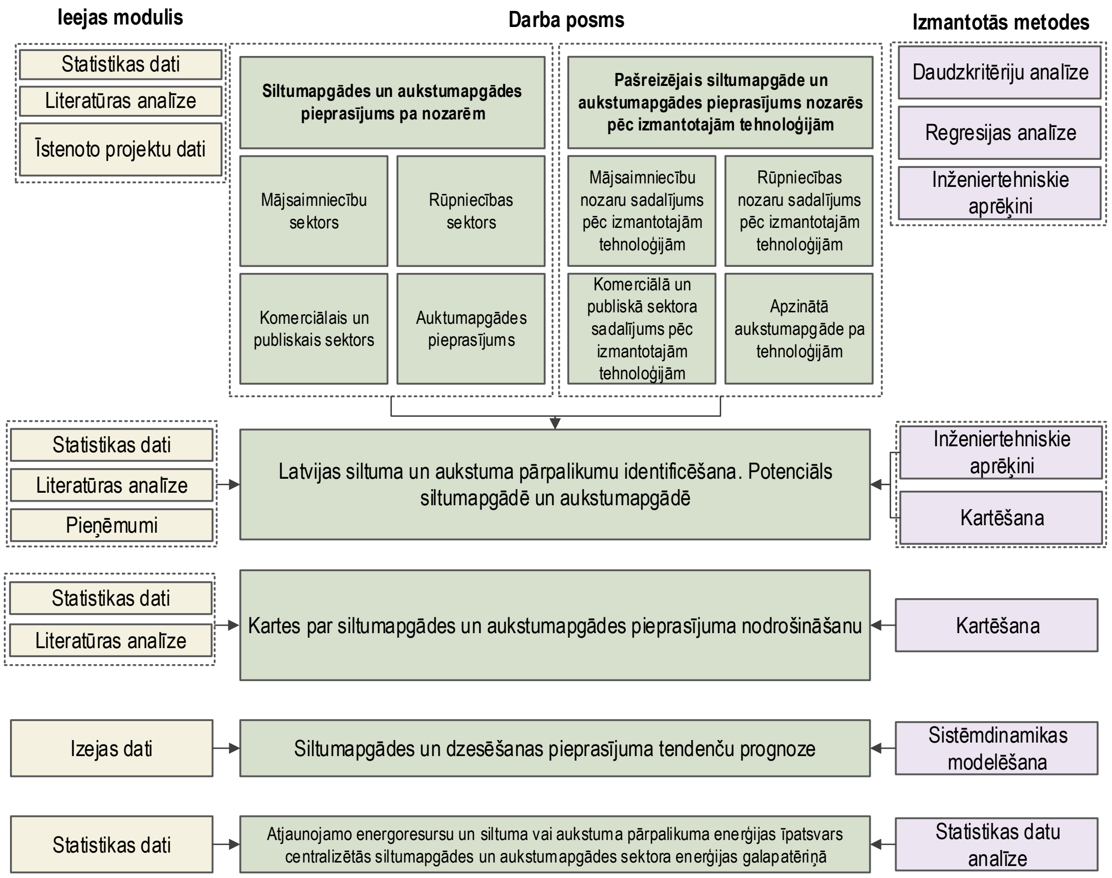


Figure 2. Algorithm for assessment of the current situation [*for translation, please see (3) in accompanying document*]

The analysis of heating and cooling demand includes a number of main sections and subsections. The demand analysis is based on data from databases, reports, scientific publications and implemented projects, as well as on assumptions. There are different methods used for heating and cooling assessment in each of the working phase modules. These are mainly engineering calculations, statistical data analysis, multi-criteria analysis, regression analysis, system dynamic modelling and mapping.

2.1. Heating and cooling demand determined by the estimated useful energy and quantified as per final energy consumption by sector

In 2018, heat consumption amounted to 6 998 GWh [Data from the Central Statistical Bureau], of which around 62 % or 4 315 GWh were consumed by households, 21 % or 1 501 GWh by commercial and public buildings and 15 % or 1 050 GWh by industrial and construction sector. Approximately 2 % (132 GWh) of heat was consumed by other sectors, such as agriculture, forestry, etc.
The most significant changes in the distribution of final heat consumption are observed in the industrial and construction sectors, with slight changes in commercial and public sector as well (see Figure 2.1). An increase in final heat consumption by the industrial and construction sector corresponds to the period 2012-2013, with an upward trend maintained. As a result, heat consumption by this sector has increased from 72 GWh (2012) to 1 050 GWh (2018). This consumption level is explained by the recovery of the industrial and construction sector from the economic crisis. Therefore, regarding the period 2013-2018, the industrial and construction sector continues to develop, requiring more heat.

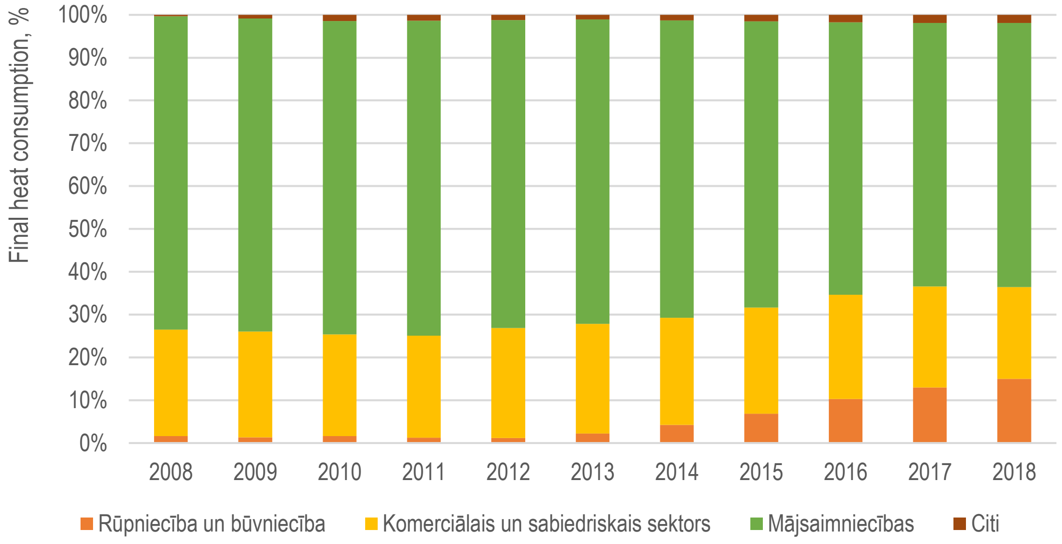


Figure 2.1. Distribution of final heat consumption – changes over the period 2008-2018 [Data from the Central Statistical Bureau]

Rūpniecība un būvniecība - Industry and construction; Komerciālais un sabiedriskais sektors - Commercial and public sector; Mājsaimniecības - Households; Citi - Other

Figure 2.2 shows the variability of heat consumption by the household sector, having decreased by 560 GWh over the period 2012-2015. Periodic heat demand by the household sector depends on various aspects, where the decline in demand is related to the increased EE of buildings, while the re-increase may result from the commissioning of new heated areas in the sector. In turn, heat consumption by the industrial and construction sector has increased by up to 85 % over the period 2013-2018. Final heat consumption by commercial and public sector increased by 7 % over the period 2008-2017.

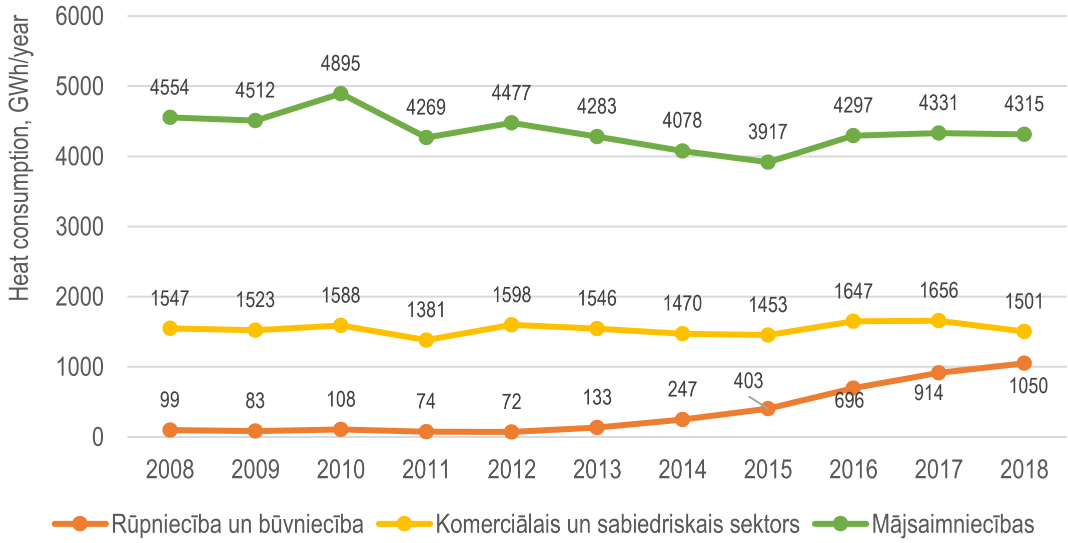


Figure 2.2. Trends in final heat consumption by sectors over the period 2008-2018 [Data from the Central Statistical Bureau]

Rūpniecība un būvniecība - Industry and construction; Komerciālais un sabiedriskais sektors - Commercial and public sector; Mājsaimniecības - Households

The research carried out is based on the European Commission recommendations prescribing the determination of the heat density per territory administrative unit as compulsory for the assessment of the heat demand. Although the Central Statistical Bureau provides various data sets and reports, to make future estimates and assess the demand for the current heating systems and energy per administrative unit, data was requested from the Environment and Energy Statistics Division of the Agricultural and Environmental Statistics Department of the Central Statistical Bureau. (see Table 2.1). The Central Statistical Bureau provides data on Riga, Pierīga Region, Vidzeme, Latgale, Zemgale and Kurzeme, but this type of data is insufficient to obtain a complete overview for the determination of heat demand by territories.

The Central Statistical Bureau has developed Quality Guidelines establishing requirements for data analysis and preparation for publication. CSB data on heat balance in cities and municipalities of the Republic was prepared in compliance with confidentiality provisions. The information shall be deemed confidential if ([23]):

- the aggregate indicator is derived from one, two or three statistical units (enterprises);
- the share of one statistical unit in a given indicator is 80 % and above;
- the cumulative share of two statistical units is 90 % and above.

TABLE 2.1. HEAT BALANCE, (GWH/YEAR), IN CITIES AND MUNICIPALITIES OF THE REPUBLIC, 2018 [DATA FROM THE CENTRAL STATISTICAL BUREAU]

Administrative territory	Heat produced, total	Energy sector	Including: own consumption	Heat used for the purposes of own business	Losses in transmission and distribution	Heat supplied to customers	including: for domestic purposes
Latvia	8 247	279	122	157	970	6 998	4 315
Riga	3 412	.	.	50	445	2 916	2 342
Daugavpils	470	.	.	.	.	390	.
Jelgava	294	.	.	.	.	179	.
Jēkabpils	93	.	.	.	13	79	.
Jūrmala	163	.	.	.	.	141	.
Liepāja	269	.	.	–	.	226	.
Rēzekne	252	.	.	–	.	224	.
Valmiera	.	–	–	–	.	.	.
Ventspils	.	.	.	–	.	.	.
Aizkraukle Municipality	88	.	–	.	.	84	.
Jaunjelgava Municipality	7	–	–	–	.	7	.
Pļaviņas Municipality	.	.	.	–	.	.	.
Koknese Municipality	23	.	–	.	.	21	.
Nereta Municipality	.	–	–	–	.	.	.
Skrīveri Municipality	.	.	–	.	.	.	.
Alūksne Municipality	.	.	–	.	.	.	.
Ape Municipality	–	–	–	–	–	–	–
Balvi Municipality	.	.	–	.	.	.	.
Viļaka Municipality	.	–	–	–	.	.	.

([23]) Central Statistical Bureau. Quality guidelines, 2008. https://www.csb.gov.lv/sites/default/files/dokumenti/item_file_11864_kvalitates_vadlinijas2008.pdf

Baltinava Municipality	–	–	–	–	–	–	–
Rugāji Municipality	–	–	–	–	–	–	–
Bauska Municipality	43	.	.	–	.	39	24
Iecava Municipality	.	.	–	.	.	.	.
Rundāle Municipality	.	–	–	–	.	.	.
Vecumnieki Municipality	13	–	–	–	.	11	.
Cēsis Municipality	64	.	–	.	.	56	.
Līgatne Municipality	.	–	–	–	.	.	.
Amata Municipality	.	–	–	–	.	.	.
Jaunpiebalga Municipality	.	–	–	–	–	.	.
Priekuļi Municipality	.	–	–	–	.	.	.
Pārgauja Municipality	.	.	–	.	.	.	.
Rauna Municipality	.	–	–	–	.	.	.
Vecpiebalga Municipality	11	–	–	–	.	10	.
Daugavpils Municipality	.	.	–	.	.	.	.
Ilūkste Municipality	.	.	.	–	.	.	.
Dobele Municipality	107	.	.	.	.	98	.
Auce Municipality	18	.	.	.	.	14	.
Tērvete Municipality	.	–	–	–	.	.	.
Gulbene Municipality	140	.	.	.	14	116	.
Jelgava Municipality	22	.	–	.	8	12	.
Ozolnieki Municipality	.	.	–	.	.	.	.
Jēkabpils Municipality	.	–	–	–	.	.	.
Aknīste Municipality	.	–	–	–	.	.	.
Viesīte Municipality	.	–	–	–	.	.	.
Krustpils Municipality	35	–	–	–	.	34	.
Sala Municipality	.	–	–	–	.	.	.
Krāslava Municipality	.	.	.	.	.	.	.
Dagda Municipality	.	.	.	.	.	.	.
Aglona Municipality	.	.	.	–	.	.	.
Kuldīga Municipality	.	.	.	.	.	.	.
Skrunda Municipality	.	–	–	–	.	.	.
Alsunga Municipality	.	–	–	–	.	.	.
Aizpute Municipality	18	.	.	–	2	16	6
Durbe Municipality	.	–	–	–	.	.	.
Grobiņa Municipality	21	.	–	.	.	19	.
Pāvilosta Municipality	.	.	.	.	.	.	.
Priekule Municipality	.	.	–	.	–	.	.
Nīca Municipality	.	.	–	.	.	.	.
Rucava Municipality	–	–	–	–	–	–	–
Vaiņode Municipality	10	.	.	.	3	7	.
Limbaži Municipality	.	.	.	.	.	.	.
Aloja Municipality	.	.	–	.	.	.	.
Salacgrīva Municipality	.	–	–	–	.	.	.

Ludza Municipality	.	.	.	–	.	.	.
Kārsava Municipality	.	–	–	–	.	.	.
Zilupe Municipality	.	.	.	–	.	.	.
Cibla Municipality	–	–	–	–	–	–	–
Madona Municipality	159	.	.	7	10	139	33
Cesvaine Municipality	.	.	–	.	.	.	.
Lubāna Municipality	.	–	–	–	.	.	.
Varakļāni Municipality	.	–	–	–	.	.	.
Ērgļi Municipality	.	.	–	.	–	.	.
Ogre Municipality	112	.	–	.	16	95	73
Ikšķile Municipality	.	–	–	–	.	.	.
Ķegums Municipality	.	.	–	.	.	.	.
Lielvārde Municipality	.	.	–	.	.	.	.
Preiļi Municipality	42	.	.	.	.	36	.
Līvāni Municipality	.	.	–	.	.	.	.
Riebiņi Municipality	–	–	–	–	–	–	–
Vārkava Municipality	.	–	–	–	.	.	.
Rēzekne Municipality	17	–	–	–	1	15	9
Viļāni Municipality	.	.	–	.	.	.	.
Baldone Municipality	.	–	–	–	.	.	.
Ķekava Municipality	.	.	.	–	.	.	.
Olaine Municipality	85	.	–	.	.	74	.
Salaspils Municipality	208	.	.	.	.	185	.
Saulkrasti Municipality	.	–	–	–	.	.	.
Sigulda Municipality	34	.	–	.	.	27	.
Inčukalns Municipality	213	–	–	–	.	211	.
Ādaži Municipality	.	–	–	–	.	.	.
Babīte Municipality	.	.	–	.	.	.	.
Carnikava Municipality	.	–	–	–	.	.	.
Garkalne Municipality	.	–	–	–	.	.	.
Krimulda Municipality	.	.	–	.	.	.	.
Mālpils Municipality	.	.	.	.	.	.	.
Mārupe Municipality	81	.	.	–	6	74	.
Ropaži Municipality	14	.	–	.	.	13	.
Sēja Municipality	.	–	–	–	.	.	.
Stopiņi Municipality	36	.	–	.	.	23	.
Saldus Municipality	104	.	.	.	14	77	24
Brocēni Municipality	.	–	–	–	.	.	.
Talsi Municipality	54	.	–	.	.	47	34
Dundaga Municipality	–	–	–	–	–	–	–
Mērsrags Municipality	–	–	–	–	–	–	–
Roja Municipality	.	–	–	–	.	.	.
Tukums Municipality	105	.	–	.	7	82	37
Kandava Municipality	.	–	–	–	.	.	.

Engure Municipality	.	–	–	–	.	.	.
Jaunpils Municipality	.	–	–	–	.	.	.
Valka Municipality	68	.	.	.	.	36	.
Smiltene Municipality	172	–	–	–	.	168	.
Strenči Municipality	.	–	–	–	.	.	.
Kocēni Municipality	.	–	–	–	.	.	.
Mazsalaca Municipality	–	–	–	–	–	–	–
Rūjiena Municipality	.	–	–	–	.	.	.
Beverīna Municipality	.	–	–	–	.	.	.
Burtnieki Municipality	.	.	.	–	.	.	.
Naukšēni Municipality	.	–	–	–	.	.	.
Ventspils Municipality	.	–	–	–	.	.	.

.	Not published data due to its confidentiality
–	Non-detected phenomenon

To assess the current heat demand in municipalities and major cities in Latvia through the heat supplied to customers, a regression equation by municipalities and cities was created. Collected data on the population in municipalities and major cities was used to coin a regression equation and determine the amount of supplied heat. If there was no information available on certain cities and municipalities or respective data was not published due to its confidentiality, the heat demand was estimated based on the area of the municipalities (GWh/km^2).

2.1.1. Households

In the household sector, buildings are classified as residential in accordance with the National Real Estate Register Information System and occupancy stock statistics. Pursuant to the primary use, buildings are classified as (1) single occupancy, (2) double occupancy, (3) multiple (three or more) occupancy and (4) different social groups houses. The area and number of residential buildings are represented in Table 2.2. ([4])

TABLE 2.2. NUMBER AND AREA OF ENERGY-CONSUMING RESIDENTIAL AND NON-RESIDENTIAL BUILDINGS, 2017

Primary use	Number	Area, million m^2
Residential buildings		
Single-family houses	307 861	35.82
Two-apartment buildings	13 861	2.17
Multiple (three or more) apartment buildings	39 504	51.26
Various social groups	663	0.85
Total	361 889	90.10

It is apparent that the largest number of residential buildings by area falls within category of multiple (51.2 million m^2) and single-occupancy houses and single-occupancy, namely, private houses. In turn, the smallest number of residential buildings by area falls within category of double-occupancy houses. Figure 2.3 demonstrates changes in occupancy stock in Latvia over the period 2013-2018. It is evident that the total occupancy stock is slightly increasing, as well as the share of renovated buildings, but it accounts for a small part in relation to the total area of single-occupancy and multi-occupancy houses.

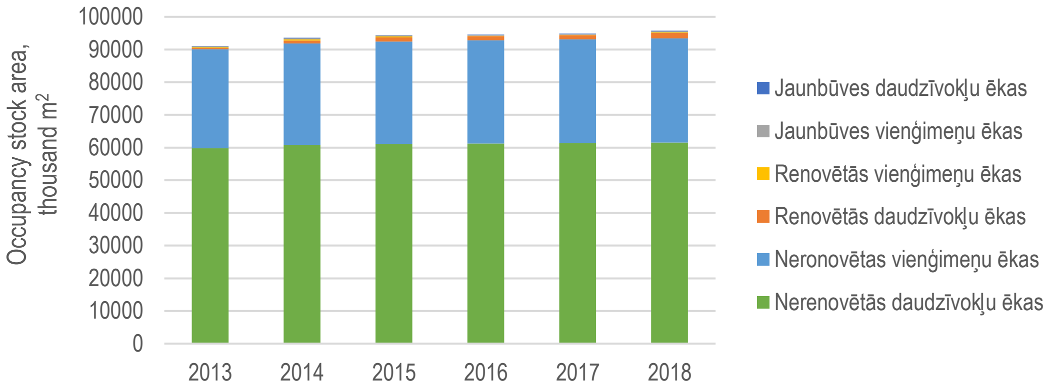


Figure 2.3. Breakdown and changes in occupancy stock over the period 2013-2018 [Data from the Central Statistical Bureau]

Jaunbūves daudzīvokļu ēkas - New build multi-occupancy houses; Jaunbūves vienģimeņu ēkas - New build single-occupancy houses; Renovētās vienģimeņu ēkas - Renovated single-occupancy houses; Renovētās daudzīvokļu ēkas - Renovated multi-occupancy houses; Nerenovētās vienģimeņu ēkas - Non-renovated single-occupancy houses; Nerenovētās daudzīvokļu ēkas - Non-renovated multi-occupancy houses

The household sector, as one of the largest consumers, is characterised not only by living area, but by the age of residential buildings, as well as being classified by thermal technical characteristics. According to 2017 data, the largest number of multi-occupancy houses were built over the period 2004-2009, with a total area of 2 480 thousand m² or 36 % of the total area of multi-occupancy houses. Another most active construction period of multi-occupancy houses fell within the period 1990-1995, with 23 % or 1 640 thousand m² of total area. (4)

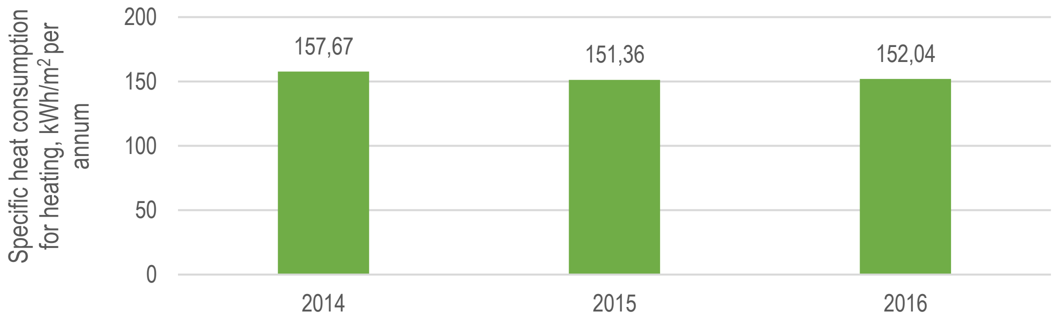


Figure 2.4. Average specific heating consumption by multi-occupancy houses (4)

The average specific heating consumption by multi-occupancy houses is gradually decreasing. This demonstrates that an increasing number of people are thinking about EE measures, building insulation, which resulted in decreased heating consumption.

Over the past five years, the household consumption of energy sources has varied. According to the CSB 2014 data, total consumption from all energy sources (including electricity) amounted to 14.16 thousand GWh compared to household sector consumption, which experienced a sharp decline in 2015, falling to 12.77 thousand GWh. The total household consumption of energy sources constituted 14 318.6 GWh in 2018, of which 12 % or 1.67 thousand GWh accounted for electricity. GWh. The remainder accounted for various types of fuel and district heating.

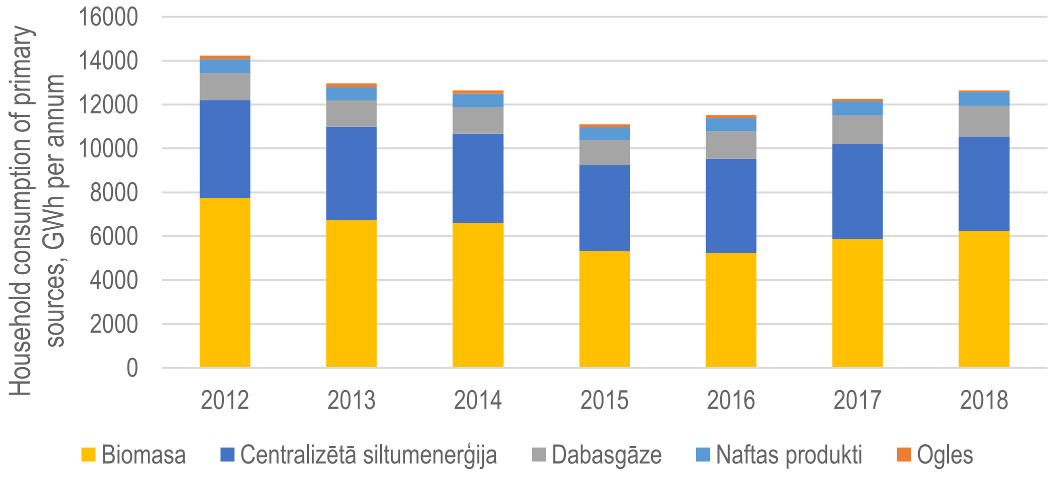


Figure 2.5. Breakdown of energy sources consumed by households over the period 2012-2018 [Data from the Central Statistical Bureau]

Biomasa - Biomass; Centralizētā siltumenerģija - District heating; Dabasgāze - Natural gas; Naftas produkti - Petroleum products; Ogles - Coal

According to an analysis of energy source consumption by sectors in 2018, households consumed 46 % of the total energy. According to Figure 2.5, the majority of energy consumed by households came from wood resources, at 43 %, or 6 218 GWh (mostly firewood), and heat from external suppliers, at 30 % (4 315 GWh). Electricity accounted for 12 % or 1 670 GWh of total energy consumption, natural gas for 10 % (1 388 GWh), oil products in total for 4 % (633 GWh) and coal for 1 %, or 77 GWh.

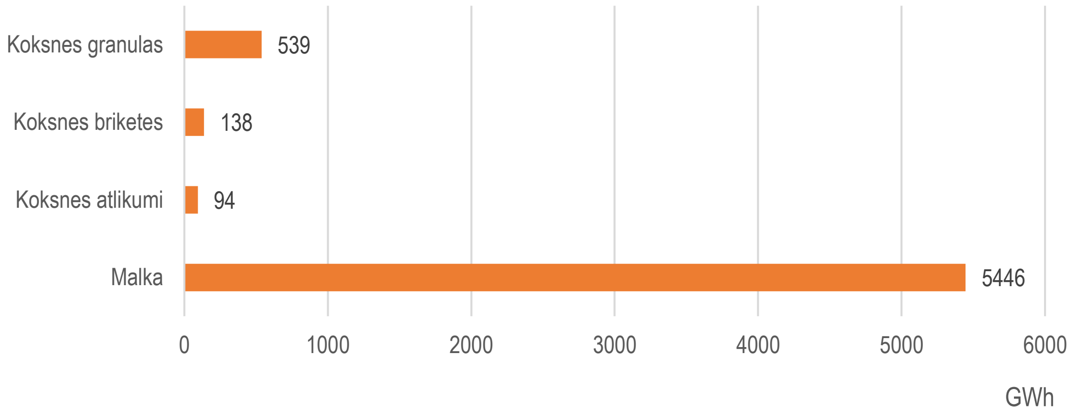


Figure 2.6. Breakdown of wood consumed by households, 2018 [Data from the Central Statistical Bureau]

Koksnes granulas - Wood pellets; Koksnes briketes - Wood briquettes; Koksnes atlikumi - Wood waste; Malka - Firewood

Of the total woodfuel consumed by households, 88 % or 5 446 GWh was firewood, 9 % (539 GWh) was wood pellets, 2 % or 138 GWh was wood briquettes, and 1 % or 94 GWh was wood waste. Over the last five years (2014-2018), the consumption of wood briquettes nearly doubled with 71 GWh consumed in 2014 and 138 GWh in 2018. While during the same period, the use of wood waste decreased from 213 GWh (2014) to 94 GWh (2018).

Households have consumed 63 % of the total final consumption of district heating since 2018. The established heat demand of the household sector in Latvia amounts to 15 500 GWh, of which 36 % is provided by the district heating system. The population of Latvia is 1 993 782, of which 67 % or 1 341 390 live in various cities (more than 56 % or 1 123 054 live in nine cities of the Republic), and the rest inhabit villages and rural areas, with the dominance of farmsteads, where district heating is irrelevant.

2.1.2. Industrial sector

Figure 2.7 shows the rapid rise in heat consumed by the industrial sector over a five-year period, an almost fourfold increase in 2018 compared to 2014. This increase resulted from the development of the industrial sector over the period 2014-2018, namely the establishment of new industrial enterprises requiring heat for the implementation of the processes.

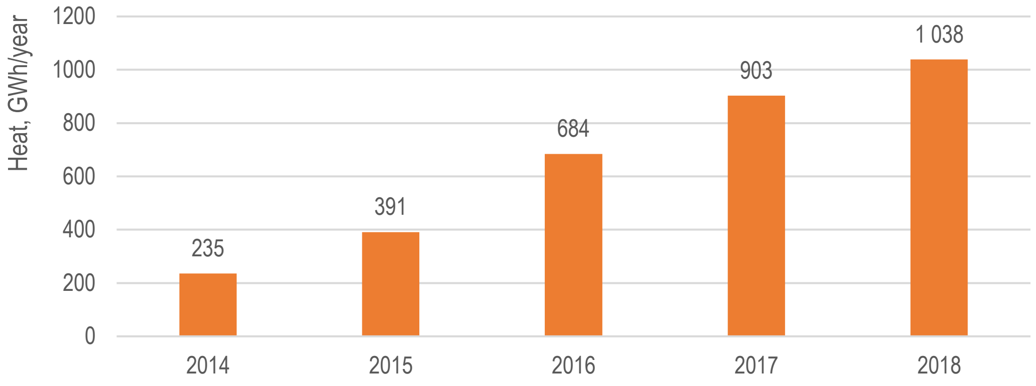


Figure 2.7. Heat consumed by the industrial sector over the period 2014-2018 [Data from the Central Statistical Bureau]

The industrial sector consumed 235 GWh in 2014 and 1 038 GWh in 2018. The total consumption of the three largest manufacturing industries in Latvia amounts to 79 % of energy consumed by the industrial sector. Since information related to commercial activities as subject to the requirements of Article 19 of the Commercial Law is not publicly disclosed and due to the limited availability of information on heat consumption by industrial companies for technological and heating needs, a heat demand of 0.8 TWh/year was established, which probably does not fully represent the actual demand.

2.1.3. Commercial and public sector

The commercial and public sector includes structures and buildings to be classified as non-residential buildings. As 2017 data indicates, this sector includes wholesale and retail buildings (4.92 million m^2), office buildings (6.51 million m^2), schools, universities and scientific research buildings (6.94 million m^2), hotel buildings (2.31 million m^2), medical or health care institution buildings (2.02 million m^2) and other commercial and public buildings.

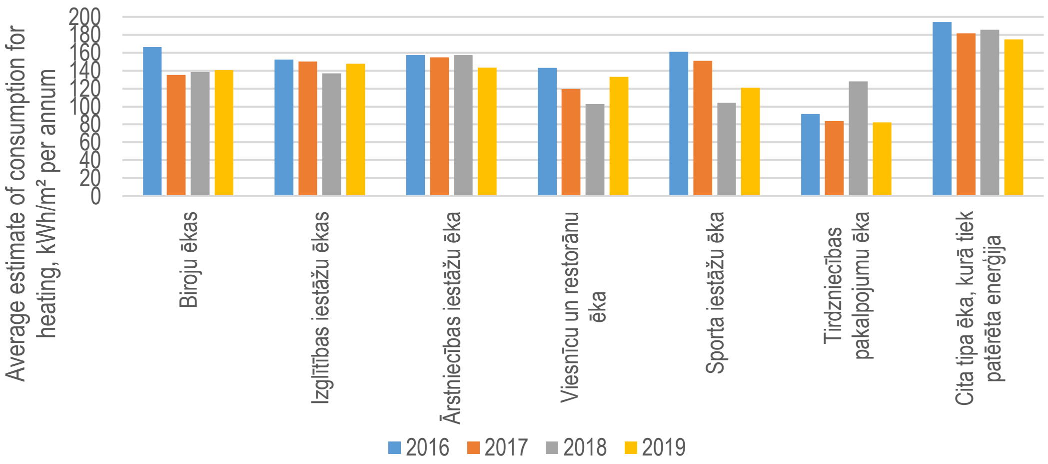


Figure 2.8. Average specific heating consumption by type of building ([24])

Biroju ēkas - Office buildings; Izglītības iestāžu ēkas - Educational buildings; Ārstniecības iestāžu ēka - Medical building; Viesnīcu un restorānu ēka - Hotel and restaurant building; Sporta iestāžu ēka - Sports building; Tirdzniecības pakalpojumu ēka - Trading services building; Cita tipa ēka, kurā tiek patērēta enerģija - Other type of energy-consuming building

The average specific consumption by multi-apartment buildings, as well as the specific heating consumption by the commercial and public sector demonstrates a tendency to decrease as a result of implemented EE measures such as building insulation. The most significant reduction is experienced in sports and office buildings. Analysing the four-year period, the reduction amounts to 25 % or 40 kWh/m^2 in sports buildings and to 16 % or 26 kWh/m^2 in office buildings.

In total, the amount of heat consumed (GWh) varies over the five-year period (see Figure 2.9). The heat consumption depends on the outdoor air temperature, the technical condition of the building and the behavioural changes of citizens or energy savings. An analysis of the heat consumption by the commercial and public sector demonstrates steady demand for heat over the two-year period 2014-2015, with sharp increase in 2016. Thus the demand for heat increased by 194 GWh. On the other hand, there was a decrease in the demand for heat over the period 2017-2018, which can also be explained by the lower average temperature during the heating season.

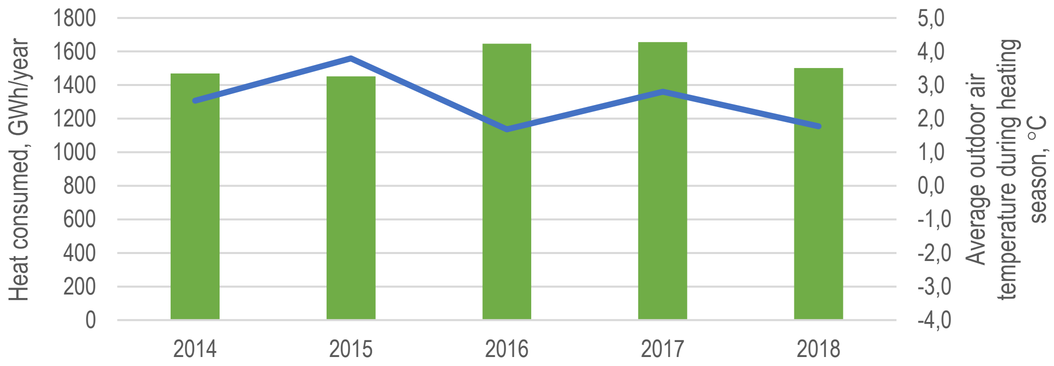


Figure 2.9. Heat consumed by the commercial and public sector [Data from the Central Statistical Bureau]

The service sector in Latvia is mostly comprised of tourism, entertainment and services. The area of the service sector by building groups was determined by employing the National Real Estate Register Information System (NRERIS). ([4]) The heat demand amounting to 3.9 TWh in 2014 was determined with respect to the specific heat consumption of each group of buildings per m^2 of area. Most of the heat is consumed by the private sector, mainly consisting of for office buildings (819 GWh), wholesale and retail buildings (476 GWh) and hotels (319 GWh). While in the public sector, the major consumers are schools (794 GWh) and hospitals (253 GWh).

2.1.4. Demand for cooling

No information is currently available regarding actual cooling requirements for premises in Latvia. The national cold energy consumption can be estimated through three different parameters: the average specific cold energy consumption per building area, the building area and the cold energy utilisation rate denoting the cooled area. The specific cold energy consumption varies considerably across different types of buildings. Compared to residential buildings, it is much higher in service sector buildings (office, educational buildings, hotels, healthcare, commercial, sports buildings, etc.). However, the cold load in these buildings varies due to differences in the microclimate requirements.

([24]) Construction information system

The cold load can be estimated through electricity consumption and the standard cooling power ratio. It is difficult to define the electricity consumption of coolers specifically, therefore, a European cooling factor was introduced to assess and understand the differences in the building cooling requirements of different European countries. ([25]) The combination of data on the European cooling factor and the measured cold energy consumption for European district cooling systems results in the ability to estimate the cold energy consumption. Table 2.3 summarises the cold energy consumption by different public service buildings and the corresponding European cooling factor.

An analysis of cold loads in Sweden reveals that almost half of the cold energy supplied is consumed by service buildings with the remainder consumed by other types of buildings, e.g. in technological processes. The national average cold energy consumption is established at about 45 kWh/m^2 with DCS in use. ([26])

TABLE 2.3. SPECIFIC COLD ENERGY CONSUMPTION AND COOLING FACTOR BY VARIOUS SERVICE BUILDINGS ([26])

Location	Source	Cooling factor	Specific cold energy consumption, kWh/m^2
Lisbon	Consumer	104	92
Stockholm	Consumer	73	56
Solna	Consumer	73	30
Gothenburg	Consumer	61	49
Helsinki	Consumer	72	39
Paris	Consumer	95	83
Sweden	National average	73	45
Stockholm, Fortum	System average	73	42
Gothenburg, Energy	System average	61	37
Helsinki, Helen	System average	72	25
Trondheim, Statkraft	System average	48	24
Grenoble, CCIAG	System average	110	88
Courbevoie, Enertherm	System average	95	77
Paris, Climespace	System average	95	77
Lyon, Elvya	System average	112	77
Geneva, SIG	System average	85	42
Brescia, A2A	System average	138	123
Barcelona, Districlima	System average	121	124

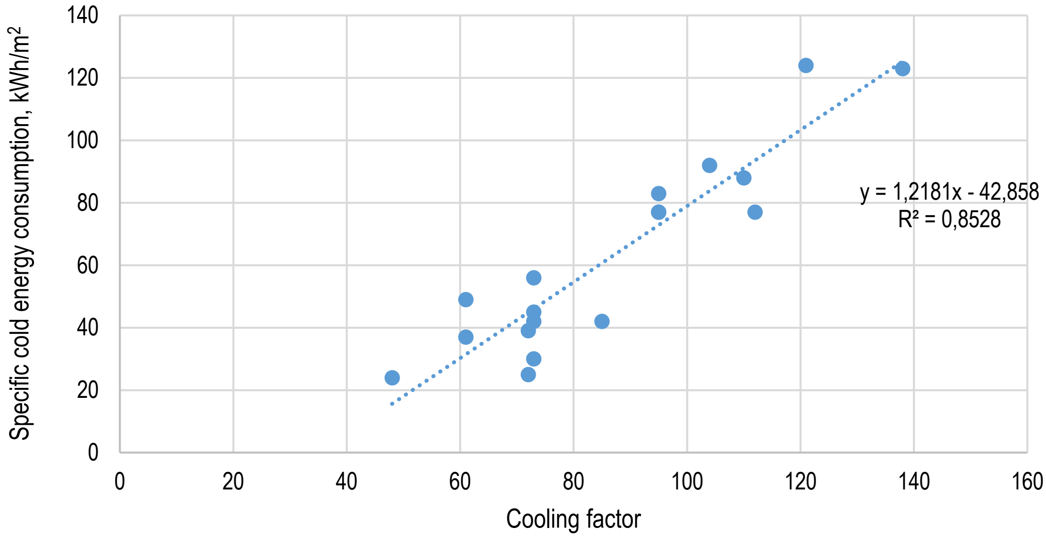
There is little research on the cold load of buildings in Latvia and its changes during the year. In his dissertation, Dz. Jaunzems simulated the cold load for a specific office building with a total area of 772 m^2 and the cooling required within certain area of 524 m^2. The share of the glass area is low, about 12 % of the building's exterior facade. The facades are oriented mainly to the northwest and southeast. Simulation results for such a building indicate a maximum cold load of 17.8 kW and an average of 5.4 kW per annum. The cold load duration of the building is 676 h/year. The estimated specific cold load consumption of the building is 6.97 kWh/m^2. It is noteworthy that this value cannot not be directly extrapolated for other buildings with different factors affecting heat gains.

According to the research performed ([26]), the normalised cooling factor for Latvia is 85. Considering the derived regression equation for the relationship between the cooling factor and the average specific cold energy consumption, the estimated average specific cold energy consumption in Latvia amounts to 61 kWh/m^2. Using the regression analysis equation from Figure

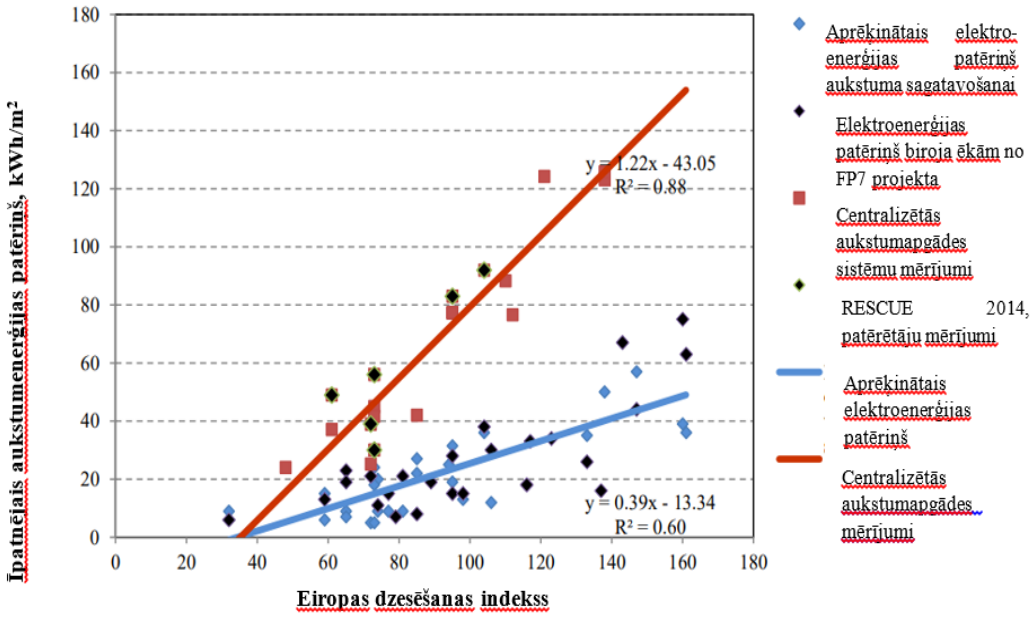
([25]) Dalin P., Nilsson J., Rubenhag A. The European cold market, WP2 report from the Ecoheatcool project. IEE Ecoheatcool project. Brussels, 2005. Available online: https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/ecoheatcool_the_european_cold_market_final_report.pdf.

([26]) Persson U., Werner S. Quantifying the Heating and Cooling Demand in Europe. 2015. Available online: https://heatroadmap.eu/wp-content/uploads/2018/09/STRATEGO-WP2-Background-Report-4-Heat-Cold-Demands.pdf

2.10 b) derived from electricity consumption by different office buildings, the specific cooling consumption in Latvia amounts to 19.81 kWh/m². The specific cooling consumption data would be more accurate if derived from the energy performance certificates of buildings, but the State Construction Control Bureau has no obligation prescribed by the current regulatory enactments to compile such information.



a)



b)

Figure 2.10. Different regression analysis results of cooling factor and specific cold energy consumption [*for translation, please see (4) in accompanying document*]

Available data on the number and area of energy-consuming residential and non-residential buildings was used to determine the potential area of cold energy consuming buildings (4). Information on areas was compiled under the assumptions made in previous research on cold load in Europe, and approximate cold energy consumption by residential, service and commercial buildings was established (see Table 2.4). Proceeding from the relevant assumptions on the share of cooled buildings and the specific cold energy consumption by certain types of buildings, the estimated cold energy consumption by residential buildings was established at 216 GWh, and by services and commercial sector buildings at 419 GWh.

TABLE 2.4. ESTIMATED COLD ENERGY CONSUMPTION BY RESIDENTIAL AND SERVICE AND COMMERCIAL BUILDINGS IN LATVIA

Type of buildings	Area, million m^2	Share of cooled buildings, %	Specific cold energy consumption, kWh/m^2	Cold energy consumption, GWh
Residential buildings of different types	90.1	10 %	24	216
Service and commercial buildings (27)	26.4	30 %	53	419

The cold energy is used by the industrial sector both for buildings' microclimate control and in various production processes. The cold energy consumption by the industrial sector is derived from energy audit data on companies' total electricity consumption and electricity consumption for cooling purposes (28). The share of cooling consumption of the total electricity consumption is determined for each sector. With regard to the sectors where data on the share of cooling consumption is not available, an average from other sectors is applied.

TABLE 2.5. ELECTRICITY CONSUMPTION FOR COOLING BY VARIOUS INDUSTRIAL SECTORS

Industrial sector	Electricity consumption, GWh	Share of cooling consumption, %	Electricity consumption for cooling, GWh
Manufacture of rubber and plastic products, furniture and other manufacturing	78	9.5 %	7.5
Manufacture of food products; manufacture of beverages; manufacture of tobacco products	288	8.0 %	23.1
Manufacture of metals	14	5.4 %	0.8
Manufacture of paper and paper products; printing and reproduction of recorded media	28	4.1 %	1.1
Manufacture of motor vehicles, trailers and semi-trailers Manufacture of other transport equipment	47	1.2 %	0.5
Manufacture of textiles, clothing, leather and leather products	30	0.7 %	0.2
Manufacture of non-metallic mineral products	261	0.4 %	1.1
Manufacture of metal products	89	0.2 %	0.2
Manufacture of wood and timber and cork products	762	0.0 %	0.1
Manufacture of chemicals and chemical products; manufacture of basic pharmaceutical products and pharmaceutical preparations	64	n/a	1.1

(27) Wholesale and retail buildings, Office buildings, Hotel buildings, Other short-stay accommodation buildings, Schools, universities and scientific research buildings, Medical or health care institution buildings, Entertainment buildings, Sports buildings, Museums and libraries, Religious buildings

(28) Data compiled under the agreement reg. No 03000-3.3.2-e/13 dated 20 May 2019, signed between the Ministry of Economics of the Republic of Latvia and Riga Technical University, on the provision of access to data for the purpose of application and elaboration in scientific investigations.

Manufacture of other metals	5	n/a	0.1
Mining and quarrying	28	n/a	0.5
Construction	68	n/a	1.2
Total consumption	1 763	3 %	37

The total amount of electricity for cooling is determined by attributing the share of cooling consumption to the total electricity consumption ([29]) by each sector (see Table 2.5). Assuming that cold energy is produced in local refrigerating appliances with an approximate average COP value of 3, the total cold energy consumption by the industrial sector of 112 GWh can be derived from the electricity consumption for cooling.

2.2. Identified or determined heating and cooling systems currently in use, broken down by type of technology used

Heating technologies across sectors can be broken down into two main categories – on-site heat production technologies and off-site heat production technologies. The first type of technology characterise mainly the household and services sectors. This category includes heat-only boilers, high-efficiency heat and electricity cogeneration technologies, heat pumps and other local heat production technologies and heat sources. The second category consists of high-efficiency heat and electricity cogeneration technologies, the use of waste heat for heat production purposes and other technologies and heat sources used off-site.

In Latvia, heat is supplied through various technologies and different resources on-site or off-site. Multi-criteria analysis and AHP were applied and a number of alternatives with regard to the heating company's technology and resource selection trends were assessed to define the criteria weights. The survey conducted among heating sector representatives and Riga Technical University experts resulted in the determination of the criteria weights.

This study is based on a multi-criteria analysis with TOPSIS analysis criteria weights derived through AHP.

The AHP method is based on a pairwise comparison. AHP is widely used both as a separate method of analysis and to estimate the degree of relevance or weight of criteria, which are further used in another multi-criteria decision-making method. For more than a decade, AHP has been the most widely applied multi-criteria decision-making method. ([30]) Hereafter follows a brief description of AHP in the estimation of criteria weights pursuant to the method used in R. K. Kansal's study on the sustainable development contribution of renewable energy projects. ([31]) The AHP method is based on the compilation of a pairwise comparison matrix A reflecting the decision-maker's choice of different criteria's relative importance.

It is assumed that a_{jk} stands for matrix A element (*j, k*). If the criteria j and k are equally relevant a_{jk} will be equal to 1 (a_{jk}=1). If a_{jk} = 5, criterion j is five times more relevant than criterion k, if a_{jk} = 9, criterion j is absolutely more relevant than k. Other possible a_{jk} values between 1 and 9 are interpreted according to the above pattern. A scale from 1 to 9 is the most commonly used rating scale; still, a different interval can be selected depending on the specific nature of a study. To ensure the unambiguity of matrix data, a_{jk}= b means by default a_{jk} = 1/b, and the values of the matrix A diagonal elements shall be equal to 1, since the criterion is compared to itself. Upon compilation of such a matrix, the elements of each column are divided by the sum of the elements in that column, thus obtaining the normalised weighted matrix N elements $\bar{a}_{jk}$.

$$\bar{a}_{jk} = \frac{a_{jk}}{\sum_{i=1}^{m} a_{jk}} \quad (2.1)$$

The relative criteria weight is calculated as the average of each row of matrix N. The criteria weight vector w_j is derived by summing the value $\bar{a}_{jk}$ in each column and dividing by the number of columns m.

$$w_j = \frac{\sum_{i=1}^{m} \bar{a}_{jk}}{m} \quad (2.2)$$

([29]) CSB. ENG020. Energy balance, TJ, thousands toe (NACE Rev. 2), 2017.
([30]) A. Mardani, A. M. Multiple criteria decision-making techniques and their applications -A Review of the Literature from 2000 to 2014. Economic Research 28(1), 2015, 516-571.
([31]) Kansal, R. K. Sustainable development contribution assessment of renewable energy projects using AHP and compromise programming techniques. 2015 International Conference on Energy, Power and Environment: Towards Sustainable Growth (ICEPE), (pp. 1-6). Shillong.

If the analysis is aimed at both determining the criteria weight, as R. K. Kansal ([31]) did, and comparing the alternatives, as in the Keeleya and Matsumotoc ([32]) studies, the assessment of alternatives shall be calculated next.

Keeleya was the first to propose TOPSIS as a method for determining the best alternative in 1981 ([33]). Unlike the multi-criteria decision-making AHP method described above, TOPSIS is based on comparing each alternative to the ideal possible solution, rather than on comparing alternatives to each other. TOPSIS allows the use of both quantitative values, such as the raw material cost (EUR/MWh), and qualitative indicators, and the comparison of alternatives to each other in order to choose the appropriate one. TOPSIS is widely used in research on the use of various renewable sources, for example in the analysis of the social impact of bio-methane production throughout its life cycle ([34]) or selecting the optimal biomass cogeneration parameters ([35]). TOPSIS process results in an assessment of alternatives by their distance both to the best possible and the worst possible solution. The evaluation derived allows alternatives to be compared to each other and the most appropriate one to be selected.

To start data analysis through the TOPSIS method, the input matrix shall be created as shown in the figure.

$$\begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccccc} x_1 & x_2 & \cdots & x_j & \cdots & x_n \end{array} \\ \begin{bmatrix} x_{11}^k & x_{12}^k & \cdots & x_{1j}^k & \cdots & x_{1n}^k \\ x_{21}^k & x_{22}^k & \cdots & x_{2j}^k & \cdots & x_{2n}^k \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ x_{i1}^k & x_{i2}^k & \cdots & x_{ij}^k & \cdots & x_{im}^k \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ x_{n1}^k & x_{n2}^k & \cdots & x_{nj}^k & \cdots & x_{nm}^k \end{bmatrix} \end{array} \tag{2.3}$$

Alternatives are expressed as $A_1, A_2, .., A_n$, criteria as $x_1, x_2, \ldots, x_n$. The matrix elements x_{ij} denote the criteria values. Each of the criteria has a different range of values (e.g. the amount of energy produced can be in thousands of kWh, while LCOE values can be below 1), so they need to be normalised for comparability purposes. Normalisation is carried out using the following formula:

$$b_{ij} = x_{ij} / \sqrt{\sum_{i=1}^{n} x_{ij}^2} \tag{2.4}$$

Normalised data is placed in a matrix and multiplied by predetermined criteria relevance factors (w_j). Criteria relevance factors or weights are usually determined by field experts. Other MCDM methods, such as the AHP method, can be applied to determine the criteria weights as well.

$$\begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccccc} w_1 b_1 & w_2 b_2 & \cdots & w_j b_j & \cdots & w_n b_n \end{array} \\ \begin{bmatrix} w_1 b_{11}^k & w_2 b_{12}^k & \cdots & w_j b_{1j}^k & \cdots & w_n b_{1n}^k \\ w_1 b_{21}^k & w_2 b_{22}^k & \cdots & w_j b_{2j}^k & \cdots & w_n b_{2n}^k \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ w_1 b_{i1}^k & w_2 b_{i2}^k & \cdots & w_j b_{ij}^k & \cdots & w_n b_{im}^k \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ w_1 b_{n1}^k & w_2 b_{n2}^k & \cdots & w_j b_{nj}^k & \cdots & w_n b_{nm}^k \end{bmatrix} \end{array} \tag{2.5}$$

([32]) Keeleya, A. R., & Matsumotoc, K. Relative significance of determinants of foreign direct investment in wind and solar energy in developing countries – AHP analysis. Journal of Cleaner Production, 1-8, 2017

([33]) Hwang CL, Y. K. Methods for multiple attribute decision making. Multiple attribute decision making. 1981.New York.: Springer

([34]) Slisane, D., Romagnoli, F., Kamenders, A., Veidenbergs, I., & Blumberga, D. Co-digestion of algae biomass for production of biogas and fertilizer: Life Cycle Cost Analysis. Environment. Technology. Resources: Proceedings of the 10th International Scientific and Practical Conference, 2015, 18-20.

([35]) Cimdiņa, G. S. (214). Sustainable Development of Renewable Energy Resources. Biomass Cogeneration Plant. The 9th International Conference.

The following TOPSIS step is the identification of the positive ideal and negative ideal solution (namely, the best theoretical and worst theoretical alternative based on all the criteria used).

The estimation of the ideal positive solution (A^+) and the ideal negative solution (A^-) depends on the values that the decision maker considered as the best for a particular criterion:

1. If decision makers consider the highest (maximum) value for a particular criterion as preferred, the following formula is applied:

$$A^+ = \max_i w_j b_{ij} \tag{2.6}$$

$$A^- = \min_i w_j b_{ij} \tag{2.7}$$

2. If decision makers consider the minimal value as preferred:

$$A^+ = \min_i w_j b_{ij} \tag{2.8}$$

$$A^- = \max_i w_j b_{ij} \tag{2.9}$$

The distance from the alternative to the positive ideal solution (S^+) is calculated as follows:

$$S^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2}, \text{ i = 1, 2, ..., m} \tag{2.10}$$

The distance/ratio from the alternative to the ideal negative solution (S^-) is calculated as follows:

$$S^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2}, \text{ i = 1, 2, ..., m} \tag{2.11}$$

The last step is the estimation of a relative distance from the alternative to the ideal solution:

$$\boldsymbol{C_i^*} = \frac{\boldsymbol{S_i^-}}{(\boldsymbol{S_i^+} + \boldsymbol{S_i^-})}, \text{ i = 1, 2, ..., m} \tag{2.12}$$

Determination of criteria weights

As part of this research, there are four aspects or criteria selected for the assessment of alternatives: investment costs, raw material costs, GHG emissions and the area for energy production. The authors asked a group of 30 experts – energy and heating specialists and professionals – who had participated in the seminar and discussion 'Development of heating and cooling in Latvia in the context of the EU Directive' to perform a comparative analysis of the criteria. For readability purposes, ratings on a scale from 1 to 4 were used. The average values of the expert assessment served as input data in estimating the criteria weights using the AHP method. The input matrix is shown in Table 2.6.

TABLE 2.6. SURVEY FINDINGS

RELATIVE IMPORTANCE OF CRITERION **J** (COLUMN) COMPARED TO CRITERION **K** (ROW) ON A SCALE FROM 1 TO 4 WHERE: 1 – CRITERIA ARE EQUALLY RELEVANT; 4 – CRITERION **J** IS ABSOLUTELY MORE RELEVANT THAN CRITERION **K**.

Criterion k / Criterion j	Investment costs	Raw material costs	GHG emissions	Area for energy production
Investment costs	1	1.11	1.59	2.04
Raw material costs	0.90	1	1.6	2.38
GHG emissions	0.63	0.63	1	2.05
Area for energy production	0.49	0.42	0.49	1

According to the survey summary, field experts perceive investment costs as the most important criterion in selecting the heating technology, with the raw material costs criterion lagging slightly behind in terms of relevance. The area for heat production is the least significant among the four criteria. The next step in the AHP analysis is the development of the normalised matrix and the calculation of the criteria weight (see Table 2.7).

TABLE 2.7 . NORMALISED MATRIX AND CRITERIA WEIGHTS

	Investment costs	Raw material costs	GHG emissions	Area for energy production	Criteria weight
Investment costs	0.33	0.35	0.34	0.27	0.32
Raw material costs	0.30	0.32	0.34	0.32	0.32
GHG emissions	0.21	0.20	0.21	0.27	0.22
Area for energy production	0.16	0.13	0.10	0.13	0.13

The derived criteria weights were further used for the assessment of the alternatives to heating technologies using the TOPSIS method.

Assessment of heating technology alternatives

Six heat production alternatives (renewable and non-renewable sources boiler house, renewable and non-renewable sources cogeneration, heat pump and heat production through solar energy) were assessed through TOPSIS using the four criteria mentioned above. Two of the criteria used are quantitative, i.e. raw material costs (EUR/MWh) and GHG emissions ($tCO_{2ekv.}$/MWh); the other two criteria were assessed by performance 'grades' on a scale from 1 to 4, where 1 stands for relatively low investment costs (land use) and 4 stands for very high investment costs (excessive land area required).

Raw material cost data was retrieved from the *Baltpool* Energy Exchange Report on energy source prices in the Baltic States. ([36]) Regarding cogeneration, it was assumed that fuel costs are divided between electricity and heat production in a ratio of 60 % to 40 %. The natural gas GHG emission rate used in this study is 0.240 $tCO_{2\text{-}ekv}$/MWh. ([37]) Natural gas cogeneration GHG emissions were estimated following the same logic as for fuel costs.

The initial decision-making matrix with inputs and AHP defined criteria weights are presented in Table 2.8.

TABLE 2.8. TOPSIS INITIAL DECISION-MAKING MATRIX

		Criteria			
		Investment costs	Raw material costs, EUR/MWh	GHG emissions, tCO_2-ekv / MWh	Area for energy production
Alternatives	Boiler house, renewable sources	1	15.97	0	3
	Boiler house, fossil sources (natural gas)	1	17.27	0.24	1
	Heat pump	4	0	0	2
	Cogeneration, renewable sources	2	6.39	0	3
	Cogeneration, fossil sources (natural gas)	2	6.908	0.096	1
	Solar energy (collectors)	4	0	0	2
Criteria weights		0.32	0.32	0.22	0.15

Table 2.9 shows the normalised weighted decision-making matrix.

TABLE 2.9. NORMALISED WEIGHTED DECISION-MAKING MATRIX

([36]) Baltpool energy exchange. Baltpool energy exchange report January 2019.
([37]) Koffi, B. C.-M. CoM Default Emission Factors for the Member States of the European Union. Dataset Version 2017. the Joint Research Centre of the European Commission.

	Investment costs	Raw material costs	GHG emissions	Area for energy production
Boiler house, renewable sources	0.0494	0.2017	0.0000	0.0737
Boiler house, fossil sources (natural gas)	0.0494	0.2181	0.2043	0.0246
Heat pump	0.1975	0.0000	0.0000	0.0491
Cogeneration, renewable sources	0.0988	0.0807	0.0000	0.0737
Cogeneration, fossil sources (natural gas)	0.0988	0.0873	0.0817	0.0246
Solar energy (collectors)	0.1975	0.0000	0.0000	0.0491

In this case, all criteria have preferred minimal values, therefore formulas (2.8) and (2.9) are used to derive a positive ideal solution (A^+) and a negative ideal solution (A^-) for each criterion. The distances from the alternative to the positive ideal solution (S^+) and the negative ideal solution (S^-) were calculated next, and finally, the relative distance of the alternatives to the ideal solution (C*) was also calculated. The TOPSIS analysis results are presented in Table 2.10 and Figure 2.11.

TABLE 2.10. DISTANCE FROM EACH ALTERNATIVE TO THE IDEAL SOLUTION (C *)

	Investment costs	Raw material costs	GHG emissions	Area for energy production	S+	S-	C*
Boiler house, renewable sources	0.05	0.20	0.00	0.07	0.2076	0.2874	0.58
Boiler house, fossil sources (natural gas)	0.05	0.22	0.20	0.02	0.2988	0.2891	0.49
Heat pump	0.20	0.00	0.00	0.05	0.1502	0.3413	0.69
Cogeneration, renewable sources	0.10	0.08	0.00	0.07	0.1066	0.2817	0.73
Cogeneration, fossil sources (natural gas)	0.10	0.09	0.08	0.02	0.1293	0.2572	0.67
Solar energy (collectors)	0.20	0.00	0.00	0.05	0.1502	0.3413	0.69
A+	0.05	0.00	0.00	0.02			
A-	0.20	0.22	0.20	0.07			

Ratings of estimated alternatives can be presented as a bar chart and compared to each other (see Figure 2.11)

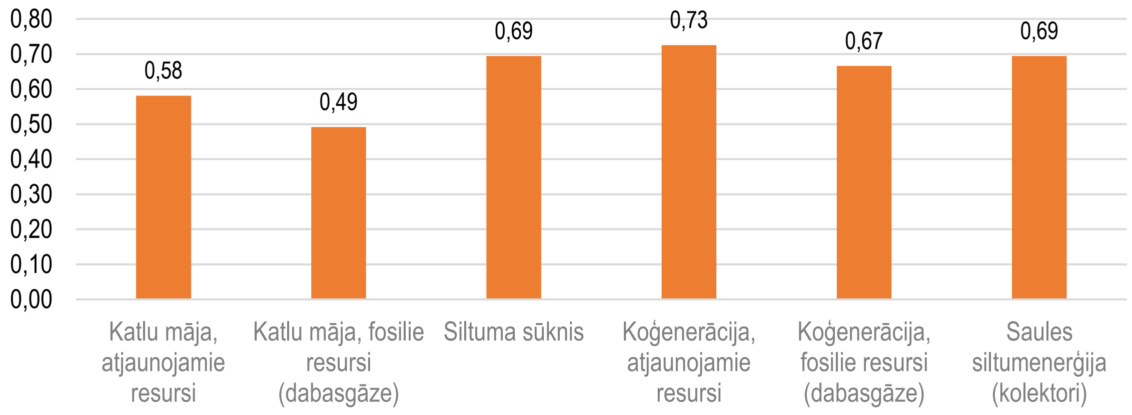


Figure 2.11. Comparison of alternatives ratings

Katlu māja, atjaunojamie resursi - Boiler house, renewable sources; Katlu māja, fosilie resursi (dabasgāze) - Boiler house, fossil sources (natural gas); Siltuma sūknis - Heat pump; Koģenerācija, atjaunojamie resursi - Cogeneration, renewable sources; Koģenerācija, fosilie resursi (dabasgāze) - Cogeneration, fossil sources (natural gas); Saules siltumenerģija (kolektori) - Solar energy (collectors)

The results demonstrate that four alternatives (heat pump, renewable sources cogeneration, natural gas cogeneration and solar energy use) are relatively close to each other. Cogeneration using renewable sources is the nearest alternative to the ideal positive solution, but it is closely followed by heat pumps and solar collector heating. According to an assessment by research criteria, these two alternatives have the same rating and are closer to an ideal positive solution than non-renewable sources (natural gas) cogeneration. It should be noted that an assumption was made for the purposes of this research, i.e. all electricity used by heat pumps is produced from renewable sources and therefore heat pumps do not emit GHG.

2.2.1. Breakdown of household sectors by technologies used for heat provision

The technologies used by the household sector are on-site heat production technologies (in this case households use heat-only boilers, heat pumps and solar collectors). Data analysis (CSB data) was performed and assumptions were made to assess the technologies used by households and the heat produced through these technologies. According to CSB data, household equipment for heat provision is divided up as follows:

- district heating boilers;
- hot water boilers;
- combined district heating and hot water boilers;
- domestic furnaces;
- economic furnaces;
- cooking stoves.

These technologies use both fossil and renewable fuels. Fossil sources include coal and natural gas, while renewable sources include firewood, wood waste, wood briquettes and wood pellets. To assess the heat produced, assumptions were made regarding the use of sources and the boiler efficiency ratios.

TABLE 2.11. CALCULATION ASSUMPTIONS FOR THE HOUSEHOLD SECTOR

Type of fuel	Boiler efficiency	Resources used for cooking, %
Coal	0.75	n/a
Natural gas	0.90	20
Firewood	0.75	7.3

Timber offcut	0.70	n/a
Wood briquettes	0.85	n/a
Wood pellets	0.85	n/a

The calculation considered that firewood and natural gas are used by households for both heat production and for cooking. According to the CSB data, 20 % of the total sources consumption corresponds to natural gas for cooking, and 7.3 % to firewood.

In 2018, the heat produced through technologies for heat provision in households amounted to 5 485 GWh, of which 4 314 GWh was used as per energy source allocation. The calculation assumes that the sources considered are used along with water heaters and room stoves using fossil sources or RES respectively. According to the breakdown of energy resources, 83 % corresponds to RES, while 17 % corresponds to fossil sources.

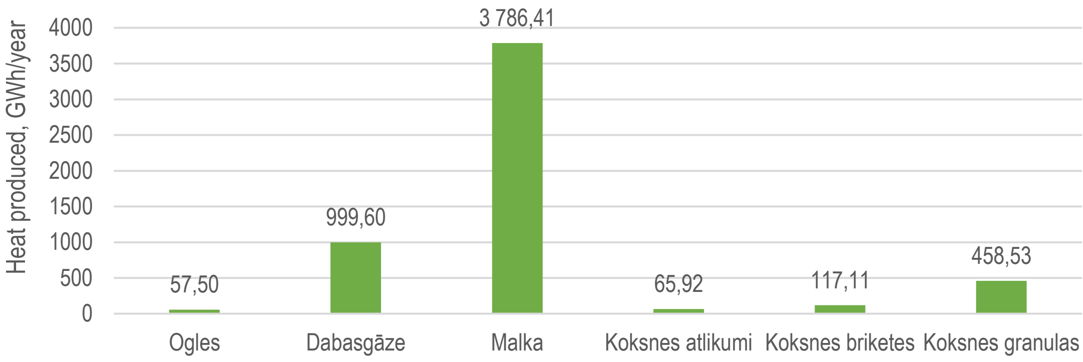


Figure 2.12. Heat produced by technology and fuel used, 2018 [Data from the Central Statistical Bureau]

Ogles - Coal; Dabasgāze - Natural gas; Malka - Firewood; Koksnes atlikumi - Wood waste; Koksnes briketes - Wood briquettes; Koksnes granulas - Wood pellets

Technologies employed for heat provision in the domestic sector include boilers and stoves using firewood and natural gas as fuel. Wood pellets and briquettes are used as fuel for stoves (efficiency 0.85) for thermal energy. Some households use coal (1 %) and wood waste (1 %) as fuel for the technologies listed, but the share of these types in the total energy consumption is relatively small.

Latvia's household sector is evolving and people are becoming increasing more aware about EE measures, and are introducing RES and climate technologies in their households. In 2011 and 2012 in Latvia, there was a two-round call for the EU Climate change financing instrument project 'The use of Renewable Sources in the Household Sector'. ([38]) This type of support for the use of RES by the household sector provides an opportunity to collect data and assess the situation regarding the introduction of climate technologies, such as heat pumps and solar collectors, for the provision of heat in households. The database of implemented projects provides information on the technology used, the output and the efficiency ratio of the installed technology. In total, 692 heat pump projects and 604 solar collector projects for heat provision were implemented in the household sector in municipalities throughout Latvia.

TABLE 2.12. USE OF SOLAR COLLECTORS FOR HEAT PROVISION ([30])

([38]) Climate change financing instrument. Tender: Use of renewable energy sources by the household sector. Available online: http://kpfi.lv/modules/Konkurs/projekti.php?id=1&lang=lv (Tier I), http://kpfi.lv/modules/Konkurs/projekti.php?id=2&lang=lv (Tier II).

Year	Average installed output, kW	Total installed output, kW	Specific produced amount, kWh/MWh	Produced per annum, MWh
2011	5.5	3 250	1 020	3 315
2012	5	1 597	1 020	1 629

The summary data on projects for heat production through solar collectors installation reveals that the technologies selected have an average installed output of 5-5.5 kW. Meanwhile, total installed output amounted to 3 250 kW in 2011 and 1 597 kW in 2012. The specific output for solar collectors is assumed to be 1 020 kWh/MWh. As a result, 3 315 MWh/year (2011) and 1 629 MWh/year (2012) were produced by the household sector through the installation of solar collectors.

Based on an evaluation of projects related to the installation of heat pumps in households, the average output was 12.5 kW in 2011 and 11.1 kW in 2012. The average COP was 4.7 and 4.6, respectively. The total installed output by established indicators was 4 722 kW in 2011 and 3 482 in 2012. Similar to solar collector installation data, more heat pumps were installed in 2011 than in 2012.

TABLE 2.13. USE OF HEAT PUMPS FOR HEAT PROVISION ([30])

Year	Average output, kW	Average COP	Total installed output, kW	Produced per annum, MWh
2011	12.5	4.7	4 722	12 561
2012	11.1	4.6	3 482	37 445

To estimate the amount of heat produced in 2011 and 2012, assumptions will be made as to the load factor and the operating time (h) of the unit concerned.

TABLE 2.14. ASSUMPTIONS CONCERNING THE USE OF HEAT PUMPS FOR HEAT PROVISION

Load factor	1	0.87	0.74	0.61	0.48	0.36
Operating time, h/year	128	180	422	1 200	2 000	1 000
Produced, MWh/year 2011	604	740	1 479	3 477	4 579	1 681
Produced, MWh/year 2012	4 087	3 884	4 578	7 803	11 132	5 962

The calculation of the heat produced (MWh) considers the load factor and the operating time (h) of the heat pump concerned.

This type of support project analysis allows the implementation of RES technologies determined by market conditions to be assessed, i.e. the range of the selected energy production technologies may vary.

2.2.2. Breakdown of industries by technology used

In the industrial sector, the identified heat supply by technologies used can be broken down as follows: heat-only boilers and high-efficiency heat and power generation. The Gaiss-2 database was used to analyse the industrial sector in Latvia in the case of supply provided on-site. An algorithm was developed to analyse enterprises in Latvia using heat generation technologies in their product manufacturing process and to obtain a breakdown of data by municipality and the amount of heat produced (GWh) as regards technologies and types of sources used.

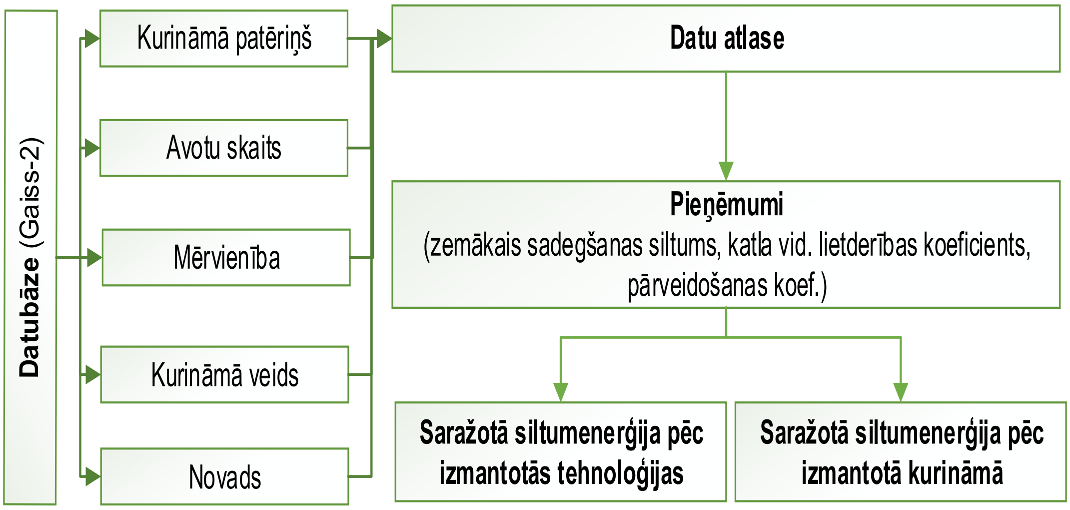


Figure 2.13. Algorithm for industry analysis by technology and fuel used [for translation, see (5) in accompanying document]

To process database data and create a breakdown of the industrial sector by the technologies and the energy resources used, assumptions were made based on the available literature and database.

TABLE 2.15. CALCULATION ASSUMPTIONS FOR THE INDUSTRIAL SECTOR

Fuel, unit of measurement	Lower heating value	Value (source)		Source	Average boiler efficiency
Diesel fuel, MWh/tonne	11.94	43	MJ/kg	Regulation of the Cabinet of Ministers No 42 Methodology for the calculation of greenhouse gas emissions	0.80
Pellets, MWh/tonne	5.00	18	MJ/kg	Data from the Central Statistical Bureau	0.85
Firewood, MWh/tonne	3.65	13.15	MJ/kg	J. Dolacis, E. Tomsons, J. Hrols. Fuel wood comparison with other types of fuel// Environment Technology Resources, 2003	0.75
Wood chips, MWh/tonne	2.84	10.24	MJ/kg	J. Dolacis, E. Tomsons, J. Hrols. Fuel wood comparison with other types of fuel// Environment Technology Resources, 2003	0.70
Liquefied gas, MWh/tonne	12.65	45.54	MJ/kg	Data from the Central Statistical Bureau	0.85
Coal, MWh/tonne	7.42	26.7	MJ/kg	Regulation of the Cabinet of Ministers No 42 Methodology for the calculation of greenhouse gas emissions	0.75
Mazut, MWh/tonne	11.22	40.4	MJ/kg	Regulation of the Cabinet of Ministers No 42 Methodology for the calculation of greenhouse gas emissions	0.80
Waste tyres, MWh/tonne	7.77	27.98	MJ/kg	Data from the Central Statistical Bureau	0.70
Other wood, MWh/tonne	2.84	10.24	MJ/kg	Regulation of the Cabinet of Ministers No 42 Methodology for the calculation of greenhouse gas emissions	0.75

Straw, MWh/tonne	4.00	14.4	MJ/kg	Data from the Central Statistical Bureau	0.70
Peat, MWh/tonne	2.8	10.05	MJ/kg	Data from the Central Statistical Bureau	0.70
Biogas, MWh/thousand m³	5.56	20	MJ/kg	Data from the Central Statistical Bureau	0.85
Natural gas, kWh/m³	13.33	48	MJ/m3	Regulation of the Cabinet of Ministers No 42 Methodology for the calculation of greenhouse gas emissions	0.90
Other fuel (SRF)	5.00	18	MJ/kg	Vounatsos P. *Characterization and classification of refuse Derived fuel in the materials recovery Facility of EPANA S.A.*	0.60

Accordingly, to determine the technologies used on the basis of fuel type, assumption-based values were accepted with regard to the lowest heating value of the energy source in question and the boiler efficiency. The heat produced by the company was analysed with regard to major cities and municipalities. When analysing the companies by type of energy source used, it was assumed that fossil sources, such as natural gas, liquefied natural gas, diesel, coal, heavy fuel oil and other fossil fuel (in tonnes) and renewable sources (chips, wood, firewood, pellets and peat) would be used by heat-only boilers, whereas fuel classified by the companies as other fuel (m³) would be used by CHP plants. In this case it is possible to analyse heat-only boilers and CHP units, while for natural gas, it is impossible to separate out the technologies used, as there is no data on natural gas use by boilers and CHP units. Biogas is considered together with CHP plants.

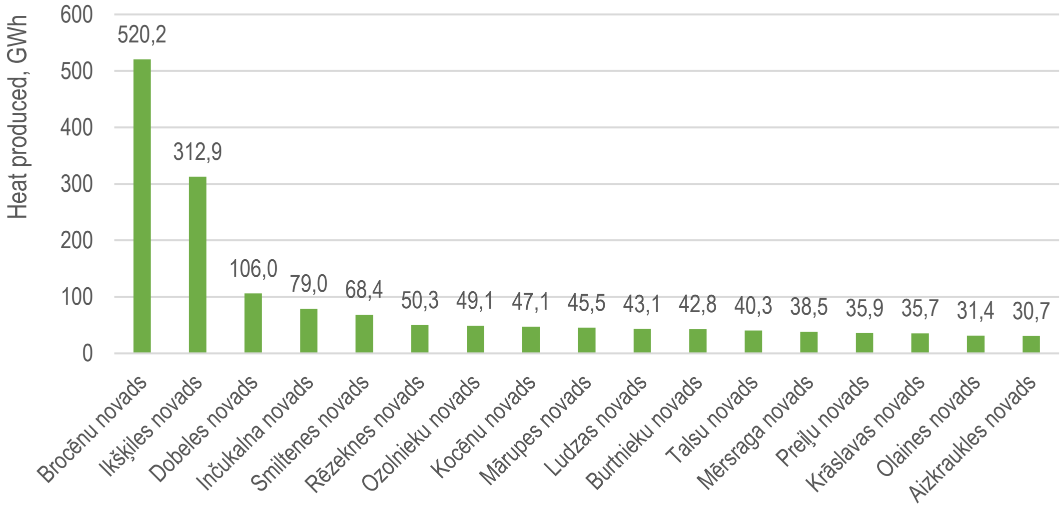


Figure 2.14. Heat produced by heat boilers by municipality, from 30 GWh to 600 GWh, 2018 [Gaiss-2 database]

novads - municipality

For visual presentation of the analysis, 678 companies were grouped by municipality and amount of heat produced within the ranges of 30 GWh to 600 GWh and 0.05 GWh to 30 GWh. Nine of Latvia's largest towns were selected for separate analysis: Riga, Valmiera, Ventspils, Rēzekne, Jēkabpils, Daugavpils, Liepāja, Jelgava and Jūrmala. The heat produced by the technology used includes heat generated by boilers and CHP units. Companies located in the Brocēni, Ikšķile and Dobele municipalities use heat-only boilers and the amount of heat produced exceeds 100 GWh. For general analysis, the companies can be divided into three groups by heat produced: below 10 GWh of heat produced, between 10 GWh and 50 GWh of heat produce, and more than 50 GWh of heat produced. The first group, with less than 10 GWh of heat produced, includes more than 53 municipalities.

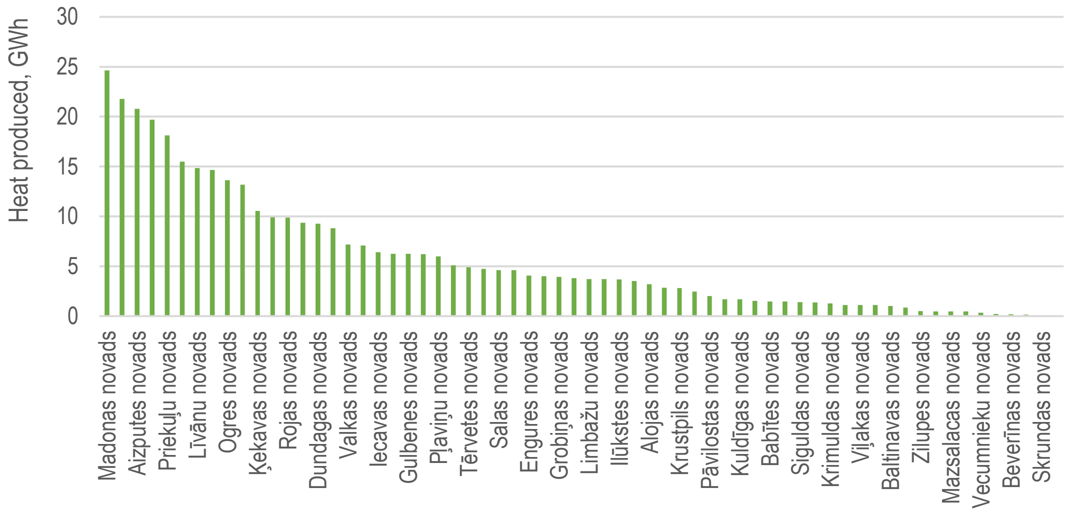


Figure 2.15. Heat produced by heat boilers per municipality, from 0.05 GWh to 30 GWh, 2018 [Gaiss-2 database]

Analysing the volume of heat produced per major city, it is apparent that the greatest amount of heat was produced by the companies located in Riga.

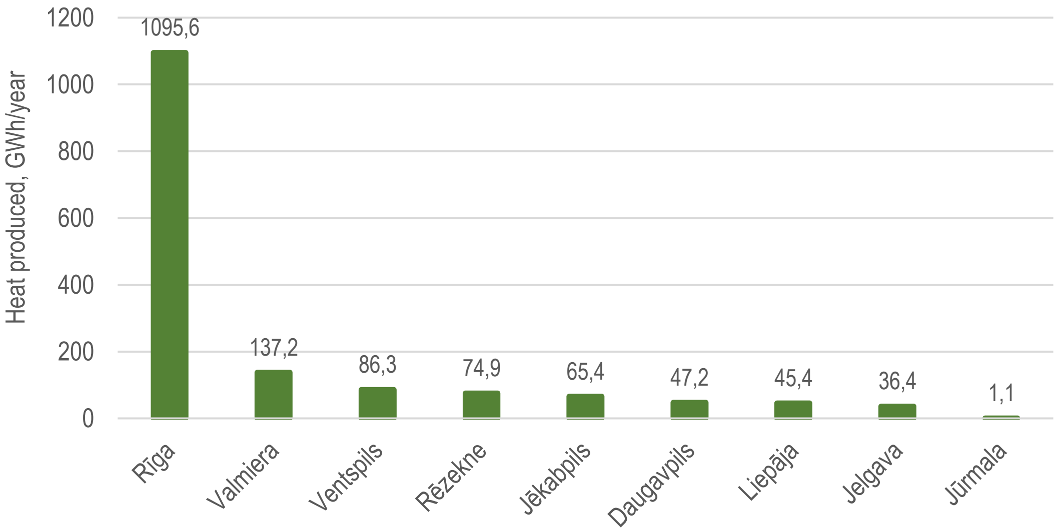


Figure 2.16. Heat produced by heat boilers per city, 2018 [Gaiss-2 database]

In 2018, production companies located in the capital of Latvia produced 1 095 GWh of heat. Other cities, excluding Jūrmala, produced 30 GWh to 80 GWh of heat.

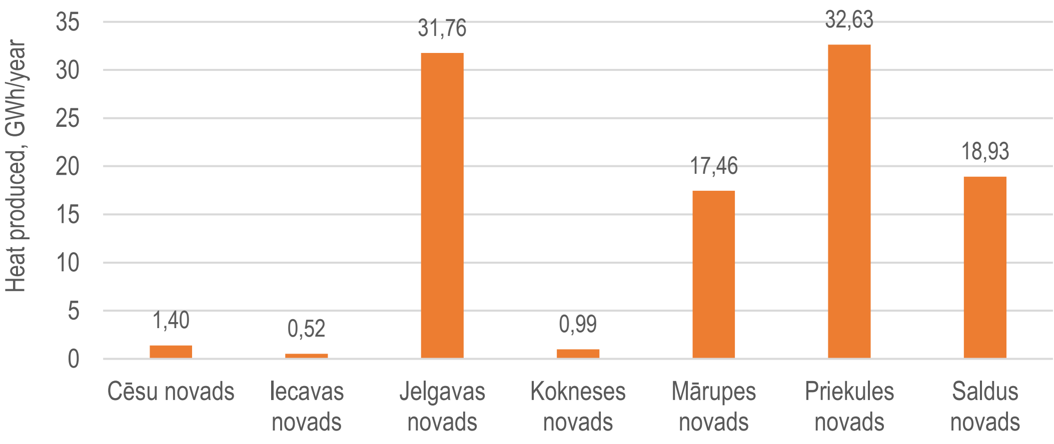


Figure 2.17. Heat produced by CHP units, 2018 [Gaiss-2 database]

novads - municipality

Biogas production and biogas-based technologies identified by the fuel used and by the company's business profile are employed in certain municipalities. Seven municipalities in Latvia have biogas CHP plants. The data analysis concludes that Jelgava (31 GWh), Priekule (32 GWh), Saldus (18 GWh) and Mārupe counties (17 GWh) use technologies with the highest share of heat produced. While the Cēsis, Koknese and Iecava municipalities use biogas CHP plants.

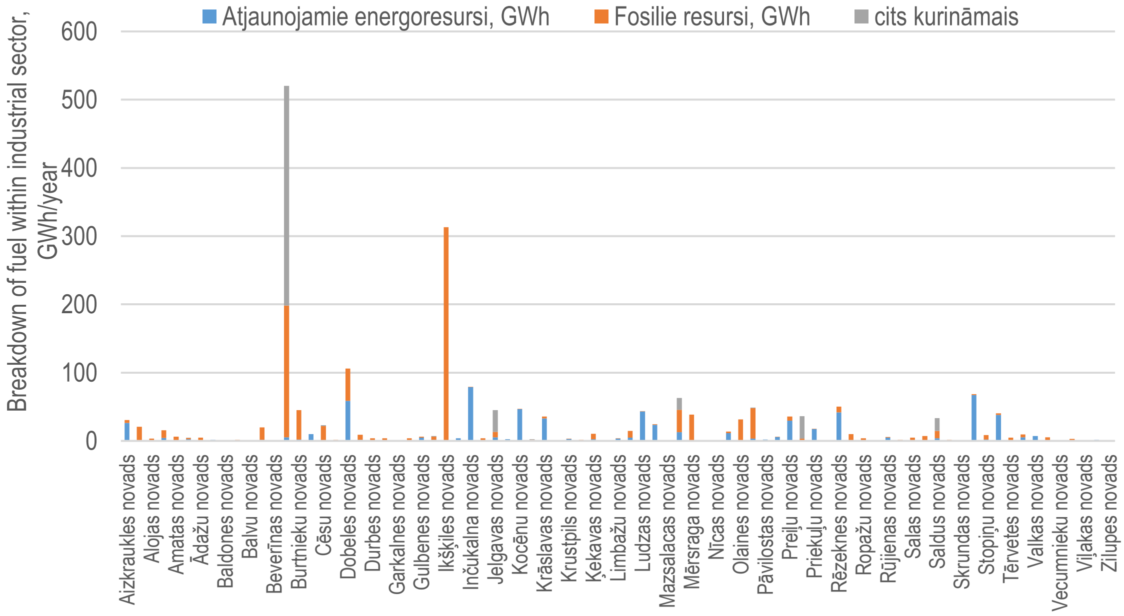


Figure 2.18. Breakdown of fuel within industrial sector per municipality [Gaiss-2 database]

novads - municipality; Atjaunojamie energoresursi - Renewable energy sources; Fosilie resursi - Fossil sources; cits kurināmais - other fuel

Information on the fuel used by a company was taken as raw data and underlying data for the Gaiss-2 database on industrial companies. It is evident that the breakdown of fossil sources and RES use by municipalities is not even and that most of the municipalities use fossil fuel sources for business needs. In the Brocēni municipality, the use of RES is quite low (5 GWh), the use of fossil fuel resources for heat production amounts to 193 GWh, and there is another fuel used as an eco-fuel for business needs. Eco-fuel consists of waste tyres, waste fuel, neutralised contaminated soil, etc. The Ikšķile municipality uses fossil sources (312 GWh) for business needs and does not use renewables.

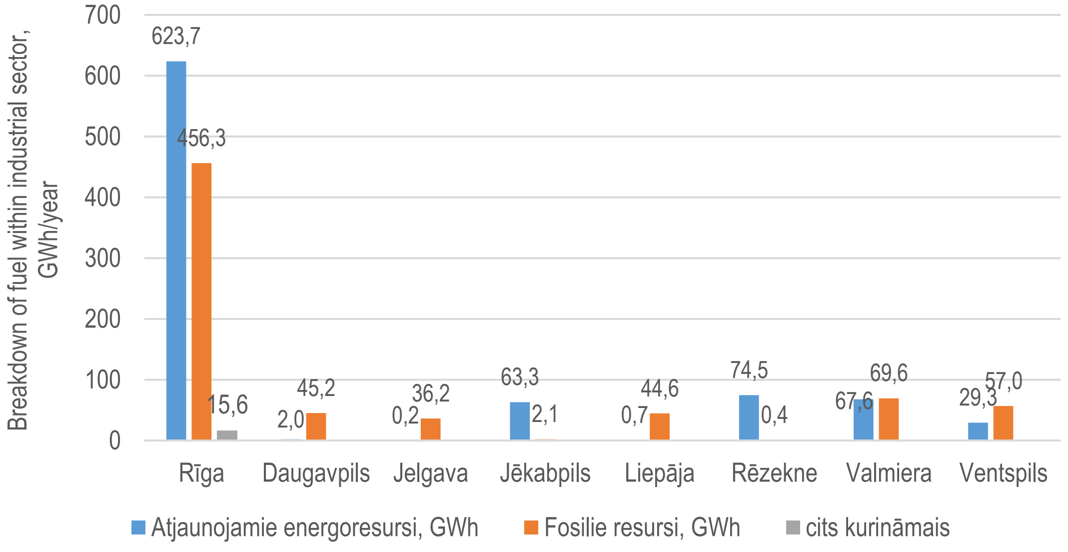


Figure 2.19. Breakdown of fuel within industrial sector per city [Gaiss-2 database]

Atjaunojamie energoresursi - Renewable energy sources; Fosilie resursi - Fossil sources; cits kurināmais - other fuel

Major cities in Latvia were considered separately from the municipalities. Riga has the highest share of energy sources among the major cities with industrial companies using renewable, fossil or other sources. This is also indicative of the location of industrial companies. Riga, Jēkabpils, Rēzekne and Valmiera have the largest share of renewable source use, while Daugavpils, Jelgava, Liepāja, Valmiera and Ventspils have the largest share of fossil source use.

2.2.3. Breakdown of the commercial and public sector by technologies used

The demand for heat in the commercial and public sector amounted to 1 501 GWh in 2018. The breakdown of the commercial and public sectors is provided pursuant to the CSB classification catalogue NACE: Statistical Classification of Economic Activities in the European Community, Revision 2. Sections E, G, H (52, 53), I, J, K, L, M, N, R, S and U are ranked as the commercial sector, while the public sector consists of sections O, P and Q. The public sector includes public administration and defence, education, health and social care. The information on these sectors is confidential. Energy sources and total heat consumption by these sectors can be analysed based on Latvia’s energy balance data, but no information is available on technologies used for heat generation by these sectors.

2.2.4. Surveyed cooling by technology

Currently, there is no data on cold energy production technologies in Latvia. Since Latvia has no district cooling systems, all cold energy supplied to buildings is generated individually, with electricity used as the main energy source.

2.3. Identification of residual heat and cooling in Latvia. Potential for heating and cooling

Identification of residual heat and cooling in Latvia, the determination of their potential is based on the algorithm presented in Figure 2.20.

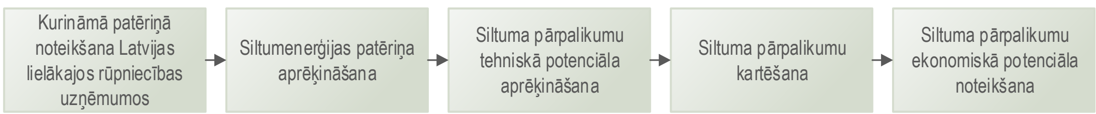


Figure 2.20. Residual heat and cold identification methodology [for translation, please see (6) in accompanying document]

The identification of waste heat in Latvia involves several stages. The identification of waste heat and the determination of its potential is based on data on the 100 largest industrial enterprises of Latvia. The first step is to derive fuel consumption from fuel consumption reports, followed by the determination of heat consumption. To determine consumption, assumptions were made with regard to the average calorific value of fuel and boiler efficiency ratios. The determination of the waste heat potential is based on the analysis of scientific literature, assuming that its potential ranges up to 15 %. Waste heat potential and integration into the district heating system can be determined by mapping, determining the distance from the plant to the nearest boiler house, thus characterising the economic potential of waste heat. Subchapter 2.4 provides the schematic waste heat potential of the largest industrial companies in Latvia.

2.3.1. Requirements under European Union Directive 2012/27/EU recommendations

Article 2 (41) of EU Directive 2012/27/EU (hereinafter – the Energy Efficiency Directive or EED) states that 'efficient district heating and cooling' means a district heating or cooling system using at least 50 % renewable energy, 50 % residual heat, 75 % cogenerated heat or 50% of a combination of such energy and heat. Figure 2.21 presents the conditions for efficient heating and cooling.

The amount of waste heat, the share of renewable energy and cogenerated heat, as well as the size of heating and cooling systems, influence this proportion.

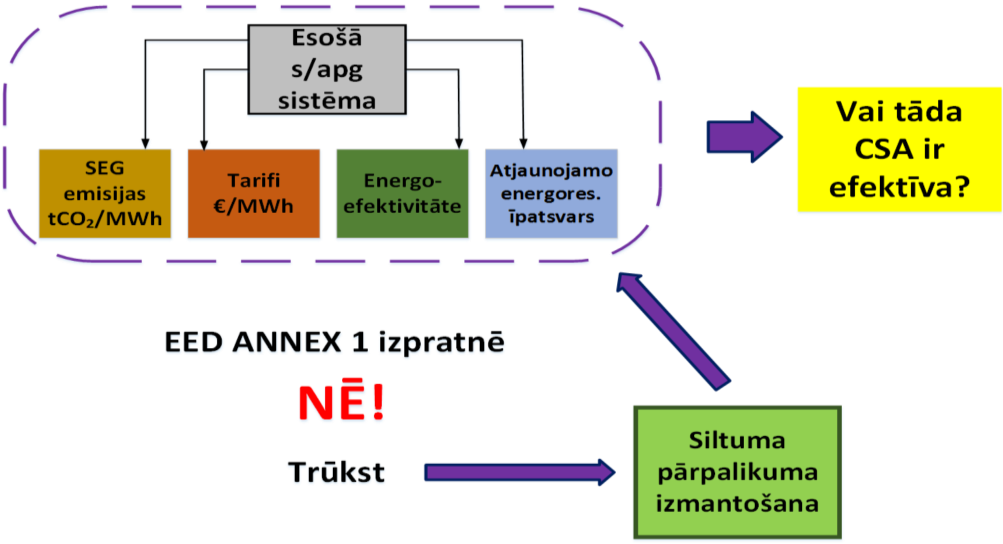


Figure 2.21. Visualisation of Conditions for Efficient Heating and Cooling Supply [for translation, see (7) in accompanying document]

In the case of Latvia, on the one hand, district heating is well-developed, but, on the other hand, there is little potential for using residual heat due to the small number of producing companies in the industrial sector.

Article 2(b) of EU Directive 2012/27/EU (Annex VIII) and [ANNEX I Contents of comprehensive assessments of the potential for efficient heating and cooling 1. GENERAL RECOMMENDATIONS TO ANNEX VIII EED] recommends five thermal energy production facilities to be analysed for the purpose of residual heat assessment.

- Thermal power plants – thermal energy and electric power production facilities able to supply residual heat or be transformed for their supply, if the total heat output exceeds 50 MW.
- Thermal energy and electric power production CHP plants using technologies referred to in Article 2 (Annex I), if the total heat output exceeds 20 MW.

- Waste-incineration plants.
- RES facilities, if the total heat output exceeds 20 MW, which is different from Article 2(b).
- Industrial companies able to supply residual heat, if the total heat output exceeds 20 MW.

The residual heat and cooling identification matrix in the context of EU EED recommendations is presented in Table 2.16.

TABLE 2.16. RESIDUAL HEAT AND COOLING IDENTIFICATION MATRIX

Technologies	Heat output threshold value	Measurement unit of thermal energy and cooling energy volume	Thermal energy volume	Cooling energy volume
Thermal power plants	50 MW	GWh/year		
CHP plants	20 MW	GWh/year		
Waste incineration	-	GWh/year		
Renewable energy sources	20 MW	GWh/year		
Industrial facilities	20 MW	GWh/year		

Recordkeeping for residual heat and cooling of processes is complicated, because, when the residual is used by the company itself, it is not considered residual heat, but rather an EE improvement and reduction of operating costs. Residual heat is residual only when it has emerged as a by-product of other processes and is released into the surrounding environment until being made useful outside the company.
Industrial residual heat ensures an equal amount of heating output as provided by other methods. It may be accounted for as residual heat, if:

- the purpose of heat production is internal or external heating or cooling and it is a by-product of other processes, it has an independent energy inlet;
- heat is obtained from a CHP plant, because its use is and EE measure of cogeneration and it is not residual heat from unused cogeneration heat;
- heat cannot be used within the company – in the same company.

The most common examples of residual heat and cooling can be found in office buildings, shopping centres, CHP plants and industrial companies:

- data centres and shopping centres requiring cooling and the heat generated from cooling may be used by an external consumer;
- the use of heat from cooling of the condenser of power stations by an external user, e.g., for the heating of greenhouses;
- if by-products are produced from renewable energy sources used for heat production, they are considered as residual heat (i.e., incineration of biodegradable waste and biomass).

Residual heat and cooling in the context of EU EED recommendations must be presented by indicating the arrangement of heat and cooling on a map by using the following information:

- name and location of the source;
- availability of existing and potential residual heat and cooling;
    - quality (GWh/year);
    - quality (temperature and heat transfer medium);
- availability of residual heat and cooling (hours/year).

2.3.2. Large thermal power plants with a heat output exceeding 50 MW

Thermal energy and electric power production equipment able to supply residual heat or transform residual heat for supply, if the total heat output exceeds 50 MW.

Latvia has three large natural gas thermal power plants. All of them are located in Riga, which must be considered as concentration of load (see Figure 2.22).

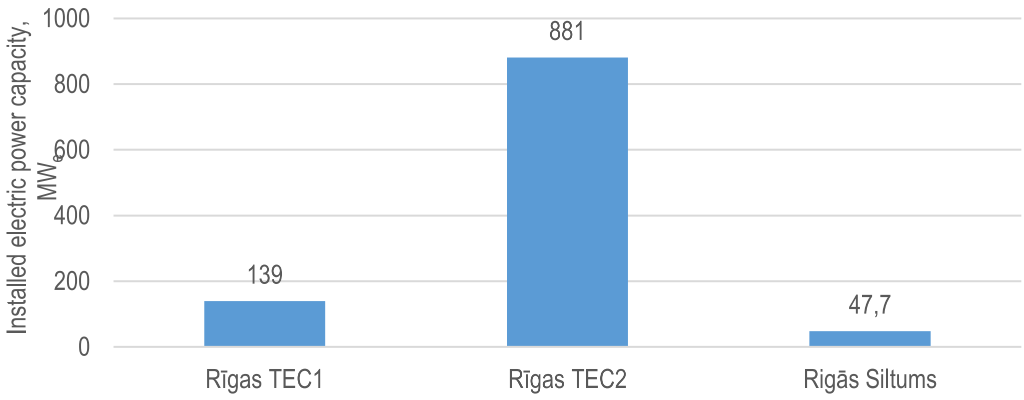


Figure 2.22. Installed capacities of a large and medium capacity natural gas CHP plant (exceeding 4 MWe)

Latvia has three large natural thermal power plants with a heat output exceeding 50 MW, and additional research is necessary on these thermal power stations to identify residual heat.

2.3.3. CHP plants with a heat output exceeding 20 MW

Latvia has two thermal energy and electric power CHP plants using technologies defined in Article 2 of EED (*Annex I*), where the total heat output exceeds 20 MW and is ensured only by cogeneration facilities:

- Juglas jauda SIA – 14.7 MWe;
- FORTUM Jelgava SIA – 25.6 MWe.

Additional research is necessary with respect to the major energy sources in Latvia's municipalities, where in CHP plants heated by water, boilers are installed, with the installed heat output exceeding 20 MW, but the boilers are not actually operating, e.g., the Daugavpils heating company's heating stations.

Another restriction is the assessment of residual heat through the analysis of the determination of heat produced in CHP plants in cogeneration mode. Useful heat produced is determined for each cogeneration facility depending on the technological solution:

$$Q = E/\alpha, \text{ MWh/year} \tag{2.13}$$

Where:
Q - thermal energy produced, MWh/year;
Q - electric power produced, MWh/year;
α – thermal energy and electric power ratio produced.

This time, in the context of EED, the focus is on the installation of additional facilities for deep flue gas cooling after the CHP plant. For instance, FORTUM Jelgava SIA has installed flue gas condensers for the recovery of the physical heat of flue gasses and vapour condensation heat from the combustion product flow.

Figure 2.23. FORTUM Jelgava

If the total volume of cogeneration heat is known, the produced useful heat calculated using the equation must be deducted from it (2.13). EED Annex I stipulates its presentation in reports for the correct assessment of residual heat in a CHP plant. It must not be calculated as residual heat for potential heat and cooling supply.

Three types of energy must be individually determined:

- electric power;
- thermal energy from cogeneration;
- residual heat not used and potentially obtained from a flue gas condenser.

For the heat and cooling supply system, a trigeneration plant is installed at the energy source, and its residual heat is assessed similarly to a CHP plant.

2.3.4. Waste incineration plants

Until now, waste incineration plants in Latvia have existed only for the incineration of hazardous waste. The Olaine hazardous waste treatment company incinerates 200 t of hazardous waste per annum. The CHP plant in Sātiņi has received a polluting activity permit for co-incineration of hazardous waste. However, it has not started incineration of railway sleepers and polluted soil yet.

The Ventspils waste incineration plant which has received EU co-funding, has:

- a heat output of 8 MW;
- an electric power capacity of 1.3 MW_e.

Information about municipalities with companies incinerating their waste considered to be a by-product is summarised in Table 2.17. It presents a description and the volumes of waste in 2018. The data summary shows that considerable heat generated from waste can be established in the Vecumnieki, Ozolnieki and Saldus municipalities.

TABLE 2.17. WASTE INCINERATION LOCATIONS AND COMPANIES, 2018 [STATE STATISTICAL REVIEW '3-WASTE']

No	City	Company	Type of waste (by-product type)	Waste (by-products), t/year

1.	Daugavpils	DITTON PIEVADĶĒŽU RŪPNĪCA AS	Wood packaging	15.34
2.	Daugavpils	Latvijas dzelzceļš VAS	Wood packaging	108.86
3.	Liepāja	Scan-Plast Latvia LSEZ SIA	Wood packaging	4.75
4.	Liepāja	Scan-Plast Latvia LSEZ SIA	Sawdust, wood scrap, damaged wood and wood particles	65.75
5.	Rēzekne	ALEGRO SIA	Sawdust, wood scrap, damaged wood and wood particles	5.45
6.	Bauska Municipality	AUSMAS SIA	Paper and cardboard packaging	0.03
7.	Vecumnieki Municipality	PIEBALGAS SIA	Sawdust, wood scrap, damaged wood and wood particles	2 844.24
8.	Jaunpiebalga Municipality	Wenden Furniture SIA	Sawdust, wood scrap, damaged wood and wood particles	430.00
9.	Dobele Municipality	JELD-WEN LATVIJA SIA	Sawdust, wood scrap, damaged wood and wood particles	264.60
10.	Jelgava Municipality	JELGAWOOD PLUS SIA	Sawdust, wood scrap, damaged wood and wood particles	32.58
11.	Ozolnieki Municipality	Sadales tīkls AS	Sawdust, wood scrap, damaged wood and wood particles	1 688.22
12.	Skrunda Municipality	AK LRPMK SIA	Waste tyres	80.00
13.	Madona Municipality	BIODEGVIELA SIA	Wastes from distillation of spirits	41.74
14.	Rēzekne Municipality	Maltas dzīvokļu komunālā saimniecības uzņēmums Pašvaldības SIA	Wood packaging	1.14
15.	Rēzekne Municipality	Maltas dzīvokļu komunālā saimniecības uzņēmums Pašvaldības SIA	Bulky waste	7.50
16.	Rēzekne Municipality	Maltas dzīvokļu komunālā saimniecības uzņēmums Pašvaldības SIA	Paper and cardboard	12.15
17.	Rēzekne Municipality	Maltas dzīvokļu komunālā saimniecības uzņēmums Pašvaldības SIA	Textiles	3.33
18.	Rēzekne Municipality	SORMS SIA	Sawdust, wood scrap, damaged wood and wood particles	53.54
19.	Saldus Municipality	Hoppekids SIA	Sawdust, wood scrap, damaged wood and wood particles	815.00
20.	Talsi Municipality	Vika Wood SIA	Other waste in this group	392.00
21.	Talsi Municipality	Vika Wood SIA	Wood	2.00
22.	Rūjiena Municipality	Garants SIA	Sawdust, wood scrap, damaged wood and wood particles	334.32
	Total			7 202.54

2.3.5. Renewable energy sources with a heat output exceeding 20 MW

RES facilities, if the total heat output exceeds 20 MW, which is different from Article 2(b) of Annex I, have been selected using the Emissions Trading Database 2012-2020. The information shows that all companies, except Cesvaines Piens AS, use a combination of fuels: biomass and fossil fuels (see Table 2.18).

TABLE 2.18. SOURCES OF RENEWABLE ENERGY SOURCES IN INDUSTRIAL COMPANIES

No	Municipality	Energy source of the company	Installed capacity, MW	Notes
1.	Riga	LATVIJAS FINIERIS AS	58	natural gas is also being used
2.	Riga	KRONOSPAN Riga SIA	222	natural gas is also being used
3.	Riga	GAMMA-A SIA	28.9	natural gas is also being used
4.	Valmiera	Valmieras piens AS	22.5	natural gas is also being used
5.	Cesvaine	Cesvaines piens AS	6.9	
6.	Preiļi	Preiļu siers AS	35	natural gas is also being used

During the next reporting period, a survey of energy sources will be carried out to refine their heat outputs, volumes of produced heat energy and electric power, and potential residual heat.

2.3.6. Industrial companies with a heat output exceeding 20 MW

Industrial companies with a total heat output exceeding 20 MW and able to supply residual heat. The quality of residual heat depends on various factors:

- temperature – depending on the temperature (most of the potential is present at low temperatures), the potential for the use of residual heat in Europe is assessed within the limits of at least 50 %, and the classification of residual heat based on temperature is presented in Figure 2.24;

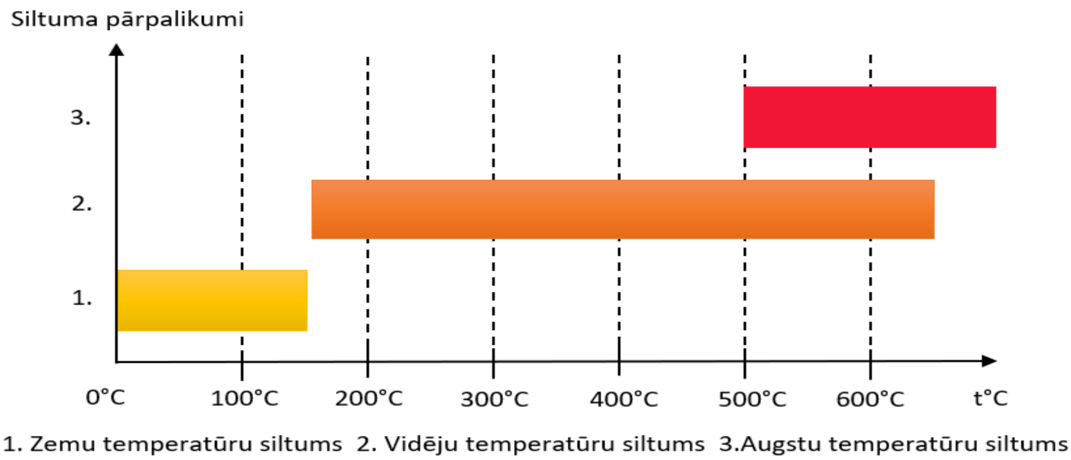


Figure 2.24. Breakdown of residual heat by temperature [for translation, see (8) in accompanying document]

- type of heat transfer medium – depending on the aggregate state of heat transfer media (water, high-temperature heat transfer medium, vapour, gas), residual heat is obtained, sometimes transformed and used in heat exchange processes with the highest EE;
- type of use – residual heat may be used as an energy source or transformed into electric power (if the temperature exceeds 150 °C, residual heat may be transformed into electric power). Globally, various approaches and methods for increasing EE have been found and used,

however, little attention is paid to the use of residual heat. Significant residual heat is generated in plants both by heat exchange and mechanical processes.

Industrial companies in Latvia with potential residual heat recommended by EED are presented in Table 2.19 and Figure 2.24. They present also industrial companies in Latvia whose plants have technological residual heat. Sources of potential residual heat in industrial companies have been selected from among emissions trading operators by forecasting their interest in increasing EE and CO_2 quota trading.

TABLE 2.19. POTENTIAL SOURCES OF RESIDUAL HEAT IN INDUSTRIAL COMPANIES

No	Municipality	Company	Installed heat output, MW	Notes
1.	Riga	LATVIJAS FINIERIS AS	58	Potential technological heat
2.	Riga	KRONOSPAN Riga SIA	222	Potential technological heat
3.	Riga	Rīgas kuģu būvētava AS	22.1	
4.	Riga	B.L.B. Baltijas termināls AS	20.3	Potential technological heat
5.	Riga	Rīgas laku un krāsu rūpnīca SIA	13.3	
6.	Riga	GAMMA-A SIA	28.9	Potential technological heat and cooling
7.	Mārupe	SABIEDRĪBA MĀRUPE SIA	12.4	
8.	Valmiera	Valmieras piens AS	22.5	Potential technological heat
9.	Cesvaine	Cesvaines piens	6.9	Potential technological cooling
10.	Preiļi	Preiļu siers AS	35	Potential technological heat and cooling
11.	Stopiņi Municipality	KNAUF SIA	25.7	Potential technological heat
12.	Ķekava	Putnu fabrika Ķekava AS	4.1	
13.	Liepāja	LAUMA FABRICS SIA	25	Potential technological heat
14.	Vangaži	Binders SIA	20	
15.	Olaine	BIOLARS AS	10.8	
16.	Olaine	Olainfarm AS	26	Potential technological heat
17.	Brocēni	SCHWENK Latvija SIA	51.5	Potential technological heat
18.	Brocēni	Pillar 21 SIA	20	
19.	Ozolnieki	LODE SIA	12	Potential technological heat
20.	Valmiera	VALMIERAS STIKLA ŠĶIEDRA AS	31.1	Potential technological heat
21.	Ventspils	Ventbunkers AS	36.6	

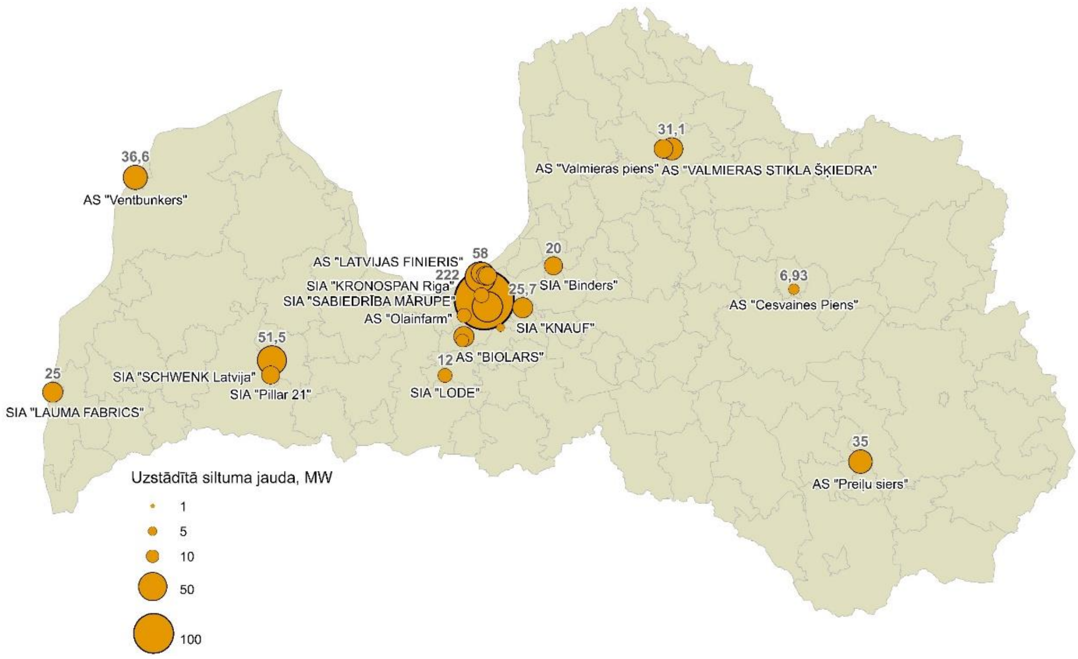


Figure 2.25. Territorial locations of industrial companies with potential residual heat and an installed heat output exceeding 20 MW

Uzskaitītā siltuma jauda = Installed heat output

A description of heat transfer media (water, vapour, salt, etc.) is an important condition in the analysis of residual heat and cooling. These factors determine the potential use and heat transmission distances influencing the choice of potential scenarios for the use of residual heat and cooling. Most suitable heat transfer media in the case of residual heat use:

- combustion products from glass and aluminium melting furnaces, cement kilns and boilers;
- technological gasses from steel furnaces, drying furnaces and ovens;
- the cooling water of furnaces, air compressors and internal combustion engines.

Vapour is seldom used as residual heat, because it is usually produced in accordance with the technological process. Table 2.20 indicates categories based on temperature levels and potential suppliers of residual heat.

TABLE 2.20. INDUSTRIAL RESIDUAL HEAT RECOMMENDED BY EED

Category	Heat transfer medium/coolant	Temperature levels, °C	Plants	In Latvia
High-quality heat	Direct heating with flame, high-temperature heat transfer media	> 500	steel, cement, glass	Cement plant
Medium-quality heat	High-pressure vapour	150-500	vapour processes in the chemical industry	
Medium/low-quality heat	medium-pressure vapour	100-149	vapour processes in the chemical, paper and food industries,	Milk, fish processing
Low-quality heat	hot water	40-99	heating of premises, processes in food industry	milk, fish, meat, sweets, wood processing, plants
Cooling	water	0 – ambient air temperature	cooling of premises, processes in the milk industry	
Refrigeration	Refrigerating agent	< 0	Refrigeration in the chemical and food industries	processing of meat, fish and other food products

The use of residual heat and cooling for heat supply has no restrictions. Therefore, the current volume and potential of residual heat and cooling may be directly used for other processes (if the temperature level is appropriate) or be transformed and adjusted for the use of heat pumps outside a company.

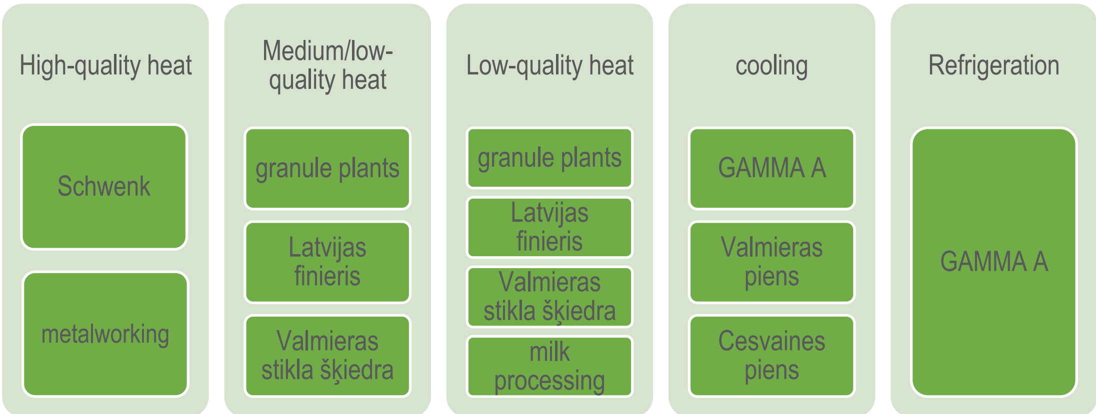


Figure 2.26. Potential opportunities the use of residual heat and cooling

2.3.7. Methodology of residual heat and cooling analysis

The methodology of the analysis of the opportunities of using residual heat and cooling includes eight modules, which have been combined into a methodology algorithm (see Figure 2.27).

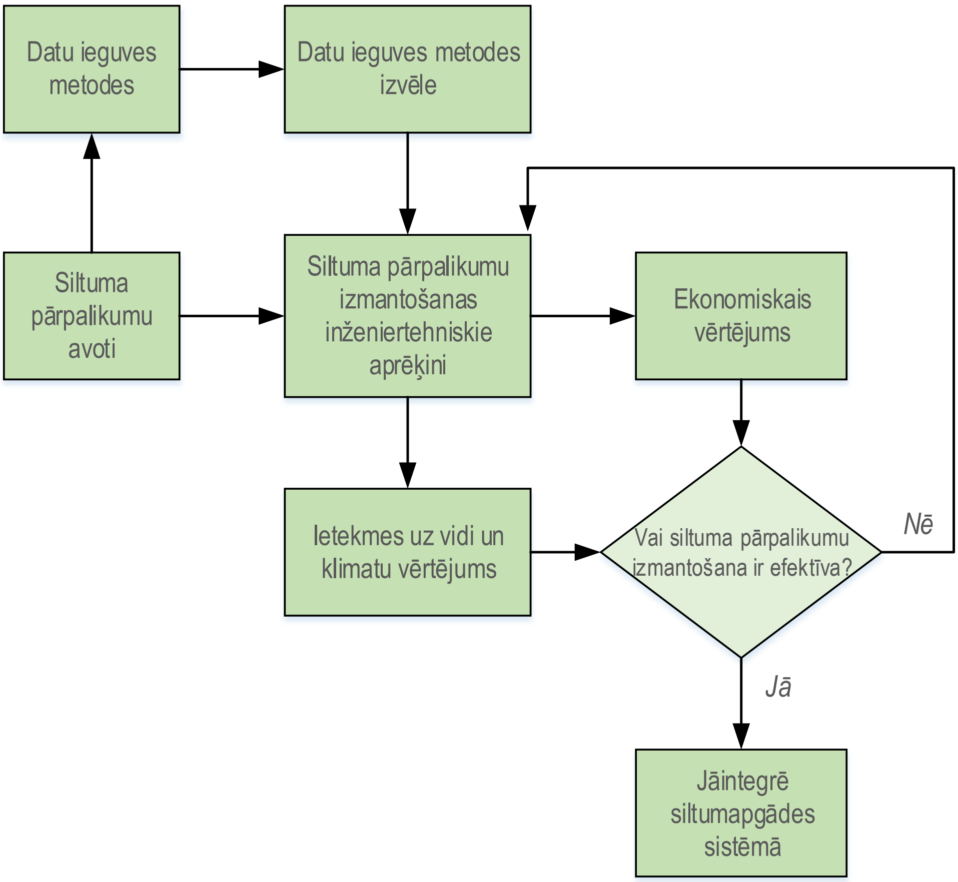


Figure 2.27. Methodology algorithm. Integration of residual heat and cooling in district heating [*for translation, see (9) in accompanying document]*

The methodology algorithm includes a data acquisition module. To acquire more precise information from companies with available residual heat and cooling, companies must be surveyed, obtained data must be analysed, and the potential must be assessed with its economic and ecological justification provided.

In this case, the three data acquisition methods presented in Figure 2.28 are the most suitable ones. They differ by the accuracy their of results and their application.

EED recommendations suggest surveying companies to obtain quantitative data about the following:

- total input energy;
- heat productivity;
- volume of the share of used heat;
- volume of cooled heat (or volume of heated cooling) or heat transmitted to the surrounding environment.

Another option is the assessment of the potential of the residual heat and cooling by using the indirect method, which is based on assumptions acquired by analysing similar plants:

- in the same industry;
- companies of a similar age group;
- companies with similar energy levels;
- companies with similar measures for energy loss reduction.

A similar volume of residual heat and cooling might be determined using the available volumes per ton of production (all technologies at a certain age should have similar residual heat profiles). The calculated potential may be established using the availability factor, in which the following is considered:

- heat recovery technologies;
- age of the plant;
- energy levels or degrees;
- levels of recent investments made into the heat recovery technologies.

Data analysis method	Benchmark method	Similarity method
□total input energy; □heat productivity; □volume of the share of used heat; □volume of cooled heat (or volume of heated cooling) or heat transmitted to the surrounding environment.	□in the same industry; □company of a similar age group; □similar energy levels; □similar measures for energy loss reduction.	□heat recovery technologies; □age of the plant; □energy levels or degrees; □levels of recent investments made into the heat recovery technologies.

Figure 2.28. Data collection methods

2.3.8. What should heating companies do?

In the cases in which an enterprise categorised as a company with a potential of residual heat and cooling is located on the territory of the DH company, the DH company should assess the opportunities for integrating the enterprise into the heating system by identifying the quality and quantity of the potential.

The most important preconditions include the establishment and development of efficient DH infrastructure to ensure the use of residual heat in the most suitable locations and by choosing economically justifiable technological solutions. For example, the transformation of residual heat into electric power is an innovative technological solution, however, the economic justification of its use without subsidies will be difficult to prove.

EED recommends prioritisation of the use of residual heat from heating. The adaptation of the prioritisation scheme for residual heat from heating in Latvia is presented in Figure 2.29.

Figure 2.29. Prioritisation of residuals from heating system

The heat generated during waste incineration evidently takes the first place and is the first component integrated into the centralised heating system, because, if there is heat that has no consumer, it is released into the environment. In this case, none of the tasks defined to achieve the three major objectives (EE, RES and climate) are accomplished. Only in the event that all other technological solutions do not confirm the option of covering the maximum load, can the water heating boiler be used in the boiler house of the heating system.

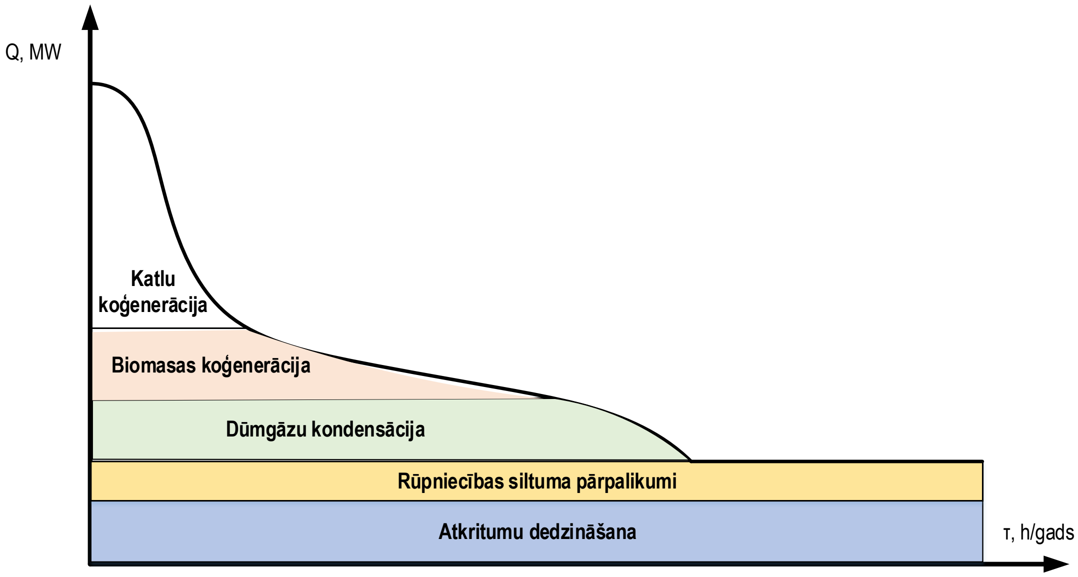


Figure 2.30. Prioritisation of residuals from the heating system in the heat load duration schedule [for translation, see (10) in accompanying document]

Figure 2.30 shows the priorities for handling residuals from the heating system in the heat load duration schedule. Making representatives of the DH system interested by helping them understand the potential of the use of residual heat and cooling and the technical-economic benefits allowing reduction of heating tariffs is very important.

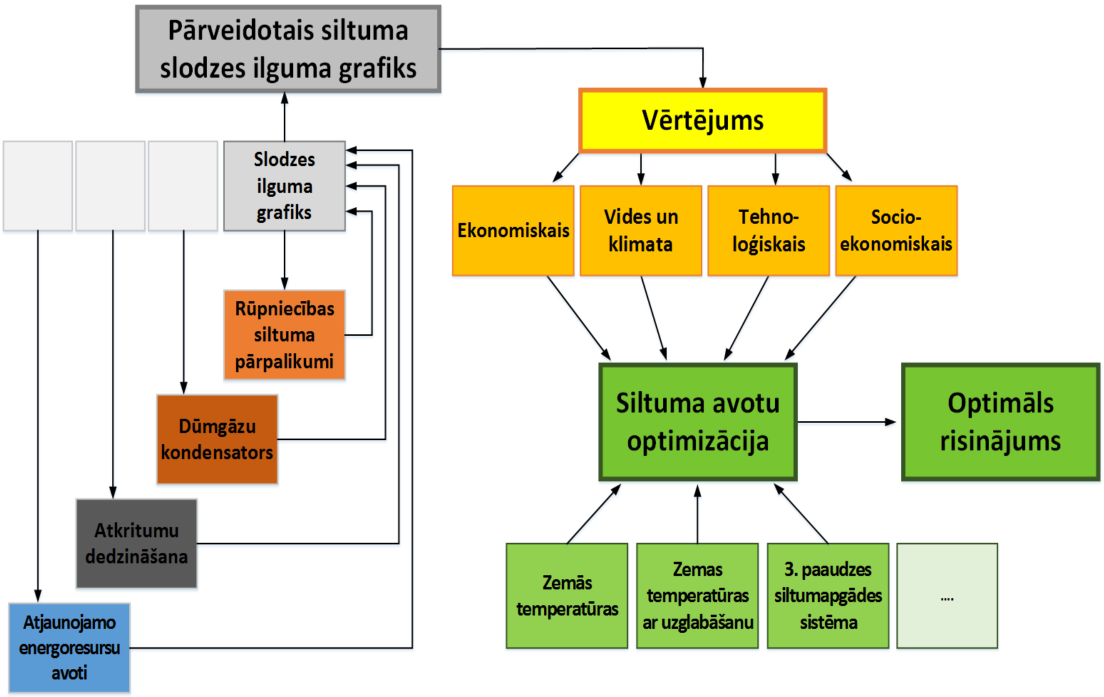


Figure 2.31. Optimisation methodology algorithm [for translation, see (11) in accompanying document]

An optimisation methodology algorithm for district heating companies has been developed for the analysis of heating companies (see Figure 2.31). It is based on the principle of cost-effectiveness: The proposal to provide residual heat to a DH company must be economically profitable, ecologically justifiable and energy-safe.

Conclusions

DH systems will have to integrate the existing residual heat into their serviced area.

It is a dual problem: on the one hand, an in-depth analysis of the sources of residual heat and cooling is required to define economically and ecologically justified solutions and potential, while, on the other hand, the proposal to provide residual heat to DH companies must be cost-effective and stable.

2.4. Maps showing the degree to which the demand for heating and cooling is met

The general work methodology algorithm (see Figure 2) specifies a mapping methodology, which has been created based on the demand for heating. Also, new planned heating points are based on the methodology described in Chapter 2.3 regarding identification and mapping of residual heat.

2.4.1. Demand for heating

The maps showing the degree to which the demand for heating is met were created based on Table 2.1 'Heating balance in republic cities and municipalities in 2018' in Chapter 2.1. Since the availability of information is limited, assumptions and the regression equation were used to obtain data access to which, according to the CSB information, is limited or the phenomenon has not been detected. In most of the territory of the country (56 municipalities) the demand for heating is up to 0.05 GWh/km^2. Heating demand in the range of 0.11 to 0.5 GWh/km^2 can mostly be observed in the Pierīga region, which is related to the fact that the area is more economically developed and has a higher population density. The demand for heating is high, i.e., 0.51-1.0 GWh/km^2, in Mārupe municipality and Aizkraukle municipality. The demand for heating in the household sector is high in Mārupe municipality due to its many residents. It is the second most densely populated municipality in Pierīga, i.e., 192 persons per km^2, and several large companies, for instance, Starptautiskā lidosta Rīga VAS, Madara Cosmetics AS etc., are located in this municipality. Similar to Mārupe municipality, in Aizkraukle municipality the majority of the demand for heating also is from the household and production sectors.

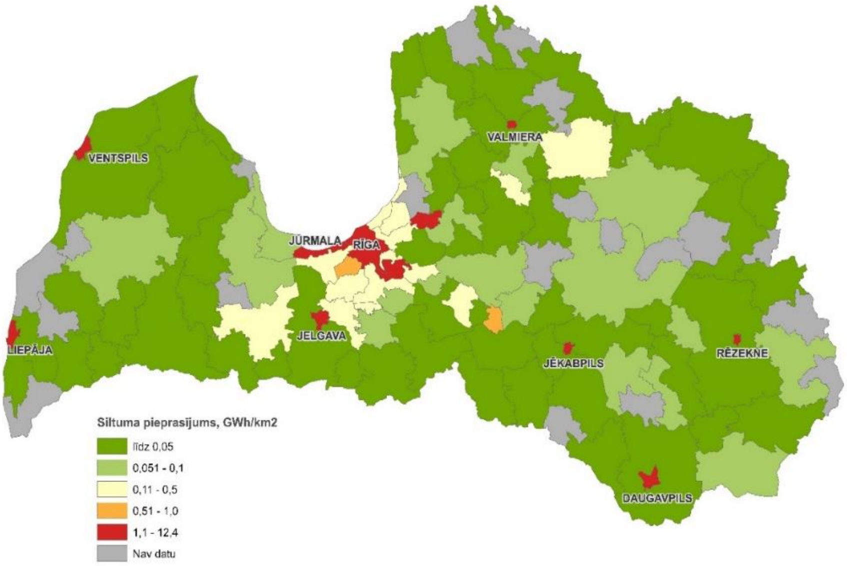


Figure 2.32. Zones of the demand for heating in municipalities and in the larger cities of Latvia [CSB data, calculations] [*for translation, see (12) in accompanying document*]

The largest demand for heating, exceeding 1.1 GW h/km^2 is in the cities of the Republic of Latvia and in Salaspils and Inčukalns municipalities. An energy-intensive company is located in Inčukalns municipality. However, data on 18.18 % of the administrative territorial entities of Latvia is not available on the basis of the CSB document Quality Requirements and of the General Data Protection Regulation 2016/679.

2.4.2. *Current and planned heating points. DH boiler houses*

Mapping of the present situation was carried out using the data analysed as part of the study on the demand for heating and the data about the 100 largest industrial companies. The maps show industrial companies and boiler houses in the largest regional cities and municipalities in Latvia. ([39])

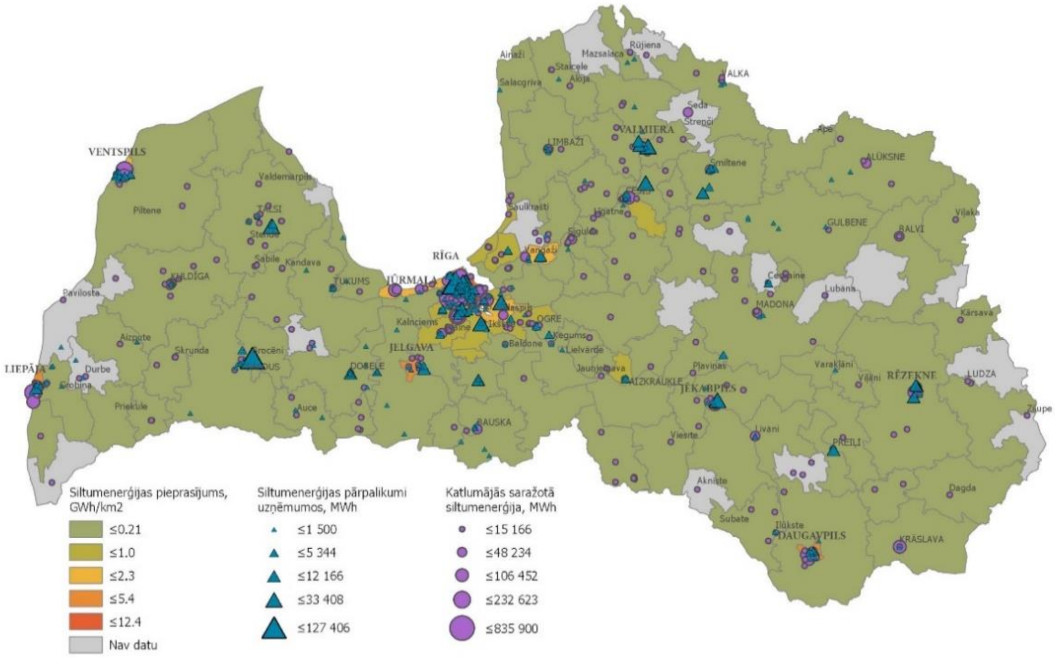


Figure 2.33. Current and planned heating points. DH boiler houses [*for translation, see (13) in accompanying document*]

The current situation and potential was construed on the basis of the map of demand for heating, which already indicates the density of demand for thermal energy in cities, towns and municipalities. This type of mapping and visualisation provides a visual overview of the current situation, allowing for identification of the future potential of using residual heat in DH systems. On the maps, three symbols have been used for visual presentation of data, indicating respectively the demand for thermal energy in GWh/km^2, residual heat in companies in MWh, and the thermal energy produced in boiler houses in MWh. It is apparent that municipalities in Latvia have uneven arrangement of DH points. In certain municipalities, the boiler houses are located only in the city or town and other territories in the municipality have no DH boiler houses. The most significant density of DH boiler houses is found in Riga and Pierīga region and in the largest cities of Latvia. In terms of the siting of industrial companies, it is apparent that these are sited and are concentrated in Riga and Pierīga, Saldus, Liepāja, Ventspils, Valmiera, Jēkabpils, Rēzekne and Daugavpils. To determine the economic potential of industrial companies, the use of reports, databases and available information on boiler houses allows the distance of a company from the closest boiler house to be determined. More detailed maps of specific towns have been provided to give a sense of the distance of industrial companies from boiler houses. A key to the industrial companies indicated in the maps has been provided in Annex 3.

Considering Riga separately, it is apparent that the city's boiler houses have a produced thermal energy volume of between 10 360 MWh and 835 900 MWh. It is apparent that in certain parts of the city, e.g., Bolderāja, there is a company close to a centralised heating boiler house with a possible residual heat potential of 127 406 MWh.

([39]) Mapping was carried out based on the data from 2018, but the Saeima made a decision on municipal reform in June 2020.

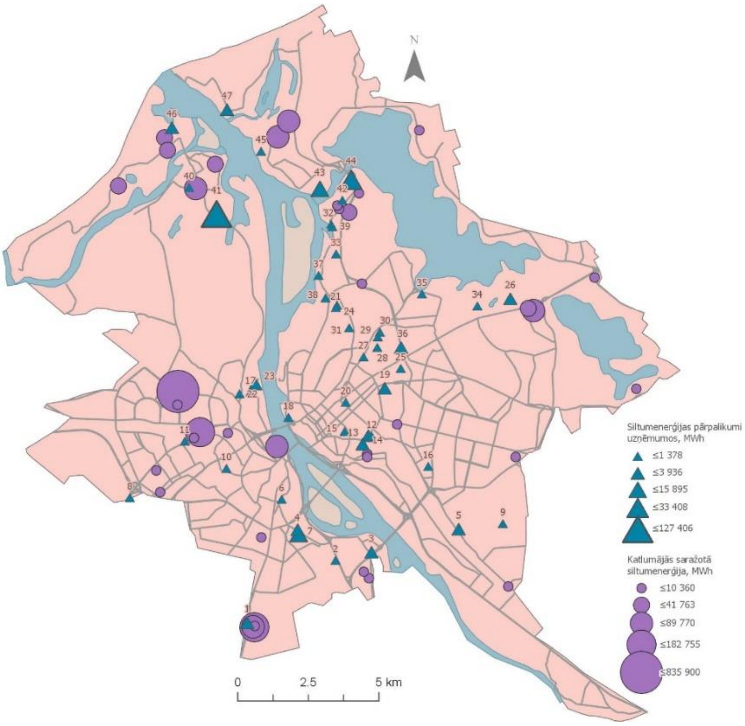


Figure 2.34. Potential of residual heat and boiler houses in Riga [*for translation, see (14) in accompanying document*]

It should be noted that the current methodology has been created for determination of potential, but the establishment of the actual volume of residual heat in a company requires the performance of detailed engineering technical calculations, the assessment of technologies present and the creation of scenarios for the development and assessment of the potential.

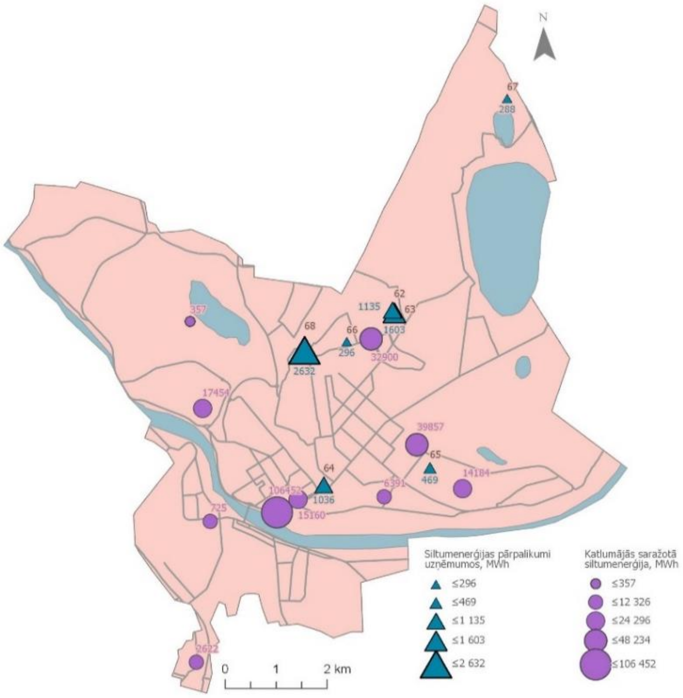


Figure 2.35. Potential of residual heat and boiler houses in Daugavpils [*for translation, see (15) in accompanying document*]

From an assessment of the potential of Daugavpils, it is apparent that companies No 62 to No 66 are located less than 1 km from a centralised boiler house. Respectively, these industrial companies might consider the future potential and integration of residual heat into the DH system.

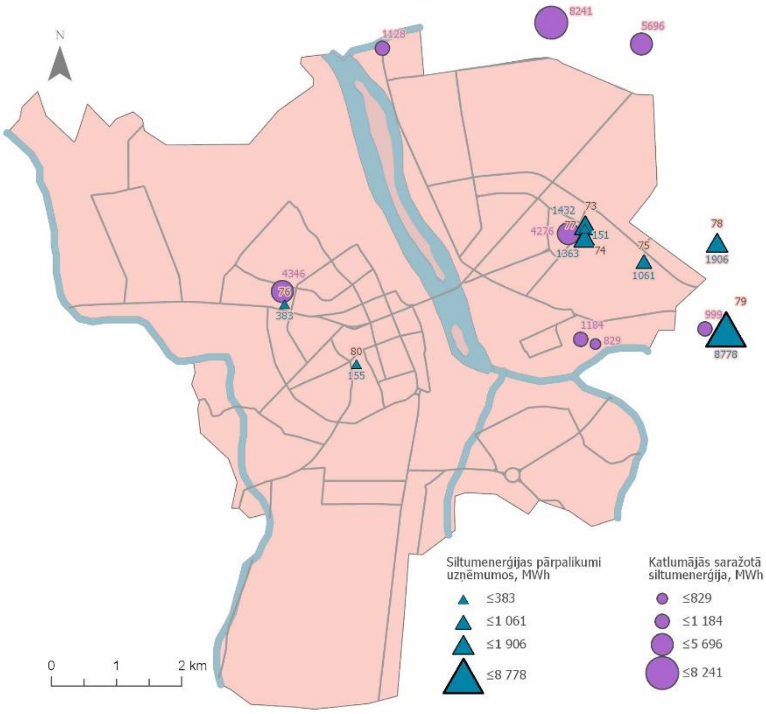


Figure 2.36. Potential of residual heat and boiler houses in Jelgava [*for translation, see (16) in accompanying document*]

The situation in Jelgava is similar, i.e., industrial companies are located less than 1 km from a DH boiler house. The number of centralised boiler houses in Jelgava and its vicinity is small. Analysis of the available data shows that five centralised heating boiler houses are located in Jelgava City. One of the boiler houses is located in an urban area with intense industrial activity. The study concludes that considering connecting the potential of residual heat to DH is profitable, if it is not located more than 1 km away from the boiler house; in this case, three industrial companies are located less than 500 m away from the boiler house. For several industrial companies, e.g. company No 79, the residual heat considerably exceeds the heat produced in the boiler house next to the company. In this case, not only transfer of residual heat to DH network, but also possible extension of the operation of the company with the use of the emerging residual heat in the production process, may be considered.

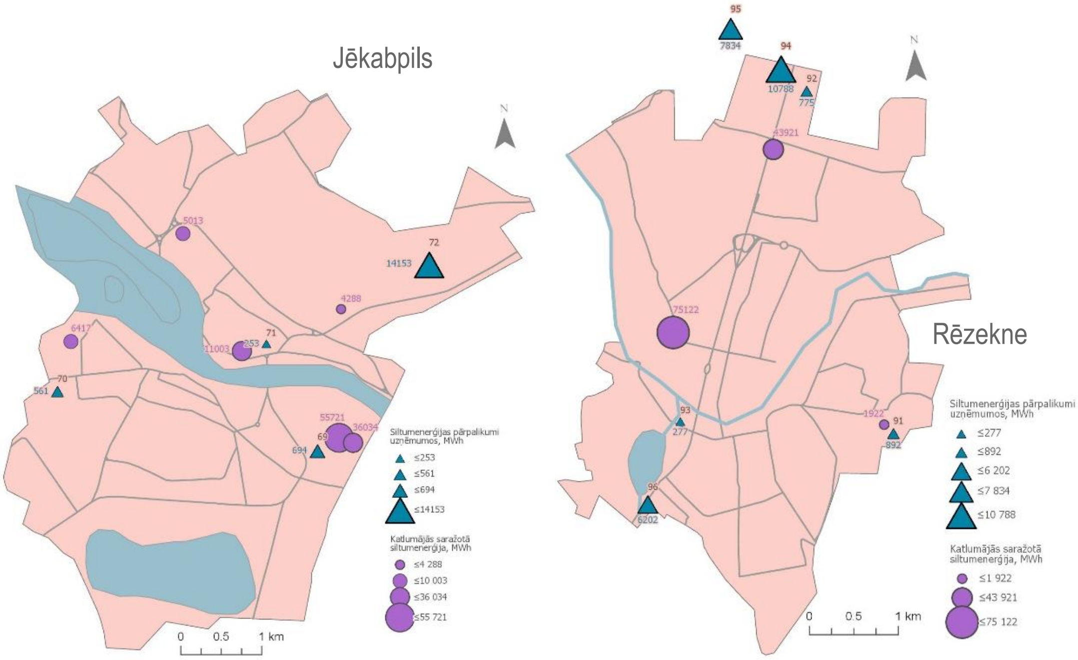


Figure 2.37. Potential of residual heat and boiler houses in Jēkabpils and Rēzekne [*for translation, see (17) in accompanying document*]

In Jēkabpils and Rēzekne, the number of large industrial companies is not as significant as in the aforementioned cities. Jēkabpils has two smaller (by the volume of residual heat in MWh) companies located less than 500 m away from a boiler house. Rēzekne and its suburbs have three companies also located at a distance of less than 1 km, and in-depth research of the potential of residual heat may be considered.

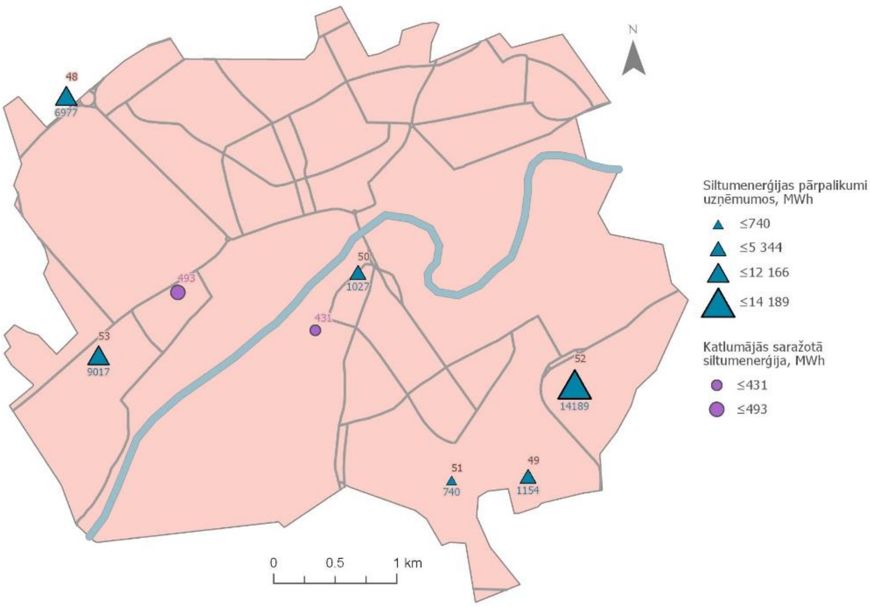


Figure 2.38. Potential of residual heat and boiler houses in Valmiera [*for translation, see (18) in accompanying document*]

It is apparent that Valmiera has six industrial companies (the 100 largest companies in Latvia were analysed in the study). Valmiera is an industrial city, and it is home to most of the largest companies in the Vidzeme region. Valmiera is home to the largest production companies of the Vidzeme region and has also been of national importance since the mid-20th century. At this point, only one company is located less than 1 km from a boiler house, and in this case determination of the potential of residual heat may be considered.

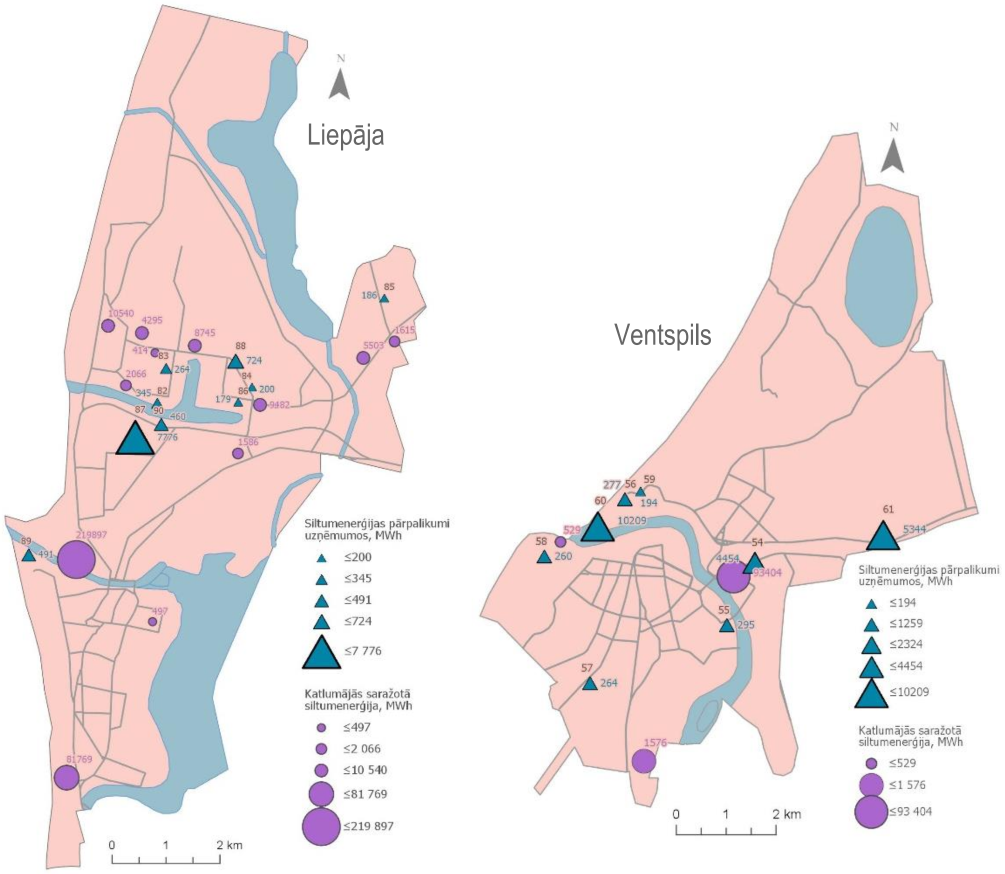


Figure 2.39. Potential of residual heat and boiler houses in Liepāja and Ventspils [*for translation, see (19) in accompanying document*]

Liepāja and Ventspils have both industrial production companies and DH boiler houses. In both cities, in most cases the locations of companies and boiler houses are at a distance of less than 500 m.

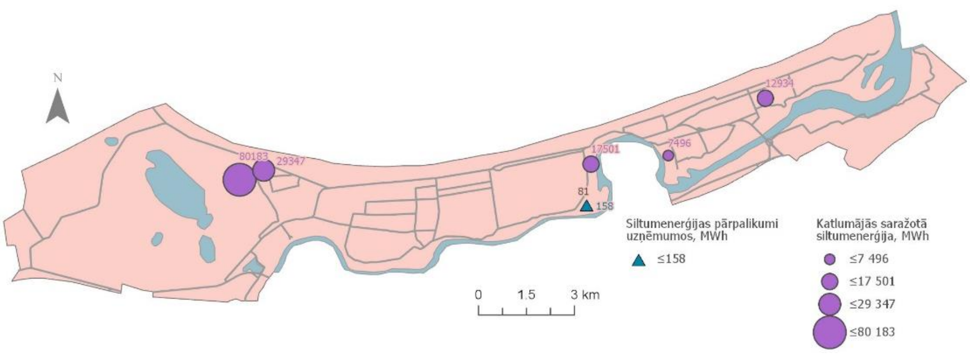


Figure 2.40. Potential of residual heat and boiler houses in Jūrmala [*for translation, see (20) in accompanying document*]

It is apparent that the number of large industrial companies in Jūrmala is minimal. This city has boiler houses that provide heating for apartment buildings.

2.5. Forecast of trends for the demand for heating and cooling

The forecast of trends for the demand for heating was carried out on the basis of two scenarios put forward – the baseline scenario and EE scenario, which envisions implementation of EE activities in buildings. The future forecasts were modelled on the basis of available data and using modelling of system dynamics. The elaborated scenarios and selected policy instruments are used for both individual heating and district heating.

Within the household sector, four groups of buildings have been modelled, i.e., non-renovated buildings and renovated buildings built before 1990, buildings built in the period from 1990 until 2018 and buildings built after 2018. When modelling thermal energy consumption, the heated square metres of buildings have been considered. It is assumed that the consumption in renovated buildings built before 1990 corresponds to consumption in buildings built in the period from 1990 to 2018. The household sector has been broken down into single-family or private buildings and apartment buildings.

The renovation rate depends mostly on what economic benefits accrue from renovations; however, available construction capacity also plays a significant role. If the supply offered by construction companies, i.e., the maximum amount of renovations possible, is less than the demand for the renovation of buildings, only part of the buildings for which renovations are desired will indeed be renovated. Insufficient capacity may affect construction costs.

TABLE 2.21. MAIN PARAMETERS OF THE HOUSEHOLD SECTOR, 2017

	Area, thousand m^2	Average thermal energy consumption, $kWh/m^2/year$
Non-renovated single-family buildings	8 554	215
Renovated single-family buildings	9 453	116
Single-family buildings built after 1990	7 742	100
Non-renovated apartment buildings	30 848	197
Renovated apartment buildings	1 488	80
Multi-apartment buildings built after 1990	5 161	100

Industrial and service sectors are defined in the model not by the number of square metres, but rather by the number of companies, because in these sectors, unlike in households, part of the premises is not heated and some the energy resources are employed not only to produce thermal energy to heat the premises, but also for technological processes ([40]). Unlike households, in the industrial and service sector, not only renovation of buildings, but also other EE measures, including increasing the efficiency of production processes, is considered for the purpose of reducing thermal energy consumption. ([41])

Companies are divided into the large companies and large consumers of electric power and small companies. Such division is used because the difference between large companies and other companies with regard to specific energy consumption is significant.

TABLE 2.22. MAIN PARAMETERS OF THE INDUSTRIAL AND SERVICE SECTOR ([42])

([40]) Asere L., Blumberga A. Government and Municipality Owned Building Energy Efficiency System Dynamics Modelling. Energy Procedia 2015: 72: 180-187.

([41]) Blumberga A., Cilinskis E., Gravelsins A., Svarckopfa A., Blumberga D. Analysis of regulatory instruments promoting building energy efficiency. Energy Procedia 2018: 147: 258-267.

([42]) Kubule A., Ločmelis K., Blumberga D. Analysis of the results of national energy audit program in Latvia. Energy, 2020: 202; 117679.

	Number, pc.	Average electric power consumption, GWh/pc./year	Average thermal energy consumption, kWh/pc./year
Large industrial companies	380	4.9	18.82
Small industrial companies	2 500	0.05	0.192
Large service companies	700	3.32	3.09
Small service companies	18 200	0.033	0.041

The EE scenario provides for support for implementing EE measures at apartment buildings, commercial buildings, public buildings and industrial businesses. The volume of support has been obtained from the forecasted values for up to 2030 of Annex 4 of the National Energy and Climate Plan of Latvia. Support is allocated for the period up to 2030 with the condition that part of it can also be used after 2030 provided that the application for funding has been received by 2030. Additional funding after 2030 is not allocated. The main amounts of funding and level of support have been presented in Table 2.23.

TABLE 2.23. SUPPORT IN THE ENERGY EFFICIENCY SCENARIO AND LEVEL OF SUPPORT

	Total amount of support, MEUR	Level of support, %
Residential buildings	1 200	30
Commercial sector buildings	300	30
Municipality buildings	100	30
Private buildings	100	30
Industrial sector	225	20

The obtained results of trends for the demand for thermal energy in DH and individual heating are presented in Figure 2.41. Within the analysed EE scenario, the total demand for thermal energy fell by 2 504 GWh in 2050, comparing to the baseline year. The demand for DH thermal energy fell by 890 GWh in 2050, but the demand for individual heating fell by 1 613 GWh in 2050.

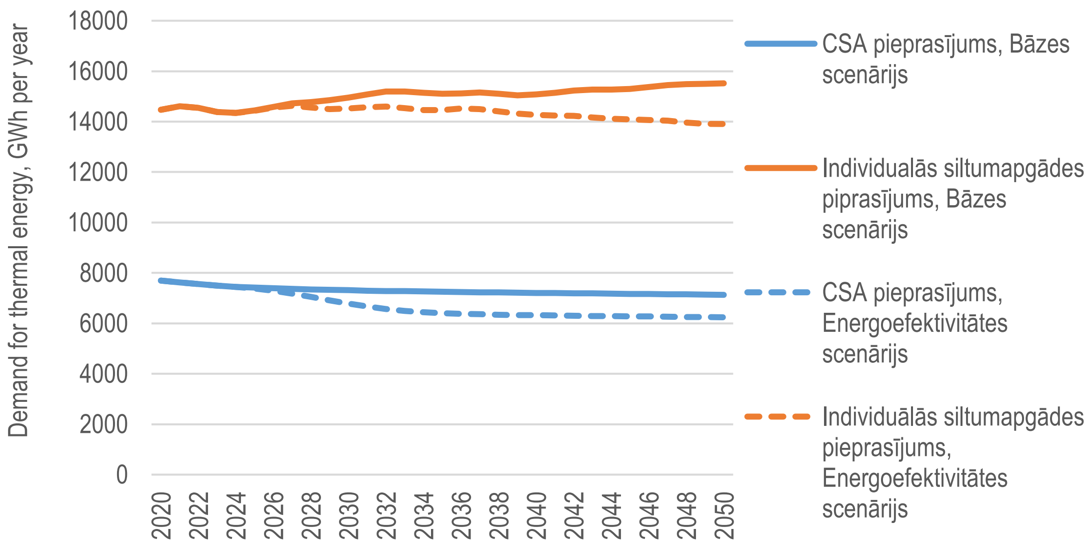


Figure 2.41. Forecast for the demand for DH and individual heating within the analysed scenarios

CSA pieprasījums, Bāzes scenārijs - Demand for DH, baseline scenario; Individuālās siltumapgādes pieprasījums, Bāzes scenārijs - Demand for individual heating, baseline scenario; CSA pieprasījums, Energoefektivitātes scenārijs - Demand for DH, energy efficiency; Individuālās siltumapgādes pieprasījums, Energoefektivitātes scenārijs - Demand for individual heating, energy efficiency scenario

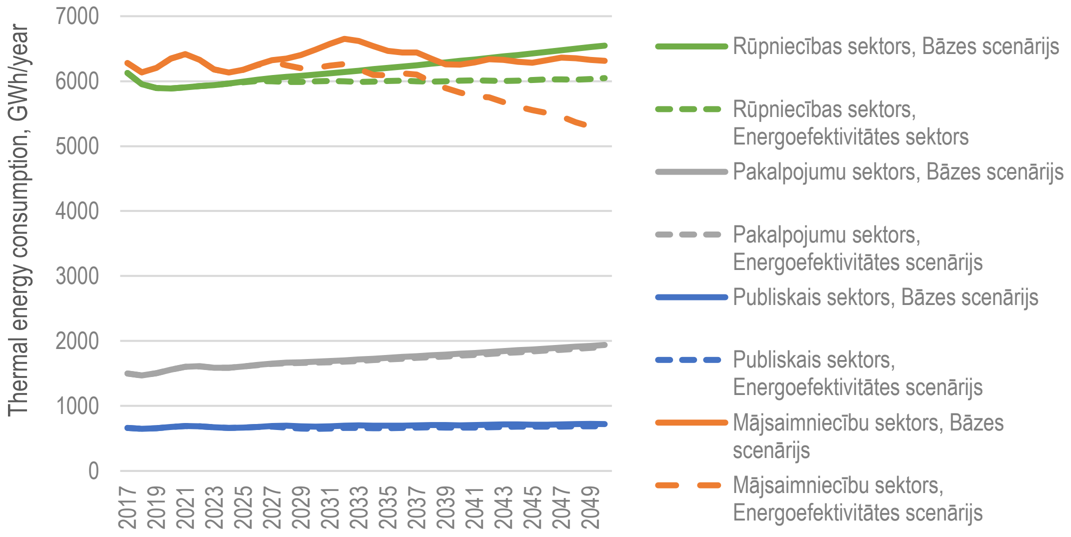


Figure 2.42. Forecast for the demand for heating by sectors within the analysed scenarios

Rūpniecības sekotrs, Bāzes scenārijs - Industrial sector, baseline scenario; Rūpniecības sektors, Energoefektivitātes sektors - Industrial sector, energy efficiency scenario; Pakalpojumu sektors, Bāzes scenārijs - Service sector, baseline scenario; Pakalpojumu sektors, Energoefektivitātes scenārijs - Service sector, energy efficiency scenario; Publiskais sektors, Bāzes scenārijs - Public sector, baseline scenario; Publiskais sektors, Energoefektivitātes scenārijs - Public sector, energy efficiency scenario; Mājsaimniecības sektors, Bāzes scenārijs - Household sector, baseline scenario; Mājsaimniecības sektors, Energoefektivitātes scenārijs - Household sector, energy efficiency scenario

A forecast of the demand for individual heating thermal energy by sub-sectors is presented in Figure 2.42. The most significant reduction of thermal energy consumption is forecasted for the household sector, within which the most extensive financial support for thermal insulation has also been planned. Reduction of thermal energy consumption in 2050 reaches 1 050 GWh in the EE scenario, compared to 2050. Reduction of demand for thermal energy has also been observed in the industrial sector (500 GWh, comparing the rates of 2050 with the baseline scenario), but the reduction in the demand for thermal energy planned in the public and the services sectors in the EE scenario is insignificant (the total amounts to approx. 62 GWh, when comparing the rates of 2050 with the baseline scenario).

2.6. Share of renewable energy sources and residual thermal or cooling energy within the final energy consumption of the DH and cooling supply sector

From 2013 to 2017, the share of produced energy in the gross final energy consumption increased by 1.97 percentage points in relation to the gradual reduction of the share of natural gas consumption and the increase in the share of energy wood [Energy Balance of Latvia, 2018].

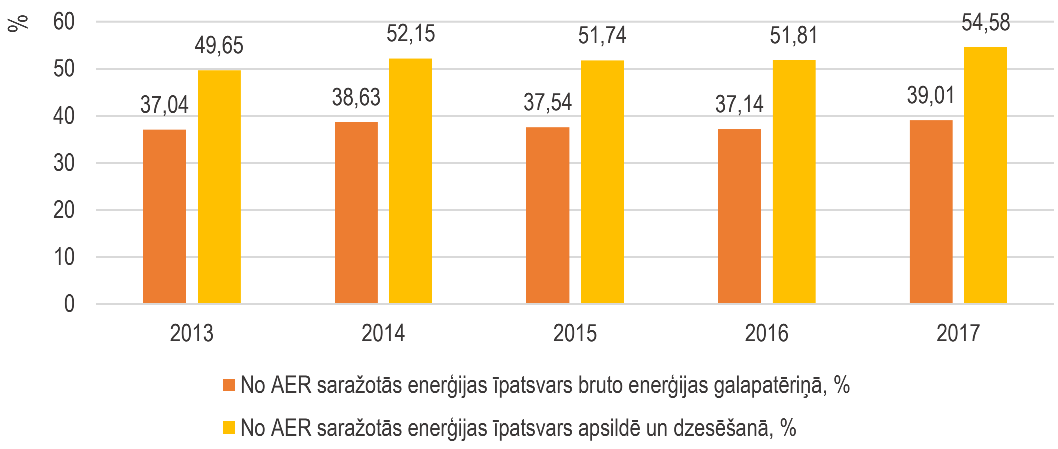


Figure 2.43. Share of renewable energy sources from 2013 to 2017 [data from the Central Statistical Bureau]

No AER saražotās enerģijas īpatsvars bruto enerģijas galapatēriņā - Energy produced from RES as share of gross final energy consumption; No AER saražotās enerģijas īpatsvars apsildē un dzesēšanā - Energy produced from RES as share in heating and cooling

From 2013 to 2017, the energy produced from RES as share of heating and cooling increased by 4.93 %.

TABLE 2.24. SHARE OF RENEWABLE ENERGY SOURCES

	2013	2014	2015	2016	2017
Energy produced from RES as share of gross final energy consumption, %	37.04	38.63	37.54	37.14	39.01
Energy produced from RES as share in heating and cooling, %	49.65	52.15	51.74	51.81	54.58

In heating and cooling, the share of energy produced from RES increased more rapidly, which can be related to the inclusion of transportation in the calculations of gross final energy consumption, because it is the largest consumer of energy resources. In 2018 in Latvia, the RES share in the transportation sector constituted 4.7 %. ([43])

In Latvia, detailed information about the share of residual thermal or cooling energy within the final energy consumption of the DH and cooling supply sector is not available.

([43]) CSB. Energy Balance of Latvia, 2019.

3. TARGETS, STRATEGIES AND POLICY MEASURES

This chapter describes targets, strategies and policy measures related to heating. The chapter is based on the algorithm presented in Figure 3.

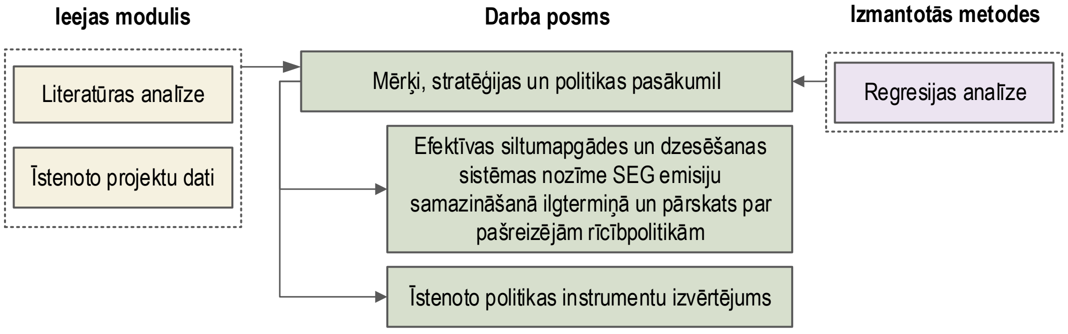


Figure 3. Methodology algorithm for the assessment of targets, strategies and policy measures [*for translation, see (21) in accompanying document*]

The assessment of targets, strategies and policy measures includes two sub-tasks related to the role of efficient heating and cooling systems in the long-term reduction of GHG emissions: an overview of current policies and an assessment of implemented policy instruments.

3.1. The role of efficient heating and cooling systems in the long-term reduction of GHG emissions and an overview of current policies

The planned contribution of a member state to the national targets, target values and five dimensions of the Energy Union

The targets of Latvia and the measures of their implementation have been established in the NECP 2021-2030 and in the Latvia 2030 – Sustainable Development Strategy of Latvia. The NECP includes the national targets (contributions) in each dimension of the Energy Union, planned policy measures for their implementation, the current situation and projections for their implementation, contribution of planned policy measures for implementing the targets (contributions), methodologies and policy measures for achieving energy savings and the interaction of all dimensions of the Energy Union.

1. Decarbonisation dimension

Historically, the majority of DH system operators are participants of the non-included activity sector of the emissions trading system (non-ETS). Only 20 operators participated in the emissions trading scheme 2013-2020. According to a report on GHG emissions from Latvia's Environment, Geology and Meteorology Centre (LEGMC), 64 % of the total GHG emissions in 2016 were created by the energy sector. Most of these emissions come from the transportation sector, but 25.6 % comes from the energy sub-sector and 19.9 % comes from other sectors including heating of individual buildings and the use of fuel in agriculture, forestry and fishery.
In draft version No 2 of the National Energy and Climate Plan of Latvia 2021-2030, Latvia establishes its climate policy targets up to 2030: reduction of GHG emissions in non-ETS sector by 6 %, compared to the volume of non-ETS GHG emissions of Latvia in 2005.

TABLE 3.1. TARGETS OF GHG EMISSIONS AND CO_2 REMOVAL POLICY OF LATVIA AND THEIR RESULTATIVE RATES

	Actual value	Target value

Result of the policy in the sub-dimension of GHG emission reduction and CO_2 removal of the decarbonisation dimension	2017	2020	2030
reduction of non-ETS GHG emissions			
in %, compared to 2005	+8.1	+17	-6
Mt CO_2 equivalent	9.24	10	8

The total target of the period has also been divided into binding annual targets. The annual targets of non-ETS GHG emission reduction in 2021-2030 will only be determined for Latvia in 2020-2021.
No specific decarbonisation targets for heating and cooling have been detailed in political documents.

2. Renewable energy

The target of RES share established in Latvia for production of thermal and cooling energy by 2030 is 57.59 %, which is above the total share of the final energy consumption (see Table 3.2).

TABLE 3.2. TARGETS OF RES USE POLICY OF LATVIA AND THEIR RESULTATIVE RATES

Result of the policy in the sub-dimension of RES energy of the decarbonisation dimension	Actual value	Target value				
	2017	2020	2022	2025	2027	2030
Share of RES in final energy consumption (%)	39	40	41.8	44.3	46.5	50
indicative share of Res in thermal and cooling energy production (%)	54.6	*53.4*	*55.2*	*56.1*	*56.7*	*57.6*

In the period up to 2030, Latvia is planning to increase the RES share in the heating and cooling sector annually by at least 0.55 % by modernising the capacities of installed biomass use facilities and increasing the capacities of installed heat pumps and the use of solar energy in the production of thermal energy.

3. Energy efficiency dimension

Latvia must annually ensure new savings of 0.8 % from the annual final energy consumption, by calculating it as the mean of the rates of the last three years prior to 1 January 2019.

TABLE 3.3. TARGETS OF THE ENERGY EFFICIENCY IMPROVEMENT POLICY OF LATVIA AND THEIR RESULTATIVE RATES

Policy outcome in the energy efficiency dimension	Actual value	Target value	
	2017	2020	2030
optional target – primary energy consumption			
PJ	187.41	225	*170*
GWh	52 058.33	62 500	*47 222*
Mtoe	4.48	5.4	*4.06*
optional target – final energy consumption			
PJ	168.01	187	*145*
GWh	46 669.44	51 944	*40 278*
Mtoe	4.01	4.47	*3.46*
national optional target – cumulative savings of final energy consumption			
PJ	7.54	35.6	74.31
GWh	2 093.4	9 896	20 473
Mtoe	0.18	0.85	1.76

Latvia is planning to renovate 3 % of central government buildings annually by 2030, but the forecast for the total renovated builds has not been calculated.

During the period up to 2030, Latvia proposes to ensure the reduction of the average specific consumption of thermal energy in buildings for heating up to 100 kWh/m^2/year, which would also considerably reduce the demand for thermal energy produced by DH.

A significant role in the plan is played by the improvement of DH system operation efficiency and an increase in the use of RES, which should be ensured by replacing facilities used in DH to more efficient ones and installing different RES technologies with a focus on zero-emissions technologies.

4. Energy security dimension

Latvia 2030 – Sustainable Development Strategy of Latvia establishes a reduction of the import of energy and energy resources from the existing third-country suppliers by 50 %, compared to 2011. It also includes a reduction in the consumption of imported natural gas used in district heating.

TABLE 3.4. TARGETS FOR THE ENERGY SECURITY IMPROVEMENT POLICY OF LATVIA AND THEIR RESULTATIVE RATES

Policy outcome in the energy security dimension	Actual value	Target value	
	2017	2020	2030 ([44])
Share of import in gross inland energy consumption (incl. bunkering) (%)	44.1	44.1	30-40
Share of import from third countries in gross inland energy consumption (incl. bunkering) (TWh)	17.7	-	14.1
Opportunities to purchase natural gas from different sources (*number of sources*)	> 2	≥ 1	> 2

With regard to targets for the diversification of energy sources in district heating and cooling, the objective of Latvia is to achieve a considerable increase in the capacity of installed wind and solar technologies and of heat pumps, where the current volume is insignificant.

([44]) The text in the standard font includes already valid goals, which are set in binding EU legal acts, other policy planning documents or legal acts of Latvia, whereas binding goals to be determined in the plan are written in bold.

5. Internal energy market dimension

The established targets primarily influence the supply of electricity. One of the targets influencing heating and cooling is to continue contributing towards the development of natural gas infrastructure after completion of the existing infrastructure projects, in order to improve the security of supply.

One of the actions proposed to help attract new consumers and ensure constantly low thermal energy supply tariffs, uninterrupted and secure heating, and different options for the consumer to use thermal energy in a rational manner, is to increase DH EE. This is why new and especially efficient systems for thermal energy transmission and distribution must be built, particularly in territories with a sufficient density of construction and a sufficiently large population. Heating (market) liberalisation is another method to ensure this, and therefore this option should be assessed in more detail.

6. Research, innovation and competitiveness dimension

The Sustainable Development Strategy of Latvia to 2030 includes a vision for the use of RES and technological development, and identifies the need to develop collaboration between research institutions and companies in the field of RES. Four out of the six priorities of the strategic energy technology (SET) plan for which research and innovation (R&I) should be developed, are currently relevant for Latvia.

TABLE 3.5. CONTRIBUTIONS OF LATVIA TO SET PLAN PRIORITIES (AS % OF THE TOTAL R&I CONTRIBUTIONS)

SET plan priorities	Actual value	Target value
	Period 2014-2018	Period 2021-2027
Renewable energy	10 %	*data update pending*
Smart energy systems	26 %	*data update pending*
Energy-efficient systems (residential buildings and industry)	28 %	*data update pending*
Sustainable transportation	15 %	*data update pending*
Energy management and market	20 %	*data update pending*

To use the most suitable thermal energy production and supply technologies in Latvia, the most efficient type of the specific heating system must be assessed, i.e., whether the local heating (LH) and the individual heating system may be connected to DH, whether zero emission technologies can be installed for thermal energy production, and whether high-efficiency facilities using biomass can be installed.

General overview of the current policies and measures for district heating and cooling

Policy planning documents and laws and regulations

Policy planning documents and reports

- Latvia 2030 – Sustainable Development Strategy of Latvia until 2030 (2010), https://www.pkc.gov.lv/sites/default/files/inline-files/Latvija_2030_7.pdf
- Saeima Report on the National Development Plan of Latvia 2014-2020 (2012), https://www.pkc.gov.lv/lv/valsts-attistibas-planosana/nacionalais-attistibas-plans
- Information report Long-Term Energy Strategy of Latvia 2030 – Competitive Energy for the Society (2013)
- Low Carbon Development Strategy of Latvia 2050 (2017)
- National Energy and Climate Plan (draft, 2018)

Laws

- Energy Law (adopted: 03.09.1998, effective: 06.10.1998), https://likumi.lv/doc.php?id=49833
- Law On Regulators of Public Utilities (adopted: 19.10.2000, effective: 01.06.2001)
- Energy Efficiency of Buildings Law (adopted: 06.12.2012, effective: 09.01.2013), https://likumi.lv/ta/id/253635-eku-energoefektivitates-likums

- Energy Efficiency Law (adopted: 03.03.2016, effective: 29.03.2016), https://likumi.lv/doc.php?id=280932
- Subsidised Electricity Tax Law (adopted: 06.11.2013, effective: 01.01.2014), https://likumi.lv/doc.php?id=262304
- Protection Zone Law (adopted: 05.02.1997, effective: 11.03.1997), https://likumi.lv/doc.php?id=42348&from=off

Cabinet of Ministers regulations and other laws and regulations

- Order of the Chairman of the Riga City Council Order No 349-r of 19 April 2000 on the procedure of determining the type of heating for construction plans and coordination thereof in Riga city, https://likumi.lv/ta/id/5188
- Cabinet Regulation No 876 of 21 October 2008 regarding the supply and use of thermal energy, https://likumi.lv/doc.php?id=183035
- Cabinet Regulation No 221 of 10 March 2009 regarding electricity production and price determination upon production of electricity in cogeneration, https://likumi.lv/doc.php?id=189260&from=off
- Decision No 1/7 of the Board of the Public Utilities Commission of 14 April 2010 'Methodology for the Calculation of Thermal Energy Supply Service Tariffs' https://likumi.lv/ta/id/208283-siltumenergijas-apgades-pakalpojumu-tarifu-aprekinasanas-metodika
- Cabinet Regulation No 824 of 31 August 2010 on the second round and the following rounds for selection of project applications in the sub-activity 3.5.2.1.1 'Measures to Increase the Efficiency of District Heating Supply Systems' of the Complement of the Operational Programme 'Infrastructure and Services' https://likumi.lv/ta/id/217641-noteikumi-par-darbibas-programmas-infrastruktura-un-pakalpojumi-papildinajuma-3-5-2-1-1-apaksaktivitates-pasakumi-centralizetas...
- Cabinet Regulation No 312 of 19 April 2011 Procedures for the supply of energy users and sale of heating fuel during declared energy crisis and in case of endangerment to the state, https://likumi.lv/ta/id/229557-energijas-lietotaju-apgades-un-kurinama-pardosanas-kartiba-izsludinatas-energetiskas-krizes-laika
- Cabinet Regulation No 243 of 19 April 2016 regarding the energy efficiency requirements for centralised heating supply systems in the possession of a licensed or registered energy supply merchant, and the procedures for conformity examination thereof, https://likumi.lv/ta/id/281914
- Cabinet Regulation No 135 of 7 August 2017 on implementation of the first round of selection of project applications of the specific support objective 4.3.1 'To Promote Energy Efficiency and Use of Local RES in the District Heating Supply' of the Operational Programme 'Growth and Employment', https://likumi.lv/ta/id/289471-darbibas-programmas-izaugsme-un-nodarbinatiba-4-3-1-nbsp-specifiska-atbalsta-merka-veicinat-energoefektivitati-un-vietejo-aer-i...
- Cabinet Regulation No 495 of 22 August 2017 on implementation of the second round of selection of project applications of the specific support objective 4.3.1 'To Promote Energy Efficiency and Use of Local RES in the District Heating Supply' of the operational programme 'Growth and Employment', https://likumi.lv/ta/id/293209-darbibas-programmas-izaugsme-un-nodarbinatiba-4-3-1-nbsp-specifiska-atbalsta-merka-veicinat-energoefektivitati-un-vietejo-aer-i...

Policy planning documents and reports

Latvia 2030 – Sustainable Development Strategy of Latvia

The production of district heating is an important constituent of energy, which accounts for more than half of the consumption of primary energy resources and ensures the needs of the population of Latvia for heating during winter, as well as for water, are met. During the development of Latvia 2030, data showed that the consumption of district heating in the country has fallen by one

tenth in recent years. More than 80 % of district thermal energy was produced using natural gas. Latvia 2030 notes that the share of oil product in district heating has decreased, mostly having been replaced by natural gas and, to a relatively lesser extent, by wood. The share of RES in the production of district thermal energy from 2000 to 2007 slightly increased from 11.3 % to 15 %, but the share of thermal energy produced in CHP plants has rapidly increased and constitutes 55.5 %. Latvia 2030 indicates that, when renovating the existing and constructing new boiler houses and CHP plants, the local energy resources, e.g., wood, straw, reed and also peat, using environmentally-friendly extraction methods, must be used for the production of thermal energy.
The chapter Energy Efficiency Measures of 'Latvia 2030' emphasises the fact that the performance of renovation for apartment buildings, district heating systems, boiler houses and transmission lines is especially important to reduce thermal energy consumption and loss and that increasing the number of DH connections is desired to improve the efficiency of district heating system operation. ([45])

National Development Plan 2014-2020 (NDP)

The tasks of the course of action 'Production of Energy Efficiency and Energy' include [206] the use of RES for the production of energy by reducing fossil energy resource dependence and the facilitation of EE in district heating, specifying the Ministry of Economics, Ministry of Environmental Protection and Regional Development, Ministry of Agriculture and municipalities as the institutions responsible for the completion of the task. ([46])

Information report Long-Term Energy Strategy of Latvia 2030 – Competitive Energy for Society (Strategy 2030)

The Strategy 2030 assigns an important role to EE by indicating the importance of planning an EE increase, which is a national priority in the period of Strategy 2030. Low EE level leads to risks of energy supply safety, sustainability and competitiveness, but an increase in this level is the fastest and the most cost-efficient manner to reduce risks by creating additional places of employment and encouraging development at the same time.
The provision of EE constitutes a significant market failure, especially in the sector of buildings and transportation. To prevent this and to facilitate EE in all sectors, The Strategy 2030 establishes several preconditions, also bearing in mind that the production of thermal energy, including district thermal energy, accounts for the largest consumption of energy resources, and the determination of more rigid requirements for DH systems has been envisioned with respect to the reduction of energy loss in networks by assessing the usefulness of investments and by reducing the benchmark of loss to 10 % by 2030, as well as stimulation of new consumers connecting to efficient DH systems, including restrictions on the installation of low-expedience fossil autonomous heating facilities in territories with district heating available.
The Strategy 2030 also draws much attention to facilitation of the use of RES in the production of electric power and thermal energy. The objective of Latvia is for energy produced from renewable energy sources to constitute 40 % of gross final energy consumption by 2020. To achieve this objective, Strategy 2030 envisions activities concerning district heating: considering the national and EU-scale RES goals and the fact that Latvia is currently widely using fossil energy resources for the production of thermal energy, to apply a state support exception for the achievement of the

([45]) Sustainable Development Strategy of Latvia until 2030, Articles 204, 212. Available online: https://www.pkc.gov.lv/sites/default/files/inline-files/Latvija_2030_7.pdf
([46]) Saeima Report on the National Development Plan of Latvia 2014-2020, Article 206. Available online: https://likumi.lv/doc.php?id=253919

particular objective in the mid-term (until 2020), and to secure direct high intensity support in centralised heat supply systems for the transfer to RES; To introduce requirements and support mechanisms for the promotion of the use of RES technologies in new and renovated buildings, with a view to facilitating the integration of new RES systems in district heating systems. ([47])

Low Carbon Development Strategy of Latvia 2050 (LCDS)

The strategic objectives of the LCDS refer back to the section on EE in the National Development Plan 2014-2020, which, in turn, also makes reference to a transition to renewable energy sources and a stable and flexible energy system combining the efficient high-capacity production of energy and small-scale energy production supported by the development of smart networks.

The chapter 'Sustainable Energy' envisages the complete modernisation of the heating system by 2050. New heating system technologies and methods ensuring the use of innovative technologies and solutions for the efficient operation of the heating system have been introduced into the district and local heating system. Consumption of fossil energy resources has significantly fallen in Latvia. To reduce emissions from the energy sector, a policy has been implemented to facilitate the use of sustainable and low-carbon technologies, incl. RES, and to introduce the most efficient technologies available on the market. ([48])

National Energy and Climate Plan (NECP)

The NECP contains several references to RES and EE measures in district heating (DH) for the purpose of achieving long-term EE goals for buildings in Latvia, emphasising the importance of EE enhancement and RES use in district heating and the achievement of a 60 % share of DH provided using renewable energy. The NECP indicates that the forecast of an increasing share of DH being provided using RES in the period following 2020 is based on the assumption that the number of biomass cogeneration plants will increase.

The chapter 'Energy Efficiency' (3.2) of the NECP includes references to policies and measures, including the DH EE programme (3.2.1.1), objective 4.3.1 of which is to promote EE and use of local RES in district heating within the DH funding programme 'Growth and Employment 2014-2020'. Continuation of the programme is also expected in the following EU funding period (from 2021 to 2027) through co-funding from the EU Cohesion Fund.

The assessment (carried out in accordance with the requirements of Article 14 of the Directive 2012/27/EU) of the DH potential for the use of high-efficiency cogeneration concludes that more extensive use of RES within DH has no potential for development on national level, except in individual cities (Daugavpils, Liepāja and Jūrmala). It has also been concluded that DH has a higher EE level than individual heating solutions due to its larger share of energy produced in efficient cogeneration. At the same time, it has also been concluded that the DH solution requires large investments in infrastructure and that it has high maintenance costs, making DH attractive and economically viable in territories with a relatively high density of demand for heating. The largest DH potential is in the household sector, but the demand of households and also industrial companies for DH is little, because many potential clients prefer individual heating solutions due to economic considerations. To stimulate centralisation of heating, economic stimuli targeted at the end-users of energy is required, so that DH costs do not exceed the costs of individual heating solutions for users.

([47]) Ministry of Economics, Information report Long-Term Energy Strategy of Latvia 2030 – Competitive Energy for the Society, p. 11-12, Articles 15, 16, 21, 23, 16.05.2013. Available online: http://tap.mk.gov.lv/mk/tap/?pid=40263360.
([48]) Low Carbon Development Strategy of Latvia 2050, Section 5.1, p. 25. Available online: http://tap.mk.gov.lv/mk/tap/?pid=40462398.

At the same time, it has been forecasted that the implemented EE measures will reduce the demand for DH in 2030 by 7 %.

By assessing potential new policy instruments for the achievement of the air quality objectives of the NECP, issuing co-funding from EU funds for new types of action has been envisioned, thereby supporting zero emission (solar power, wind, heat pumps) RES solutions or biomass plants servicing DH and local heating systems. Continuation of support for the modernisation of existing DH systems has also been planned to reduce loss in networks (3.3.3) and to improve the EE of public and private buildings using indoor cooling solutions, which use ground heat pumps and water bodies and adapt the existing DH and the local heating systems to carry out the cooling function (3.3.4).

Finally, the NECP tax policy measures (3.4) envision applying a natural resource tax (at 50 %) (NRT) to CO_2 emissions created by heat-producing stationary devices and newly-installed gas boilers used for DH, if they have been installed as a spare power resource for covering peak demand. ([49])

Laws

Energy Law

The Energy Law, Article 1(4[2]) defines DH as a set of heating sources, heating transmission and distribution networks and users of thermal energy that generate, convert, transmit, distribute and consume thermal energy in a co-ordinated way. Chapter IX 'Heating Supply and Cooling Supply System' of the Law determines the preconditions for providing heating services in more detail. Article 46(2) states that heating supply or cooling supply may be provided using a district heating supply or cooling supply system, individual heating supply or cooling supply system, or local heating supply or cooling supply. Article 46(5) states that the Cabinet shall determine the procedures for the calculation of savings of primary energy produced by cogeneration plants and regulations laying down energy efficiency requirements for centralised heating supply systems in the possession of a licensed or registered energy supply merchant, and the procedures for conformity examination thereof.

Article 47(1) of the Energy Law stipulates that centralised heating supply may be provided by one vertically integrated energy supply merchant. A centralised heating supply operator shall be established in systems that have several generators of thermal energy, at least one of which is the independent generator. Paragraph 2 of the same article indicates that the functions of the heating supply system operator may be performed by a vertically integrated merchant that performs mutually separate generation, transmission and distribution of thermal energy.

Although DH is considered as an optimal solution for territories with a dense demand for heating, Article 50 of the Energy Law states that the owners of buildings and constructions have the right to select the most advantageous manner of heating supply. The necessity for competition in this sector of commercial activity is indicated in Article 51 of this law; Paragraph 1 stipulates that local governments, when performing their permanent functions as specified in law, shall organise heating supply in their administrative territory, and also promote EE performance and competition in the heating supply and fuel market. Article 51(2) stipulates that local governments may specify the development of heating supply and issue binding regulations within the scope of the plan of their administrative territory, taking into account the provisions of the environmental protection and the protection of cultural monuments, and also the possibilities for the use of local energy sources and co-generation and the evaluation of the safety of heating supply and long-term marginal costs.

([49]) National Energy and Climate Plan of Latvia 2021-2030, draft, p. 29, 48, 49, 91, 99, 100, 131, 194, 195, 196. Available online: https://em.gov.lv/files/nozares_politika/LATVIA_NECP2021-2030_PROJECT_19122018.docx.

And finally, Article 52 of the Energy Law stipulates that the connection of structures and buildings to the DH system or their disconnection therefrom may not disturb other users of this system from receiving heating. ([50])

Law On Regulators of Public Utilities

Article 2(2)(2) of the Law stipulates that the State shall regulate the provision of public utilities as a commercial activity in the energy sector. ([51]) The regulator of public utilities has a significant role in the regulation of the tariffs of services provided in the sector.

Protection Zone Law

Article 17 of the Protection Zone Law includes regulation for protection zones of heating networks and stipulates that protection zones along heating networks and the equipment and structures thereof, shall be determined in order to ensure the functioning and safety of heating networks and the equipment and structures thereof. Article 17(2) of the Law specifies the parameters of a protection zone for underground and overground heating system equipment and structures by stipulating that protection zones along the heating networks shall be along heat supply lines in channels or tunnels – a land area which is occupied by underground equipment, as well as a land area and airspace, which is delimited by notional vertical planes at a distance of 2 metres on each side from the outer edge of the channel, tunnel or other structure, but around overhead heat supply lines, distribution equipment and heat supply points – a land area occupied by heating networks, equipment and structures and a land area and an air space at a distance of 1 metre on each side from the enclosure of these devices or projection of the most protruding parts thereof on the ground or on the surface of the floor.

Cabinet of Ministers regulations and other regulatory documents

Order of the Chairman of Riga City Council No 349-r of 19 April 2000 on the procedure for determining the type of heating for construction plans and coordination thereof in Riga city.
Riga is the largest individual heating consumer in Latvia using a district heating system, and the fact that Riga has an arranged heating supply has a significant effect on planning and placement of heating production sources. The order stipulates a procedure for meeting the requirements for the organisation of heating supply within the administrative territory of Riga and measures to be taken to prevent unauthorised construction, reconstruction or renovation of local heating sources. ([52])
Cabinet Regulation No 876 of 21 October 2008 regarding the supply and use of thermal energy. The regulation stipulates the procedure for recording the volume of consumed thermal energy and determining the price for buildings, for which heating supply is ensured from a joint heating source or from a DH system. ([53])
The primary purpose of a CHP plant is to ensure heating for a source for thermal energy consumption through a heating supply system. By producing heating, a CHP plant is producing also electric power. Power generating thermal energy, or a CHP plant receiving support for operation and development, are an important element in the heating system.
Decision No 1/7 of the Board of the Public Utilities Commission of 14 April 2010 Methodology for the Calculation of Thermal Energy Supply Service Tariffs
The Methodology prescribes the procedures by which a merchant shall calculate the tariff for the following regulated thermal energy supply services: thermal energy production (except the production of thermal energy by cogeneration installations with an installed electric capacity over one megawatt), transmission and distribution of thermal energy and trade of thermal energy. Article 12^1 of the Methodology stipulates that if a

([50]) Energy Law. Latvijas Vēstnesis, 273/275, 22.09.1998. Available online: https://likumi.lv/ta/id/49833
([51]) Law On Regulators of Public Utilities. Available online: https://likumi.lv/doc.php?id=12483.
([52]) Order of the Chairman of Riga City Council No 349-r of 19 April 2000 on the procedure for determining the type of heating for construction plans and coordination thereof in Riga city. Available online: https://likumi.lv/ta/id/5188.
([53]) Article 8.3 of the Cabinet Regulation No 876 of 21 October 2008 regarding the supply and use of thermal energy. Available online: https://likumi.lv/doc.php?id=183035

merchant provides thermal energy services in several technically unrelated DH systems, the merchant has the right to calculate thermal energy supply tariffs for each DH system individually. The merchant shall submit the summary of all planned regular costs and their breakdown, attributing the costs to each DH system. ([54])

Cabinet Regulation No 824 of 31 August 2010 on the second round and the following rounds for selection of project applications in the sub-activity 3.5.2.1.1 'Measures to Increase the Efficiency of District Heating Supply Systems' of the complement of the operational programme 'Infrastructure and Services'.

The regulation establishes a procedure to implement the second and the following rounds for selecting project applications within the sub-activity 3.5.2.1.1 'Measures to Increase the Efficiency of District Heating Supply Systems' of the activity 3.5.2.1 'Measures to Increase the Efficiency of District Heating Supply Systems' of the measure 3.5.2 'Energy' of the priority 3.5 'Promotion of Environment Infrastructure and Environmentally-Friendly Energy' of the complement of the operational programme 'Infrastructure and Services', criteria for assessment of EU Cohesion Fund project applications, requirements for the applicant of a project to EU Cohesion Fund, the responsible body and the liaison body, distribution of competence between these bodies and the procedure for cooperation and the form of functional subordination of the responsible body and the liaison body.

Article 40.5 of the regulation stipulates comparative advantages for funding of heating system projects, which present a potentially increased efficiency and use of RES in heating production with the stipulation that, if, by evaluating project applications subject to criteria referred to in the Articles 1, 2, 3, 4 and 5 of Annex 3 of the Regulation, several project applications score equally, then, when arranging the projects in an order, the following principles must be complied with: preference is given to the project application, which envisions a larger saving of energy or fuel or increase in RES share in the heating system (criterion referred to in Article 2 of Annex 3), and, if several project applications indicate the same saving in energy or fuel or increase in RES share in the heating system, the preference is given to the project application that envisions a larger ratio of energy saving or reduction in costs of consumed fuel against the attributable costs.

Cabinet Regulation No 312 of 19 April 2011 Procedures for the supply of energy users and sale of heating fuel during declared energy crisis and in case of endangerment to the state.

Article 14 of the Regulation stipulates that energy supply merchants who supply heat (including district heating) shall, by taking into consideration the classification of energy users into groups and by coordinating it with a local government, compile lists of heat energy users of the first and second groups for the restriction of the heat energy supply and develop procedures for the restriction and discontinuation of heat energy supply if an energy crisis is declared.

Article 19 of the Regulation stipulates that if a local energy crisis is declared, the technical measures for the restriction or discontinuation of DH supply in the relevant territory shall be taken by an energy supply merchant who provides heat supply.

Cabinet Regulation No 243 of 19 April 2016 regarding the energy efficiency requirements for centralised heating supply systems in the possession of a licensed or registered energy supply merchant, and the procedures for conformity examination thereof.

The Regulation specifically stipulates requirements regarding EE for centralised heating supply systems in the possession of a licensed or registered energy supply merchant, and the procedures for conformity examination thereof. A procedure has also been stipulates to measure thermal energy consumed by heating users, the volume of fuel consumed for thermal energy production, and intervals in which information must be gathered.

Cabinet Regulation No 135 of 7 August 2017 On the implementation of the first round of selection of project applications of specific support objective 4.3.1 'To Promote Energy Efficiency and Use of Local RES in the District Heating Supply' of the operational programme 'Growth and Employment'.

The Regulation issued subject to Article 20(13) of the Law On the Management of European Union Structural Funds and the Cohesion Fund for the 2014-2020 Programming Period establishes a procedure to implement the first round of the selection of project applications of specific support objective 4.3.1 'To Promote Energy Efficiency and Use of Local RES in the District Heating Supply' of the operational programme 'Growth and Employment'. The purpose of implementing specific support and the selection round is to facilitate the use of EE and local RES in district heating.

([54]) Decision No 1/7 of the Board of the Public Utilities Commission of 14 April 2010 Methodology for the Calculation of Thermal Energy Supply Service Tariffs, https://likumi.lv/ta/id/208283-siltumenergijas-apgades-pakalpojumu-tarifu-aprekinasanas-metodika

Cabinet Regulation No 495 of 22 August 2017 On the implementation of the second round of the selection of project applications of specific support objective 4.3.1 'To Promote Energy Efficiency and the Use of Local RES in the District Heating Supply' of the operational programme 'Growth and Employment'.
The Regulation issued subject to Article 20(13) of the Law On Management of European Union Structural Funds and the Cohesion Fund for the 2014-2020 Programming Period establishes a procedure to implement the second round of the selection of project applications of Specific support objective 4.3.1 'To Promote Energy Efficiency and the Use of Local RES in the District Heating Supply' of the Operational programme 'Growth and Employment'. The purpose of implementing specific support and the selection round is to facilitate the use of EE and local RES in district heating.

3.2. Assessment of implemented policy instruments

During the planning period 2014-2020 of the Operational Programme 'Growth and Employment', the call for projects 'To Promote Energy Efficiency and the Use of Local RES in the District Heating Supply' was implemented within the specific support objective 4.3.1. The main purpose of providing support was to facilitate the use of EE and local RES in district heating. The selection of the call for projects took place in two rounds, and the available CF funding constituted almost EUR 50 million. A total of 129 projects were submitted within the call for projects. Currently, no detailed assessment of the total saved energy compared to the provided financial support has been performed for this programme.
In the 1st round of the call for projects coordinated by Central Finance and Contracting Agency (CFCA), 18 projects were identified, within which fossil energy sources (mostly natural gas) would be replaced by RES (mostly biomass). The total installed capacity in such projects was 136 MW. The total funding for these projects was EUR 71 million, from which almost EUR 20 million was granted as EU co-funding. Consequently, the specific costs of the granted co-funding per MW of the installed RES capacity were EUR 143 thousand. The available information does not allow the predictable volume of produced energy and the volumes of GHG emissions prevented by these projects to be determined.
The majority of the projects submitted planned the increase in the efficiency of the energy source by installing new biomass boilers, flue gas condensers or other technological solutions. Figure 3.1 analyses the specific costs of different projects of wood chip boiler houses and boiler installation. The analysis summarises information about projects implemented within the first round of the call for projects. The projects analysed include the replacement of existing inefficient wood chip boilers and construction of new boiler houses.

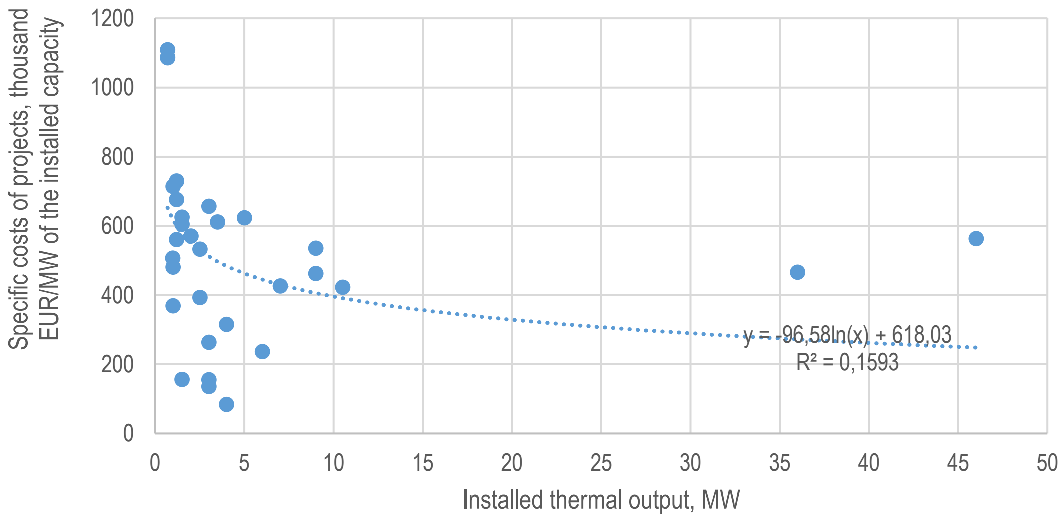


Figure 3.1. The specific costs of different projects to install wood chip boiler houses against the installed capacity

Figure 3.1 shows that the specific costs of projects may have a wide range. For example, the specific costs of a 1.5 MW wood chip boiler house may vary from EUR 156/MW to EUR 625/MW of the installed thermal output, which indicates that other factors influencing the costs irrespectively from the installed thermal output are present. It must be considered that the analysed costs includes also the costs of project implementation and maintenance.

Within the specific call for projects, some of the implemented projects were dedicated to reconstruction of heating networks to reduce heat loss and construction of new heating networks to increase the density of heating consumption. To assess the efficiency of the implemented EE policy, the specific saved energy costs were determined against the provided co-funding. In the specific study, the authors used the levelised cost of saved energy (LCSE) to assess the EE programme. According to previous studies, LCSE may be determined as the total costs of a project by dividing them by the total energy saving and considering the capital payback factor. The capital payback factor allows contributions during the project to be divided using a discount rate and EE measure duration. LCSE describes the energy saving costs from the point of view of the funding provider and includes all costs of technologies and project administration, but it does not include the general programme administration costs (including administration, marketing, training or project assessment). To determine LCSE, authors used a 5 % discount rate, which is in line with the studies. To assess the efficiency of programme costs, the publicly available information about activities performed in 29 different projects, achieved rates and granted co-funding for projects was summarised.

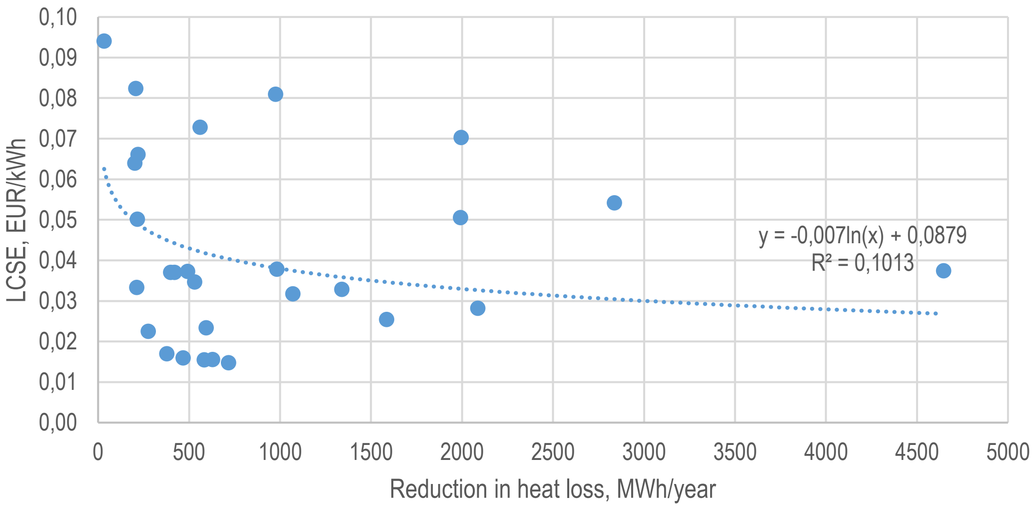


Figure 3.2. Established levelised cost of saved energy against the total reduction in heat loss

Figure 3.2 shows that the established levelised cost of saved energy fluctuates from EUR 0.01 /kWh to even EUR 0.09 /kWh. In the case of analysed DH network reconstruction projects, the obtained energy savings and costs are largely influenced by the diameters of the changed pipelines. Several projects included the construction of new heating networks not creating a direct energy saving, but providing a general benefit in the case of increased heating density.

To assess the implemented projects in detail, more specific information about the installed facilities, volume of produced energy, replaced pipelines, and achieved saving for heat loss against the granted amount of co-funding should be obtained.

4. ANALYSIS OF THE ECONOMIC POTENTIAL OF HEATING AND COOLING EFFICIENCY

4.1. Methodology of the economic analysis

The main starting point of the methodology is the summarisation of available data and definition of the baseline scenario. Since almost all of the aforementioned DH development opportunities must be analysed on a local, not national level, the source data model allows the data available for the parameters of specific DH systems to be attributed to the general heating supply in Latvia using the regression analysis method. The main source data is the available information from statistical databases (CSB, Gaiss-2, EUROSTAT etc.), DH system surveys and analyses of available literature, including of the previously performed DH studies. Considering the available information and the results of regression analysis concerning mutual influence among different rates, it is possible to define reference DH systems comprising the general heating supply in Latvia. On the basis of this reference system, the baseline scenario is defined. The baseline scenario is the reference point and it considers the characteristics of the elements of the existing policy and national heating system.

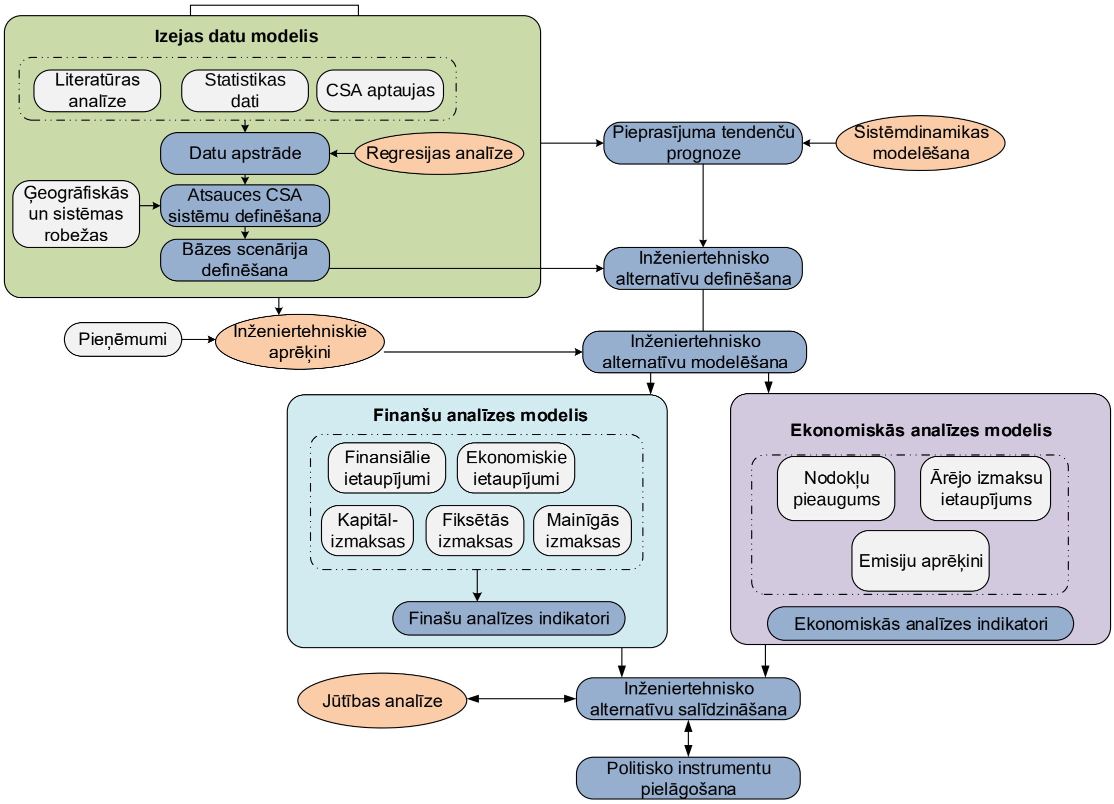


Figure 4.1. Algorithm of the economic analysis methodology and the employed analysis methods [*for translation, see (22) in accompanying document*]

Considering the forecast of demand trends, which was prepared using the system dynamics modelling method and the starting rates of the baseline scenario, engineering alternatives were defined to assess the aforementioned DH development opportunities. The engineering model is prepared for each of the defined alternatives based on the engineering calculations to assess the economic and social economic results and results of the effect on the environment and climate. The main starting rates in the economic model are financial savings and economic savings, which also includes society's savings from reduction in the harm caused to the environment. Financial savings are calculated considering the initial information about the reduction in the consumption of fuel and energy or other savings by the respective costs of fuel and thermal energy tariffs. To determine capital expenditure, different sources of available literature and source data of similar implemented projects in Latvia have been used. The made assumptions have been indicated in details for each of the analysed alternatives. The calculated costs and saving are used to establish the main economic indicators, i.e., financial and economic present value (NPV).

In addition to the economic indicators, social economic and environmental and climate indicators are also determined to allow more precise assessment of different benefits from introducing the alternatives. In the social economic model, aspects such as the effect on employment, energy supply security, tax increase and other aspects, which may be identified for a specific alternative, have been analysed. In the environmental and climate model, the amount of prevented emissions (particulate matter, NO_x, CO and CO_2) is calculated.

Considering the results of all aforementioned indicators, the opportunities to introduce the alternative defined are assessed and the necessary political instruments are identified to achieve maximum increase in DH efficiency. The elaborated methodology has been validated to analyse one of the opportunities to increase EE for the DH system, i.e., the reduction of heat transmission loss in the existing heating networks.

For the economic analysis of the potential to increase the efficiency of the heating and cooling system, a comprehensive methodology has been developed, and it may be applied for the assessment of different technological alternatives:

- for the integration of industrial residual heat and cooling;
- for the use of heat from waste incineration;
- for the increase in the potential of high-efficiency cogeneration;
- for the increase in RES (e.g., geothermal energy, solar thermal energy and biomass) share;
- for the integration of DH heat pumps;
- for the reduction of heat and cooling loss in the current district networks.

Considering the current situation in the national heating and the historic trends described in the Chapter 2, the integration of industrial residual heat and cooling, increase in RES share, integration of DH heat pumps and the reduction of heat and cooling loss in the current district networks are reviewed as the applied heating development opportunities in Latvia. An in-depth economic assessment is not carried out for the use of heat from waste incineration, because the effective laws and regulations do not provide for the installation of new waste-incineration facilities for DH. The increase in the potential of high-efficiency cogeneration is analysed indirectly through the increase in thermal energy produced in biomass cogeneration, but the future development forecast envisions a reduction in the number of natural gas cogeneration plants.

4.2. Reduction of heat and cooling loss in the present district networks

The average percentage of heat transmission loss in 2018 in Latvia was 12 %. However, the percentage of heat loss in some DH systems in Latvia fluctuates from 10 % to more than 30 % of the volume of energy input (see Figure 4.2).

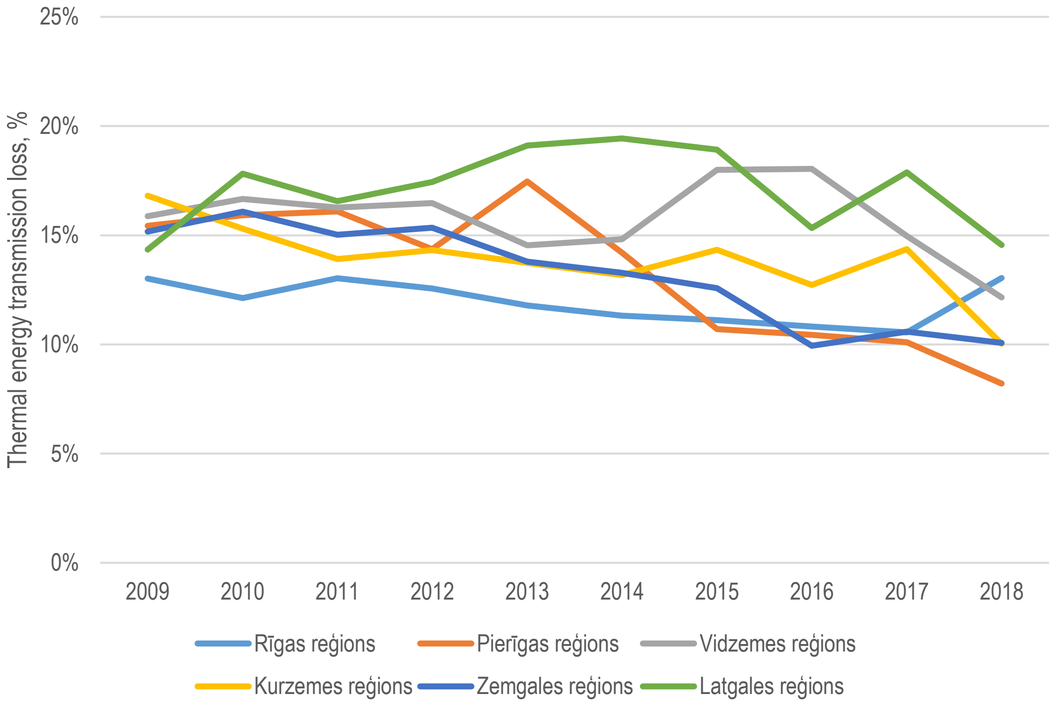


Figure 4.2. Transmission loss in different regions of Latvia ([55])

Rīgas reģions - Riga Region; Pierīgas reģions - Pierīga Region; Vidzemes reģions - Vidzeme Region; Kurzemes reģions - Kurzeme Region; Zemgales regions - Zemgale Region; Latgales regions - Latgale Region

Heat loss in networks is affected by factors such as the temperature of the heat transfer agent, pipeline dimensions, heating network length and location, flow rate etc. In the case of a low-temperature heating system, the heat loss is already reduced due to the lower temperature of the heat transfer agent, but it may be reduced even more by optimising the pipeline dimensions and thickening the pipe insulation layer. The economic analysis of the efficiency potential includes a performed assessment of the reduction in heat transmission loss. Cooling losses are not included into the assessment, because Latvia has no district cooling systems.

At the moment, the laws and regulations of Latvia stipulate that thermal energy transmission loss must not exceed the limit of 17 % ([56]). In 2017 and 2018, funding from the Cohesion Fund was available to heating companies for capital investments in increasing the EE of heating production and transmission. In line with the results of projects for transmission network reconstruction and construction of new networks within the call for proposals '4.3.1. To Promote Energy Efficiency and the Use of Local RES in the District Heating Supply, Round 1', by 2020 the total length of renovated heating networks will reach almost 30 km and of newly-constructed heating networks will reach 13 km, but the total EU funding for the reconstruction of heating transmission systems will be more than EUR 9 million. The results of projects implemented under the call for projects are presented in Figure 4.3.

([55]) Central Statistical Bureau, ENG160. Thermal energy balance in statistical regions
([56]) Cabinet Regulation No 243 Regarding the energy efficiency requirements for centralised heating supply systems in the possession of a licensed or registered energy supply merchant, and the procedures for conformity examination thereof.

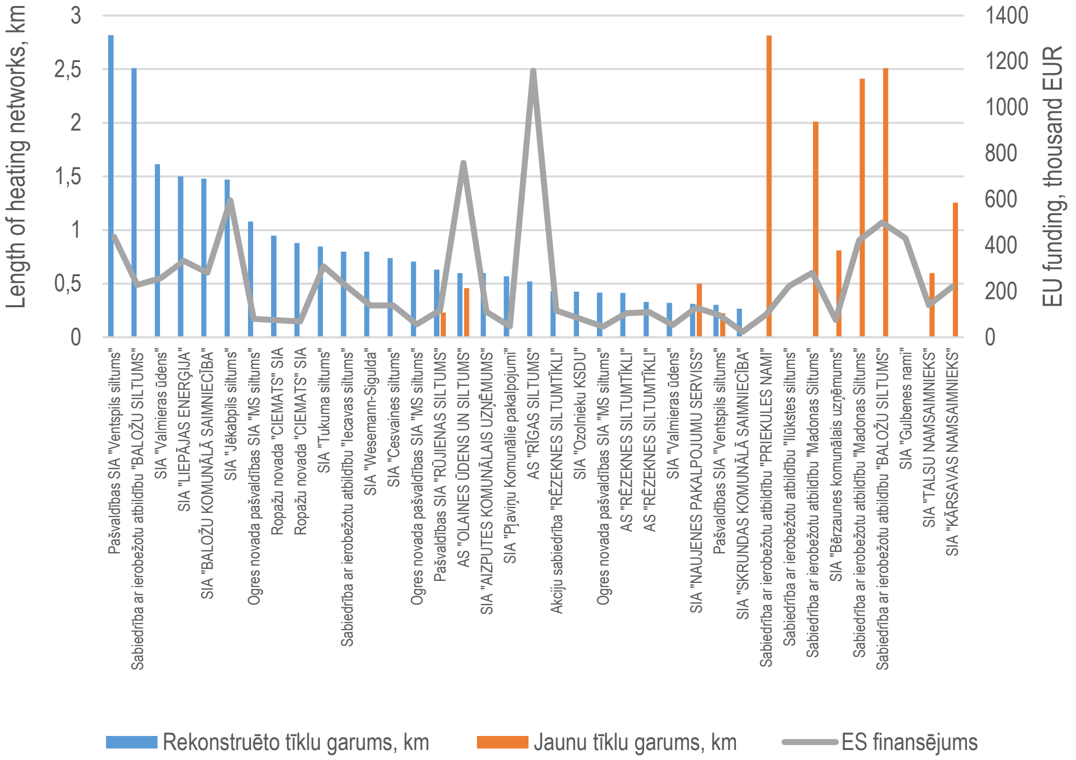


Figure 4.3. Overview of the results of transmission network reconstruction and construction of new networks submitted within the call for proposals '4.3.1. To Promote Energy Efficiency and the Use of Local RES in the District Heating Supply, Round 1' ([57])

Rekonstruēto tīklu garums - Length of renovated networks; Jaunu tīklu garums - Length of new networks; ES finansējums - EU funding; Sabiedrība ar ierobežotu atbildību (SIA) – Limited Liability Company (LLC); AS – stock corporation; pašvaldības SIA – LLC of a municipality; novads - municipality

Baseline scenario

Within the baseline scenario, the present situation in DH system transmission systems is reviewed. To determine the potential for the reduction of heat transmission loss, initial information about heating networks located in Latvia is required, but its official gathering is not currently taking place. To establish a model of heating networks in Latvia, the gathered results of the study carried out by Ekodoma SIA ([58]) in 2015 regarding the length, diameters and age of heating networks in different municipalities of Latvia are being used. Data have been updated in accordance with the results of the call for projects of CFCA heating system EE.

Taking into consideration the information about heating networks in Latvia, three different models of transmission systems have been developed, for Riga, cities of the country and other municipalities of Latvia. The main objective of the models is to create reference DH systems, which may be generalised and attributed to regions, regarding which no detailed information about heating network lengths and diameters is available. To determine the total length of heating networks in the cities of the country and in the municipalities, the regression analysis method was used by analysing the correlation between the total population and the length of heating networks (see Figure 4.4). This figure shows that the regression factor is high in both cases, and it

([57]) Central Finance and Contracting Agency. Available online: https://www.cfla.gov.lv/lv/es-fondi-2014-2020/izsludinatas-atlases/4-3-1-k-1

([58]) Ekodoma SIA. Collection and analysis of data necessary for heating planning. Long-term trends in district heating up to 2030. Available online: http://petijumi.mk.gov.lv/sites/default/files/file/pielikums_petijums_EM_2015_par_siltumapgades_datu_ieguvi_anal_un_rokasgramat_sagat_pasval_energoplan.pdf means that the acquired empirical equations may be used to determine the total length of heating networks, using the information about the population in the specific analysed region. The total length of heating networks in the Riga DH system has been updated using the available information of Rīgas Siltums AS annual reports (59).

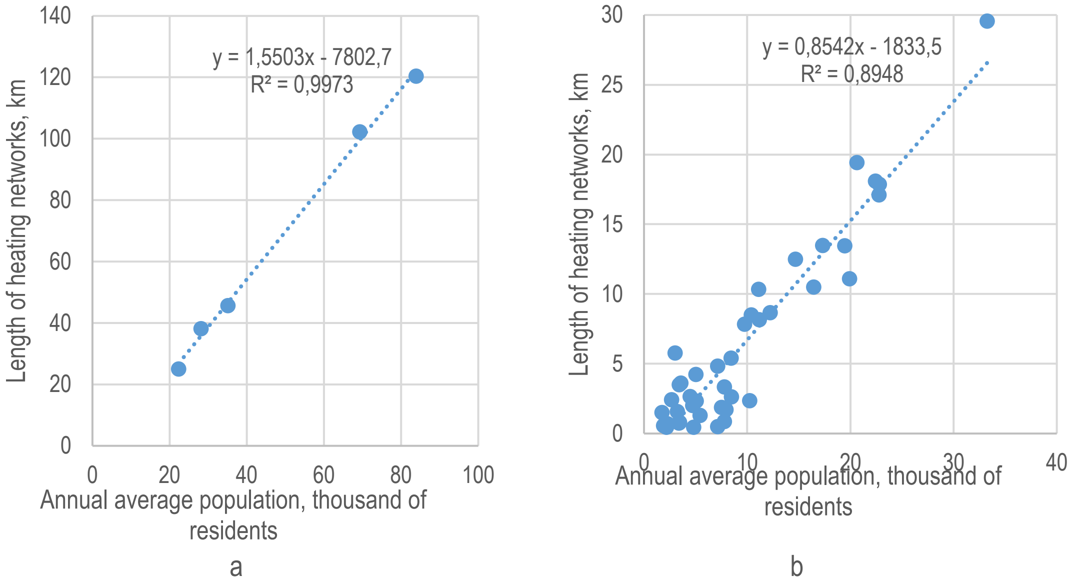


Figure 4.4. Regression analysis models for the establishment of the lengths of heating networks in the cities of the country (a) and other municipalities and centres thereof (b)

Using the information available about the lengths of heating networks and the results of regression models, the total length of heating networks in Riga has been determined to be 756 km, in the cities of the country, 460 km, and other municipalities and centres thereof, 593 km.

Heat loss significantly differs depending on the diameter of the placed heating network. To establish a reference system, the breakdown of heating network lengths by diameter has been established for the specific analysed region. Figure 4.5 presents the breakdown of pipelines by diameters for the old and the new heating networks in Riga. It is apparent that the interior diameter is from 65 mm to 200 mm for the most part of heating networks. The interior diameter of trunk pipelines reaches 1 200 mm.

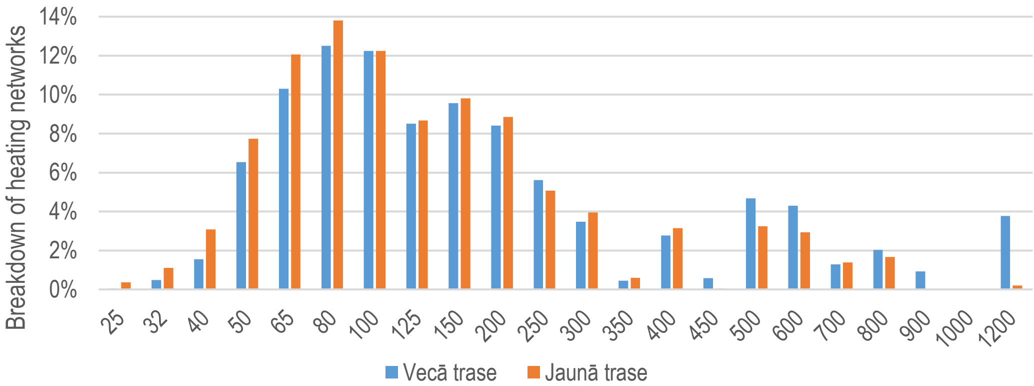
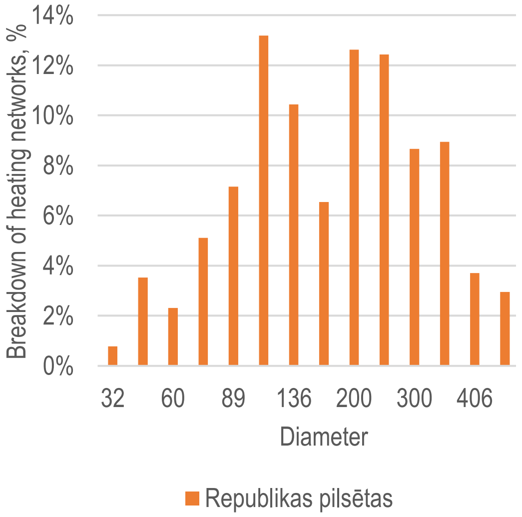


Figure 4.5. Breakdown of heating networks by diameter of placed pipelines for the old and the new heating networks in Riga

(59) Annual Report 2018 of Rīgas siltums AS. Available online: http://www.rs.lv/sites/default/files/page_file/rs_gada_parskats_2018.pdf

Vecā trase - The old network; Jaunā trase - The new network



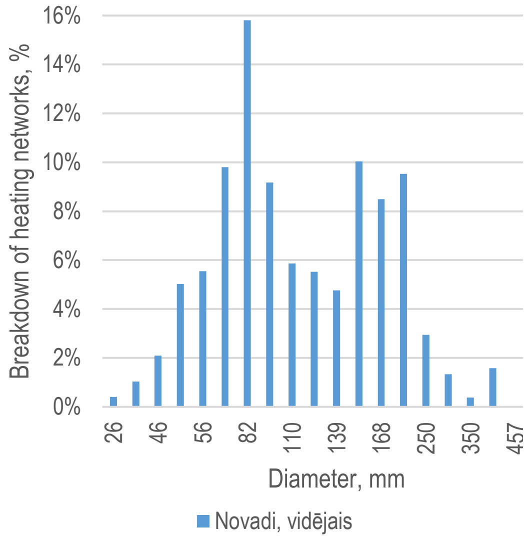


Figure 4.6. Breakdown of heating networks by the diameters of placed pipelines for the cities of the country (a) and the average rate in municipalities

Republikas pilsētas - Cities of the country; Novadi, vidējais - Municipalities, average

Figure 4.6 presents the breakdown of pipelines by diameter in Daugavpils, Jūrmala and Rēzekne, and the average rate in the municipality. The breakdown is established in accordance with the study previously carried out by Ekodoma SIA. It is apparent that in municipalities, the largest proportion is formed by pipelines with an interior diameter of 80 mm, but in the cities of the country, it is 110, 200 and 250 mm.

The technical condition of heating networks and thermal insulation parameters, which for new, industrially insulated pipelines and for older heating networks is different, is a significant factor influencing the heat transmission loss. Therefore, the calculation of thermal energy loss has been performed for old and new heating networks separately. In the transmission loss models, both the available information about the age of heating networks (DH system of Riga and cities of the country) has been used and assumptions about the breakdown of the old and the new heating networks (in municipalities) have been made. The calculations assume that in cities without information available about the age structure of heating networks (Jelgava, Jēkabpils and Valmiera) the old heating networks constitute 47 %, but the new heating networks constitute 53 % (see Table 4.1). The breakdown has been established as the average rate of the other cities of the country. In the municipalities, the average breakdown of the old and the new heating networks by the available survey data has been established. On average, 26 % are obsolete pipelines and 62 % are new pipelines.

TABLE 4.1. OVERVIEW OF THE BREAKDOWN OF THE AGE OF HEATING NETWORKS IN THE CITIES OF THE COUNTRY

Cities of the country	Proportion of the old network	Proportion of the new network
Jūrmala	72 %	28 %
Daugavpils	78 %	22 %
Liepāja (60)	8 %	92 %
Jelgava	47 %	53 %

(60) Jansons J., Use of instruments based in ĢIS (Geographic Information System) Available online: http://www.zrea.lv/upload/attach/2%20LiE_ZULU_kartesana_14nov2018.pdf

Ventspils	0 %	100 %
Jēkabpils	47 %	53 %
Valmiera	47 %	53 %
Rēzekne	75 %	25 %

Considering the information available about the diameters, lengths and condition of heating networks, the calculation of heat loss has been carried out using the methodology defined above. The calculations begin with establishing the linear resistance R ((m K)/W) for specific pipelines:

$$R = R_p + R_{insul} + R_{encl} + R_{ground} + R_{mutp} \quad (4.1)$$

where
R_p is the linear resistance of the pipe (m K)/W;
R_{insul} is the linear resistance of the insulation (m K)/W;
R_{encl} is the linear resistance of the enclosure (m K)/W;
R_{ground} is the linear resistance of the ground (m K)/W;
R_{mutp} is the mutual linear resistance of the pipes (m K)/W.

The linear resistance of the pipe is established using the formula:

$$R_c = \frac{1}{2\pi\lambda_c} \ln \frac{d_{ar}}{d_{iek}} \quad (4.2)$$

where
λ_p is the thermal conductance factor of the pipe, W/(m K);
d_{ext} is the external diameter of the pipe, m;
d_{int} is the internal diameter of the pipe, m.

The linear resistance of insulation is determined using (1.3)

$$R_{izol} = \frac{1}{2\pi\lambda_{izol}} \ln \frac{d_{izol}}{d_{ar}} \quad (4.3)$$

where
λ_{insul} is the insulation thermal conductance, W/(m K);
d_{insul} is the external diameter of an insulated pipe, m.

The linear resistance of the enclosure is determined using:

$$R_{apv} = \frac{1}{2\pi\lambda_{apv}} \ln \frac{D_{ar}}{d_{izol}} \quad (4.4)$$

where
λ_{encl} is the enclosure thermal conductance, W/(m K);
D_{ext} is the external diameter of an insulated pipe with enclosure, m.

Heating network pipes are located in the direct proximity in the channel, therefore the mutual linear resistance of pipes must be calculated:

$$R_{savs} = \frac{1}{4\pi\lambda_{gr}} \ln\left[1 + \frac{(2(H + 0{,}0685\lambda_{gr}))^2}{(A + D_{ar})^2}\right] \quad (4.5)$$

where
λ_{gr} is the ground thermal conductance factor, W/(m K);
D_{ext} is the external diameter of an insulated pipe with enclosure, m;

H is the embedding depth until the axis of the pipe, m;
A is the distance between the pipes, m.

The linear resistance of the ground is determined using:

$$R_{grunts} = \frac{1}{2\pi\lambda_{gr}} \ln\left[\frac{4(H + 0{,}068\lambda_{gr})}{D_{ar}}\right] \tag{4.6}$$

After determination of the total linear resistance R (1.1), the linear thermal conductance factor k_L W/(m K) is calculated:

$$k_L = \frac{1}{R}; \tag{4.7}$$

TABLE 4.2. ASSUMPTIONS MADE TO DETERMINE THE LINEAR THERMAL CONDUCTANCE FACTOR

Assumption	Value
Ground temperature	+ 8 °C
Thermal conductance factor of the pipe wall	50 W/(mK)
Thermal conductance factor of the pipe enclosure	0.43 W/(mK)
Thermal conductance factor of new heating network insulation	0.03 W/(mK)
Thermal conductance factor of old heating network insulation	0.45 W/(mK)
Pipe embedding depth	1.5 m
Distance between the pipe	0.15 m

Heat flow linear density q_L W/m is determined using:

$$q_L = k_L(t_{turp} + t_{atg} - 2t_{gr}) \tag{4.8}$$

where
t_{input} is the input water temperature, °C;
t_{output} is the output water temperature, °C;
t_{gr} is the ground temperature, °C.

The heat flow linear density has been established at different input and output temperatures depending on the outside air temperature. Total heat loss Q (Wh) is calculated using the formula:

$$Q = q_L LT \tag{4.9}$$

where
L is the total length of heating networks, m;
T is the number of heating hours, h.

To determine the total heat loss, the calculation assumes that the average DH system temperature mode is 95/75. Input and output temperatures at different outside air temperatures have been indicated in Table 4.3. In accordance with the data of Latvia's Environment, Geology and Meteorology Centre ([61]), the average number of hours at different outside air temperatures has been summarised. The calculation assumes that thermal energy in Riga and the cities of the country is used for both heating and providing hot water, but in some municipalities it is only used to provide heating, and therefore a smaller number of operation hours is assumed.

TABLE 4.3. OVERVIEW OF ASSUMPTIONS MADE WITH REGARD TO HEATING NETWORK TEMPERATURES AND OPERATION HOURS

Outside air temperature, °C	Hours	Input	Output
> -25	12	95	75

([61]) Latvijas Vides, ģeoloģijas un meteoroloģijas centrs VSIA, available online: https://www.meteo.lv/lapas/noverojumi/meteorologija/meteorologija_ievads?id=1121&nid=458

-20	205	90	70
-15	278	85	65
-10	402	80	60
-5	1 099	75	55
0	2 050	70	50
5	1 402	65	45
> 8	3 312	63	43

The obtained total heat loss from transmission loss models have been compared with the data available about the thermal energy loss in 2017 ([1]) (see Figure 4.7).

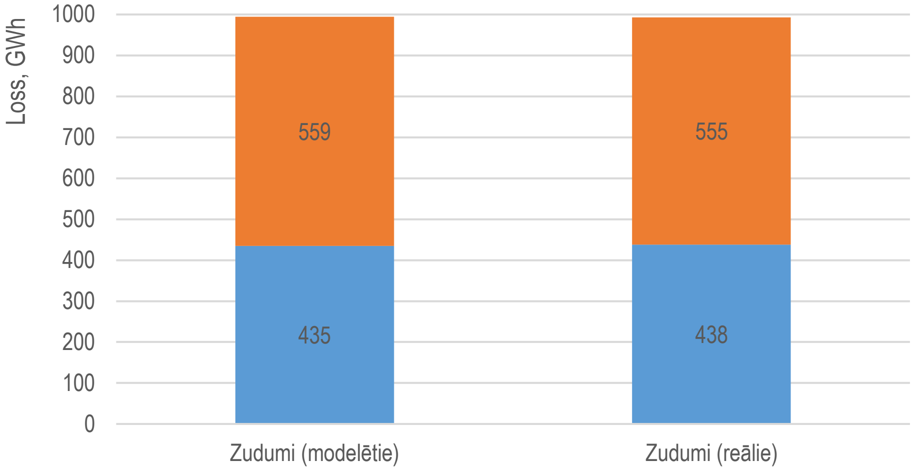


Figure 4.7. Results of transmission loss model validation

Zudumi (modelētie) - Loss (modelled); Zudumi (reālie) - Loss (actual)

The modelled heat transmission loss is comparable to the actual heat loss, and the established transmission loss models can be used for EE scenario modelling.

Scenario 1. Energy efficiency scenario of the heat transmission system

In the EE scenario of the heat transmission system, it is assumed that all obsolete heating networks of Riga, cities of the country and municipalities are to be replaced. Figure 4.8 presents the breakdown of obsolete pipelines by their diameters. The total length of obsolete pipelines is 862 km.

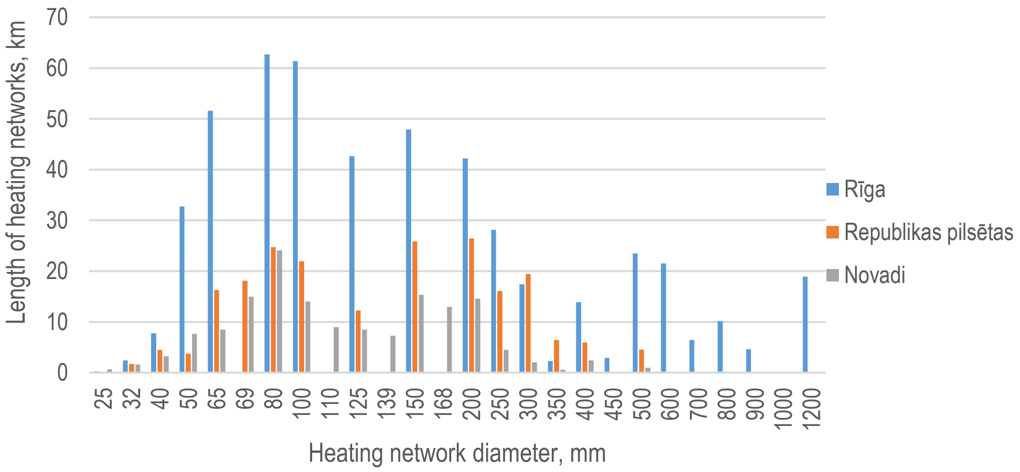


Figure 4.8. Breakdown of obsolete pipelines by the diameters of the heating network

Republikas pilsētas - Cities of the country; Novadi - Municipalities

The main costs of increasing EE derive from the replacement of heating networks, i.e., costs of materials, excavation and filling of heating pipeline trenches, resurfacing etc. The average cost of heating networks in the call for projects of the CFCA has been determined as EUR 606 /m, but the specific costs for pipelines of specific diameters cannot be determined, because these differ significantly from one another. Consequently, the empirical equation presented in Figure 4.8 for calculating the specific costs of construction of a heating network of a specific diameter has been used to determine the total costs.
The total cost of replacement of all obsolete pipelines (pipelines installed until 2000) is EUR 371 million. If the average cost of replacement of a heating pipeline, taken from the results of the call of projects of the CFCA, is used, the total cost amounts to EUR 522 million.

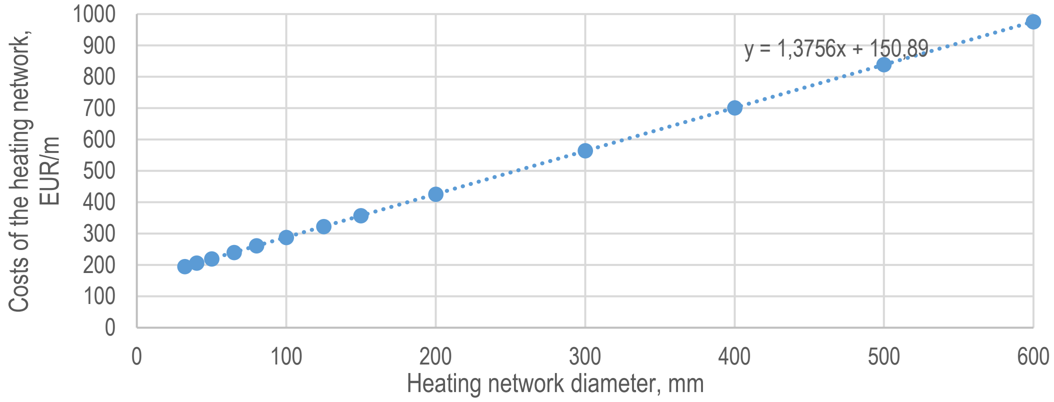


Figure 4.9. Specific costs of pipelines of specific diameter ([62])

The total energy saving from pipeline replacement has been determined using established transmission loss models, assuming that the thermal conductance factor of thermal insulation of old pipelines falls to 0.03 W/(m K). After the replacement of the pipelines, the total volume of heat loss falls by 51 % or 512 GWh of heat per year. In the following economic assessment, it is assumed that the reduction in heat loss declines annually by 0.5 % due to the ageing of the replaced pipelines.
To determine the economic savings from the reduction in heat loss, an average thermal energy tariff was established in Latvia and, according to information from the Public Utilities Commission (63), in 2017 it was EUR 54.4/MWh. The total savings from the reduction in loss at the corresponding thermal energy tariff is EUR 27 million. The calculation assumes that the thermal energy tariff will increase with each year, because the costs of the resources used will increase. The increase has been modelled using the available CSB ([64]) data regarding the thermal energy costs of the commercial and public sector and the end-user (see Figure 4.10).

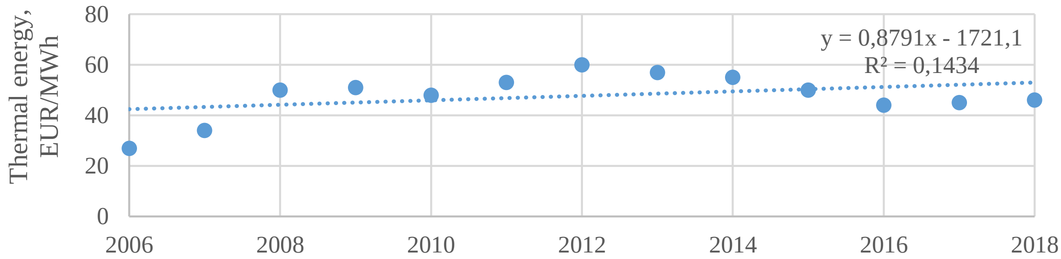


Figure 4.10. Changes in thermal energy costs

The current value (NPV) of the project was established as the main indicator for the assessment of the scenario. The assumptions used in the calculation to determine the discount rate have been specified in Table 4.4. It is

([62]) Nielsen S., Möller B. GIS based analysis of future district heating potential in Denmark, Energy, 57; 2013, 458-468
([63]) The Public Utilities Commission. Available online: https://www.sprk.gov.lv/content/tarifi-4
([64]) CSB. ENG190. Average prices of energy resources to end consumers (excl. VAT). Available online: http://data1.csb.gov.lv/pxweb/lv/vide/vide__energetika__ikgad/ENG190.px/

assumed that the available co-funding for the replacement of heating networks will be increased, and therefore the contribution of heating companies will constitute 20 % of the total costs.

TABLE 4.4. ASSUMPTIONS IN THE ECONOMIC ANALYSIS

Assumption	Value
Duration of the operation of heating networks	25 years
Inflation	5 %
Financial discount rate	4 %
Social discount rate	5 %

With the assumptions made, the financial NPV value of the project reaches 4.546 million EUR, indicating the presence of high investments and insufficient financial savings.

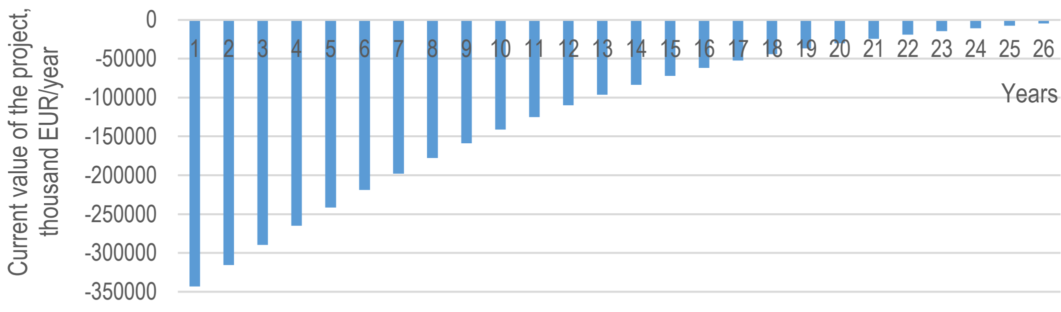


Figure 4.11. Changes in the current value of the project in a period of 25 years

To perform the economic assessment of the scenario, in addition to the reduction in the costs of thermal energy loss, the potential reduction in CO_2 costs and the reduction in external environmental costs were also considered. The potential benefit to the environment from a reduction in heat transmission loss shall be determined by multiplying the saved thermal energy reduction with the respective CO_2 emissions factor, which constitutes 0.1134 t CO_2/MWh ([65]) for the district heating in accordance with the information from the Ministry of Environmental Protection and Regional Development. In the first year, the established saving in CO_2 emissions is 58 038 t CO_2 per year. By assuming that the specific costs of CO_2 emissions are EUR 19 /t CO_2, the annual reduction in costs has been determined. The prevented environmental costs are calculated by assuming that the reduction in thermal energy loss would replace the production of thermal energy in biomass or natural gas CHP plants or boiler houses. To determine the external costs, an average factor of external costs of EUR 11.27 /MWh ([66]) has been determined. The total changes in the revenue flow are presented in Figure 4.12.

([65]) Ministry of Environmental Protection and Regional Development. Available online: http://www.varam.gov.lv/lat/darbibas_veidi/Klimata_parmainas/?doc=26279
([66]) Subsidies and costs of EU energy. An interim report, 2014.

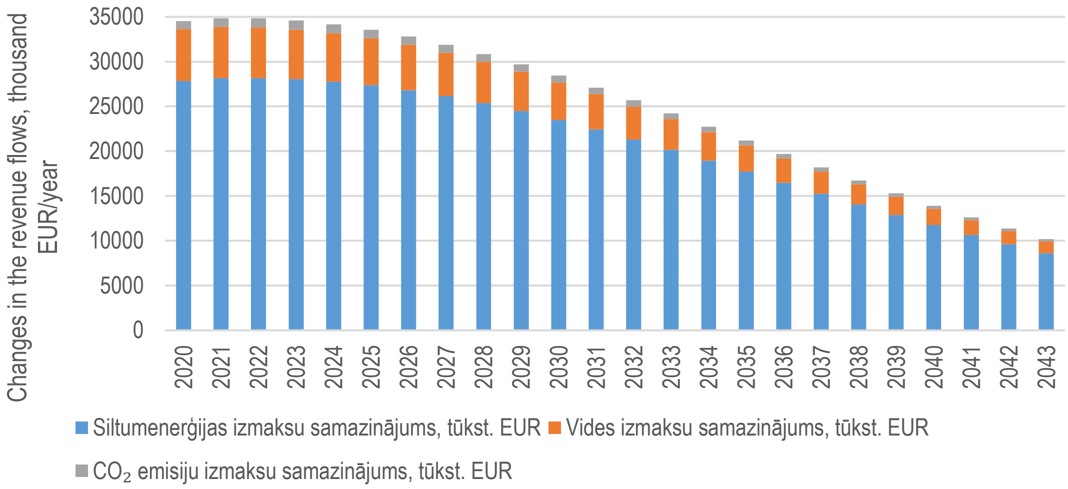


Figure 4.12. Changes in the revenue flows of the economic analysis in a period of 25 years

Siltumenerģijas izmaksu samazinājums, tūkst. EUR - Reduction in thermal energy costs, thousand EUR; Vides izmaksu samazinājums, tūkst. EUR - Reduction in environmental costs, thousand EUR; CO2 emisiju izmaksu samazinājums, tūkst. EUR - Reduction in CO_2 emissions costs, thousand EUR

To determine the current economic value of the project, the revenue flow has been discounted using the social discount rate. The economic NPV value of the established scenario is EUR 48.469 million, but the economic internal profit value is 11 %.

Scenario 2. Energy efficiency and temperature reduction scenario of the heat transmission system

Transition to the fourth generation heating system is reviewed as an additional scenario to the previously analysed EE scenario. The fourth generation heating system (4GHS) is a concept of the DH system, which envisions lowering the temperature in networks. Lowering of thermal energy temperature in networks is possible and expedient in cases in which there is an appropriately adjusted user (increased EE of buildings and/or integrated low-temperature heat emitters) ([67]).

The concept of 4GHS is envisioned for the climatic conditions of Northern European countries and provides the heat necessary for heating and covers the hot water load for the consumers. The temperature of 55-25 °C means the average level of temperature related to this temperature schedule (designation accepted in international publications). The concept envisions increasing the supplied temperature during the heating season, when the outside air temperatures become lower. The temperature level in this period depends on the availability of a higher temperature in the energy source, economic considerations and technological solutions. The further assessment concludes that the input temperature is reduced by 20° C during the peak load period, but it is only slightly reduced when the outside air temperature is above 0° C (see Figure 4.13).

([67]) Svendsen S., Li H., Nord N., Sipilä K. Low Temperature District Heating for Future Energy Systems// Energy Procedia 2017-116, 2017: p. 26-38.

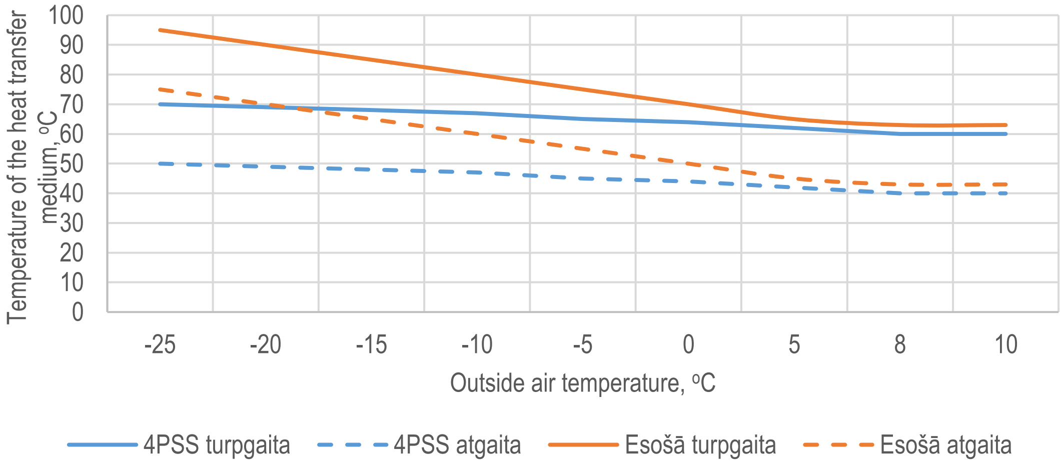


Figure 4.13. Temperature schedules of the analysed 4GHS, compared to the standard schedule

4PSS turpgaita - 4GHS input; 4PSS atgaita - 4GHS output; Esošā turpgaita - Current input; Esošā atgaita - Current output

In accordance with the laws and regulations of Latvia, the hot water temperature in the distribution place must be above 55 °C degrees, to prevent dangerous *Legionella* bacteria from developing ([68]). In accordance with German standard W551 ([69]), the hot water temperature may also be below 50 °C, if the total amount of circulating water in the system (excluding the heat exchanger) is below 3 L. As in the case of passive and low-energy buildings, the heating system and hot water supply have been designed with the smallest pipeline diameters possible, so that the total amount of water circulating in the system may be reduced. The further economic assessment concludes that the input temperature is not reduced below the level of 60 °C, so that the hot water treatment systems do not need modification.

Considering the assumptions regarding the pipelines replaced subject to the EE scenario and the opportunities to reduce input and output temperatures, the determined potential reduction in thermal energy loss is 569 GWh or 57 %. Reduction of temperature in networks provides saving of 57 GWh.

To ensure a low-temperature heating system, different types of heating units, with the direct or indirect connection, may be used by integrating an accumulation tank etc. In the event of direct connection, the hot heat transfer medium heats up the cold water through heat exchange using the heat exchanger. Part of the hot heat transfer medium is released into the circulation circuit to ensure optimum hot water supply. The heat necessary for heating is released directly from the networks to radiators and floor heating ([70]). This heating unit solution reduces the necessary investments and the dimensions of the heating unit, however, the direct connection increases the heat loss, because it is installed on the basis of the maximum consumer load. The lowering of the temperature in networks is related to both the reconstruction of heating networks and the lowering of the temperature in networks, which requires the provision of appropriate conditions and parameters (appropriate heating distribution systems in buildings, adjusted heat exchangers). The amount of the investments required for to the implementation of such measures is related to the

([68]) Cabinet of Ministers Regulation No 332 Rules on Latvia's Building Code LBN 221-98 'Internal Water Mains and Sewage of Buildings'. Latvijas Vēstnesis, 125 (5443), 30.06.2015.
([69]) DVGW. W551 e Trinkwassererwärmungs- und Trinkwasserleitungsanlagen; 1993. Bonn Available online: http://www.bosy-online.de/trinkwasser/dvgw-arbeitsblatt_w551.pdf.
([70]) Dalla Rosa A., Li, H., Svendsen S. Method for optimal design of pipes for low-energy district heating, with focus on heat losses// Energy, 36(5), 2011. pp. 2407-2418.

parameters of a specific DH system: share of energy-efficient buildings, number of heating units to be reconstructed etc. In the most cases, the lowering of the temperature in networks does not require additional investment, only accurate monitoring for the prevention of different transmission errors and long-term planning for the establishment of low-temperature housing estates.
By transitioning to a lower-temperature mode, cheaper plastic pipelines may be used. Therefore, the calculation assumes that the specific heating network costs would fall (see Figure 4.14).

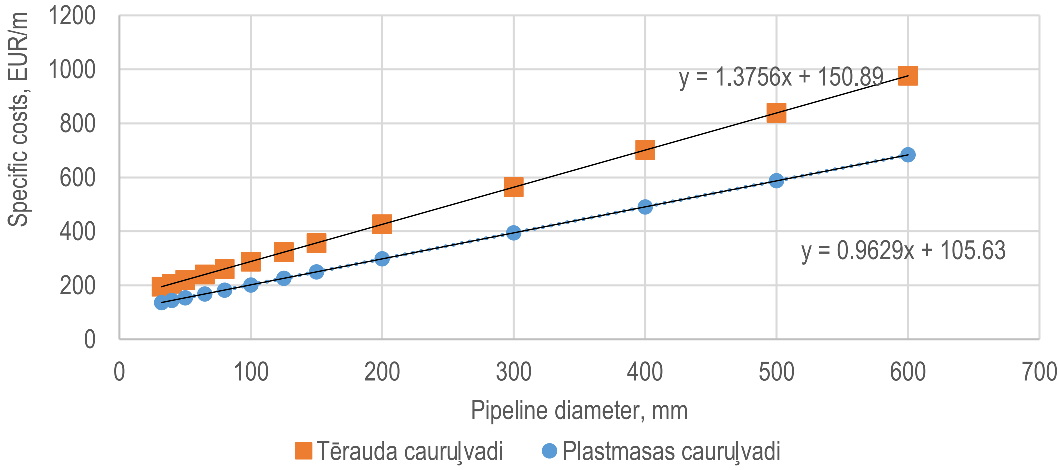


Figure 4.14. Specific costs of steel and plastic pipelines

Tērauda cauruļvadi - Steel pipelines; Plastmasas cauruļvadi - Plastic pipelines

The obtained results of the financial analysis are presented in Figure 4.15. In this scenario, the obtained financial NPV value reaches EUR 165.822 , but the internal rate of return (IRR) of the scenario is 3 %. The use of cheaper plastic pipelines ensures the main financial savings in this scenario, compared with the EE scenario. Additional savings from lowering the temperature in networks are also created in the heat source:

- from the increase in the amount of electric power produced in CHP plants;
- from the increase in the efficiency of the operation of the condensation economiser in biomass boiler houses;
- from the opportunity to integrate residual heat into technological processes
- from more efficient use of the heat from the surrounding environment, including solar thermal energy.

These aspects are not directly included into the general economic assessment, because they are specific to each analysed DH system. It is assumed that such benefits would be commensurate with the potential costs of adjusting the buildings to a lower temperature mode.

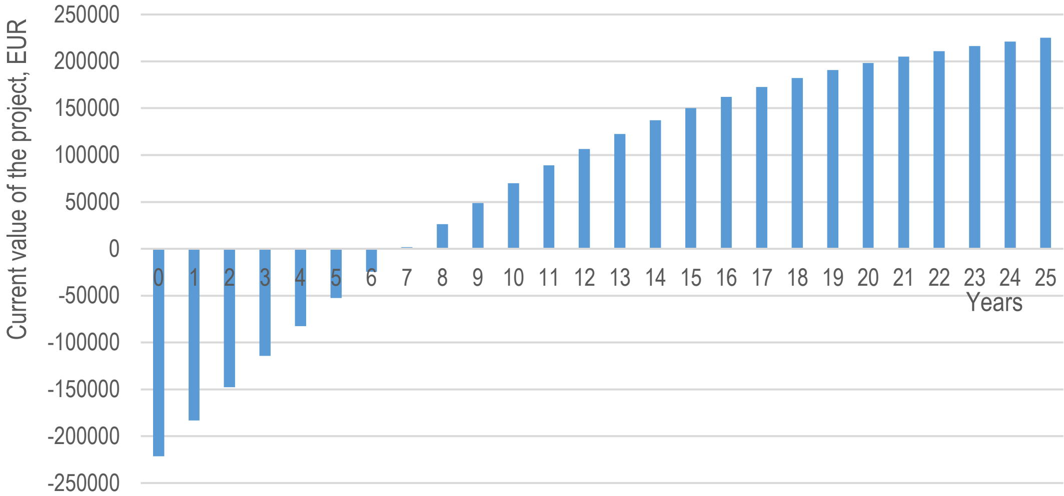


Figure 4.15. Financial NPV value of the energy efficiency and temperature reduction of the heat transmission system

To perform the economic assessment of the scenario, in addition to the reduction in the costs of thermal energy loss, the potential reduction in CO_2 costs and the reduction in external environmental costs were considered and the average specific external cost factor EUR 11.27 /MWh ([71]) has been determined for the calculations. To determine the current economic value of the project, the revenue flow has been discounted using the social discount rate. The economic NPV value of the established scenario is EUR 225.246 million, but the economic internal profit value is 8 %.

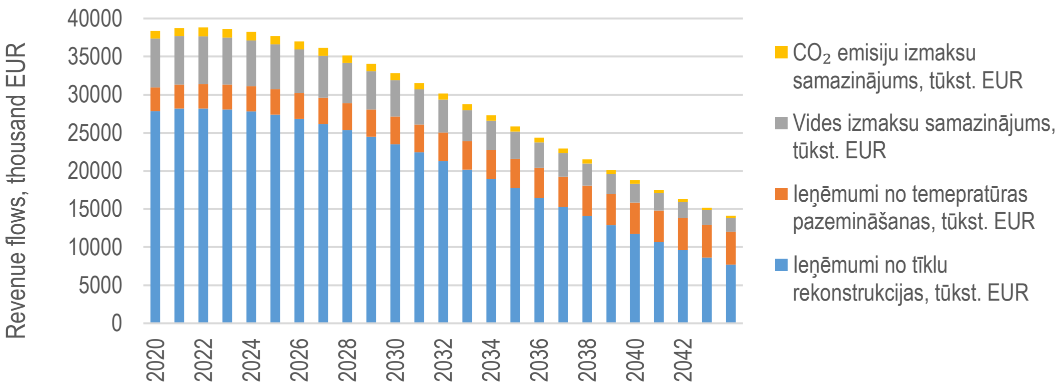


Figure 4.16. Changes in the revenue flows of the economic analysis over a period of 25 years

CO2 emisiju izmaksu samazinājums, tūkst. EUR - Reduction in CO_2 emission costs, thousand EUR; Vides izmaksu samazinājums, tūkst. EUR - Reduction in environmental costs, thousand EUR; Ieņēmumi no temperatūras pazeminašanās, tūkst. EUR - Revenues from lowering of temperature, thousand EUR; Ieņēmumi no tīklu rekonstrukcijas, tūkst. EUR - Revenues from network reconstruction, thousand EUR

TABLE 4.5. COMPARISON OF THE ECONOMIC AND FINANCIAL RATES OF THE SCENARIOS

Scenario	Financial NPV, MEUR	Financial IRR, %	Economic NPV, MEUR	Economic IRR, %
Scenario 1	-45	> -20 %	48	-11 %
Scenario 2	171	3 %	225	8 %

([71]) Subsidies and costs of EU energy. An interim report, 2014.

Table 4.5 provides a comparison of the indicators of the financial and economic analysis of the analysed scenarios. It is apparent that the economic value of the internal rate of return in scenario 2 is 8 %, which shows that the obtained additional benefit to the surrounding environment and society substantiates the investments required for the replacements to avoid heat loss and for the lowering of the temperature.
To assess the effect of the main assumptions on the obtained results of the financial analysis, a sensitivity analysis has been carried out. Image 4.17 demonstrates changes in the financial NPV, if the capital expenditure of pipelines is increased or reduced, the discount rate applied in the calculation and the thermal energy tariff. It is apparent that the most significant changes are created by the increase or the reduction of the thermal energy tariff and changes in the capital expenditure of the pipelines.

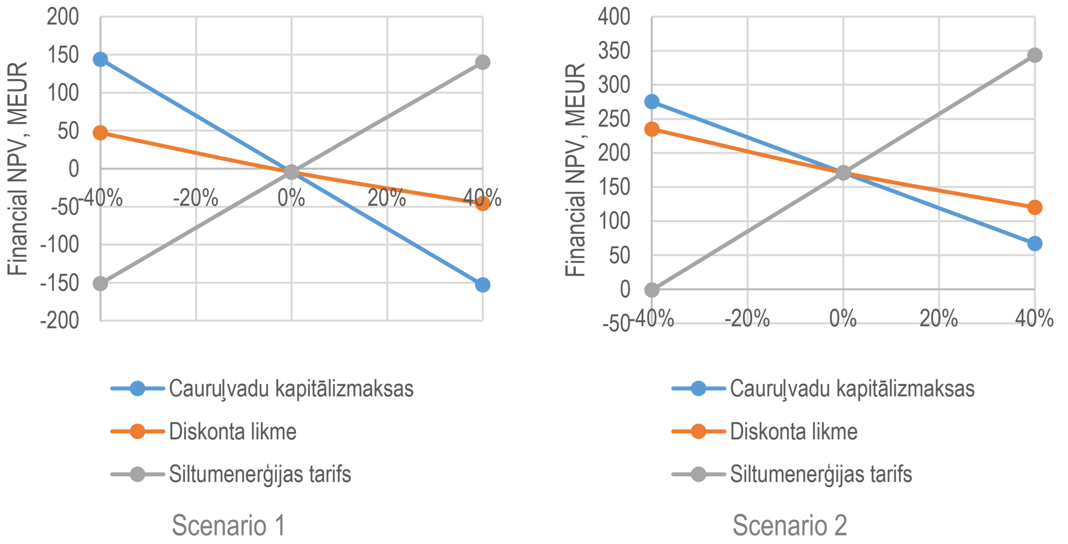


Figure 4.17. Results of the sensitivity analysis

Cauruļvadu kapitālizmaksas - Capital expenditure of pipelines; Diskonta likme - Discount rate; Siltumenerģijas tariffs - Thermal energy tariff

Figure 4.17 demonstrates that, if the thermal energy tariff used in the calculation of the savings is reduced by 40 % (from EUR 54.4/MWh to EUR 32.6/MWh during the baseline year), then, within scenario 1, the financial NP value reduces to EUR 150 million, but in the scenario 2, this is EUR 1 million. The analysed EE and the lowering of the temperature scenario (scenario 2) demonstrates that the effect of the costs of pipelines is not as significant as in scenario 1 and, if the capital expenditure increases by 40 %, the NPV value of the project is EUR 270 million.

4.3. Integration of the renewable energy sources, residual heat and heat pumps into DH

To assess the economic potential of integrating RES into the district heating, the system dynamics modelling methods has been employed, allowing the development of a dynamic model. The RES potential was assessed with respect to the energy sources and technologies solutions currently being employed in various sectors with a view to long-term development up to 2050. The cost-benefit analysis was carried out for the integration of RES into DH by considering the costs and the benefits, which would arise for the thermal energy producer and society in general as the reduction in the effect on the environment.
Considering the current development trends, three energy sources have been analysed as the main RES to be used for individual heat supply: biomass, which over the last decades has been increasingly used to substitute fossil energy sources; solar thermal power through the installation of solar collectors, which can be considered a potential energy source to cover the heating supply load in summer; and heat pumps which would use the renewable wind and solar electric power for the periods, when the production of thermal energy exceeds the consumption of electric power. A slight part of the demand for thermal energy would be covered also by the use of biogas, but no

increase in the biogas integrated into the DH system is forecasted, bearing in mind that the future use of biogas is related to a more extensive use in the transportation sector.

To assess the opportunities for the integration of RES, two different development scenarios are analysed. Within the baseline scenario, the present situation is modelled by including the policy instruments, which have become effective in 2019, but without including additional RES use policies. Within the EE scenario, additional support is provided in the form of subsidies for the integration of RES into the heating supply and the increase of the efficiency of technologies and the EE of buildings, thereby ensuring a significant increase in the share of RES in the final consumption.

The EE scenario provides for support for implementing EE measures at apartment buildings, commercial buildings, public buildings and industrial businesses. Furthermore, support has been provided for the integration of RES into DH and for the replacement of heating networks to reduce heat loss from networks. The volume of support has been obtained from the forecasted values for up to 2030 of Annex 4 of the National Energy and Climate Plan of Latvia. Support is allocated for the period up to 2030 with the condition that part of it can also be used after 2030 provided that the application for funding has been received by 2030. Additional funding after 2030 is not planned. The main amounts of funding and the level of support are presented in Table 4.6.

TABLE 4.6. SUPPORT FOR ENERGY EFFICIENCY AND RES INTEGRATION

	Total amount of support, MEUR	Level of support, %
Residential buildings (energy efficiency)	1 200	30
Buildings of the commercial sector (energy efficiency)	300	30
Municipality buildings (energy efficiency)	100	30
Industrial sector (RES and energy efficiency)	225	30
DH (energy efficiency)	500	40
DH (RES)	50	40
Transmission and distribution networks (for transition to the low-temperature DH)	60	40

Based on the assumptions made, the achievable RES share in both scenarios of DH has been forecasted as demonstrated in Figure 4.18. An 84 % share of RES is achieved in the baseline scenario, while the EE scenario almost reaches climate neutrality in DH with a 97 % of RES.

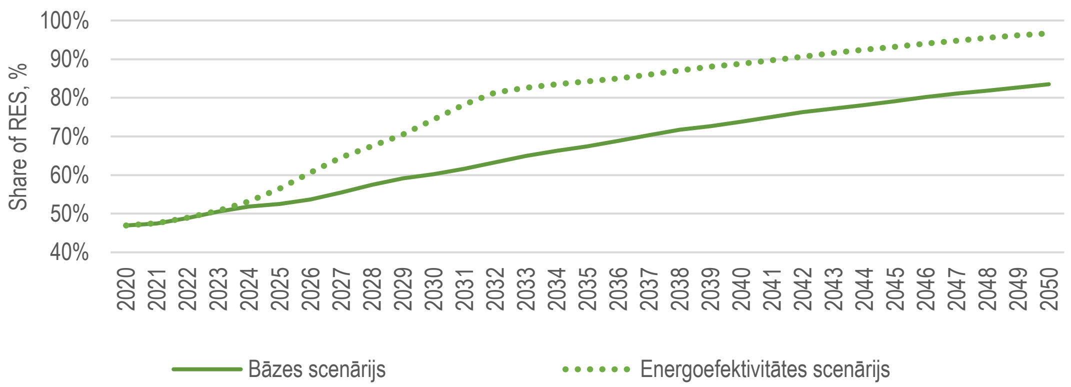


Figure 4.18. Achievable RES share in the analysed scenarios of DH

Bāzes scenārijs - Baseline scenario; Energoefektivitātes scenārijs - Energy efficiency scenario

The estimated breakdown of produced energy among various energy sources in case of the baseline scenario is given in Figure 4.19 and the EE scenario is illustrated in Figure 4.20. A continual increase in the use of biomass, as well as solar energy for heating can be observed. The share of biomass in district heating reaches 61 % by 2050 in the baseline scenario and 71 % in the EE scenario. The EE scenario foresees an increase in the potential of solar energy, estimating it at 20 % of the total thermal energy produced within district heating by 2050. In the baseline scenario, solar energy accounts for 17 %. In the EE scenario, residual heat and heat pumps provide a very small portion of the thermal energy produced.

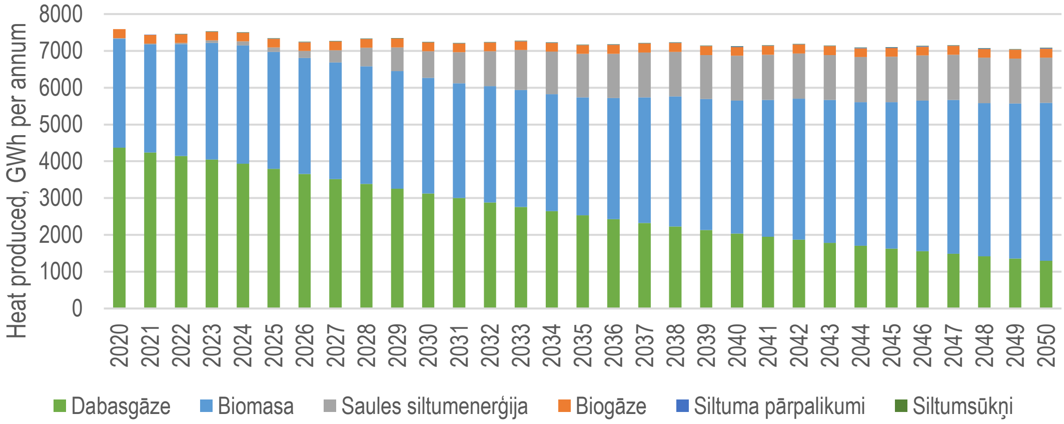


Figure 4.19. Fuel used for the production of DH thermal energy in the baseline scenario

Dabasgāze - Natural gas; Biomasa - Biomass; Saules siltumenerģija - Solar thermal energy; Biogāze - Biogas; Siltuma pārpalikumi - Residual heat; Siltumsūkņi - Heat pumps

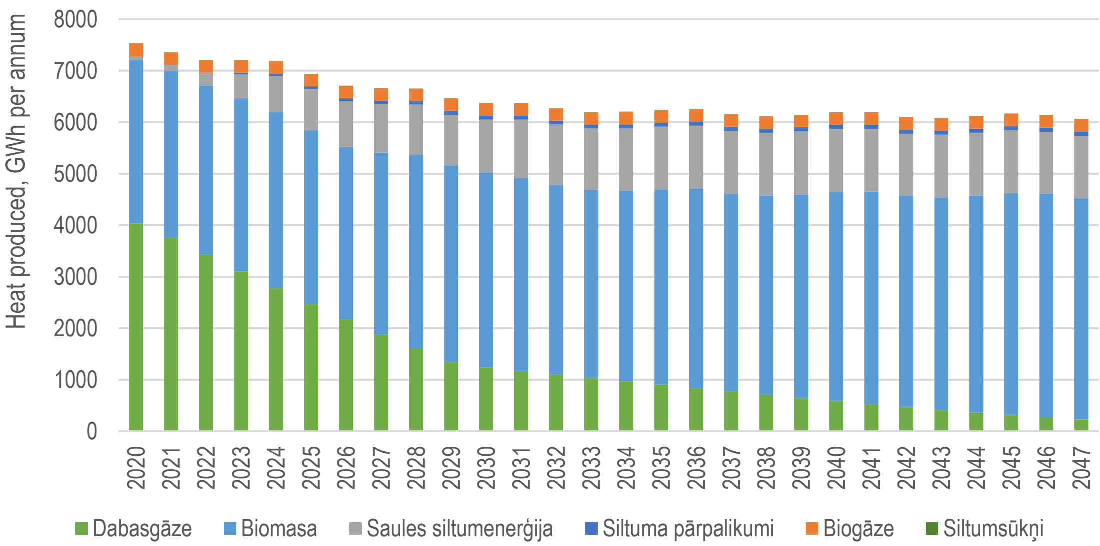


Figure 4.20. Fuel used for the production of DH thermal energy in the energy efficiency scenario

Dabasgāze - Natural gas; Biomasa – Biomass; Saules siltumenerģija - Solar thermal energy; Biogāze – Biogas; Siltuma pārpalikumi - Residual heat; Siltumsūkņi - Heat pumps

In order to ensure efficient use of biomass, small and medium (up to 20 MW) natural gas cogeneration plants are expected to be replaced with biomass cogeneration plants. In the EE scenario, large natural gas CHP plants are replaced by electric power produced from wind. This transition is also made possible by the significant reduction of thermal energy consumption of buildings and the lower demand for thermal energy. Due to the electric power produced by natural gas CHP plants being replaced with power produced from RES, the loss of revenue that would be caused by selling cogeneration plant electric power is not taken into account.

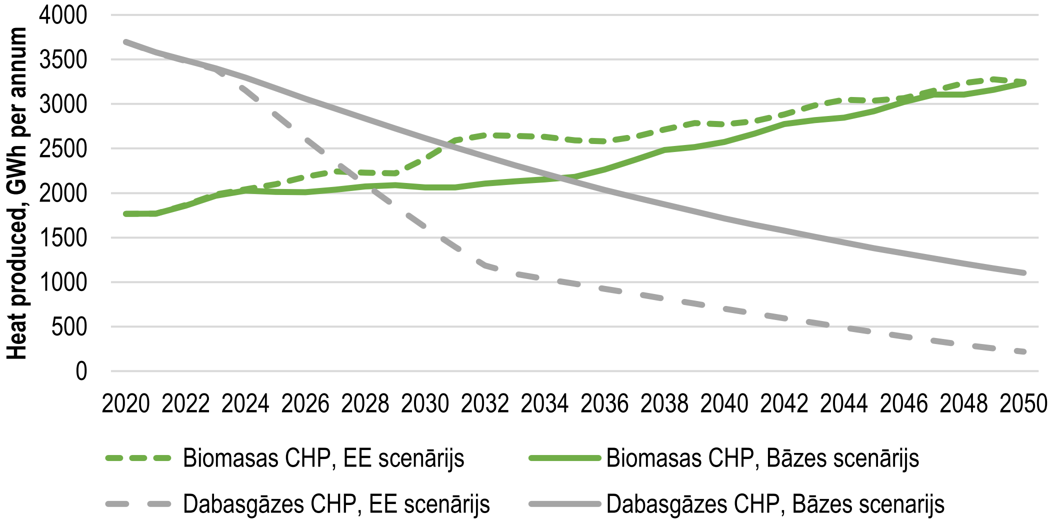


Figure 4.21. Changes in thermal energy produced by CHP plants

Biomasas CHP, EE scenārijs - Biomass CHP, EE scenario; Dabasgāzes CHP, EE scenārijs - Natural gas CHP, EE scenario; Biomasas CHP, Bāzes scenārijs - Biomass CHP, baseline scenario; Dabasgāzes CHP, Bāzes scenārijs - Natural gas CHP, baseline scenario

In order to perform a cost-benefit analysis for the transition to RES and the use of residual heat, the costs and benefits of each analysed energy source are determined, and these are then compared to the production of thermal energy at natural gas power plants. The costs of investments for the installation of technologies, as well as maintenance and service costs comprise the main expenses. Considering that investments in DH sites are not simultaneous, the model is based on annually necessary investments discounted to determine the current value of the total investment. A system dynamics model was employed to assess the most financially advantageous method of thermal energy production for the relevant year, taking into consideration the cost of fuel, technologies, operation and the available policy support. Therefore, a two-tier economic assessment is provided with the most suitable type of fuel and technology selected within the system dynamics model, and the discounted costs-benefits compared within the financial and economic assessment.
The capital expenses for technologies, operation and maintenance costs, as well as the efficiency of the equipment are based on information from a Danish technology catalogue covering the main technologies used in power supply, district heating and in local and individual heating. The Danish technology catalogue is used because Latvia has not developed its own catalogue describing the technologies used in Latvia and the technological and economic parameters specific to Latvia, however, it is assumed that even though in terms of absolute values, costs may differ, the cost relationship among technologies would remain similar to that indicated in the Danish data. The key parameters used are given in Table 4.7. Capital expenses include both expenses for technologies and installation thereof.

TABLE 4.7. MAIN EXPENSE ITEMS FOR DH TECHNOLOGIES USED IN THE MODEL ([72])

	Capital expenses, EUR/kW		Fixed operational costs, EUR/MW/year		Variable operational costs, EUR/MWh		Lifetime, years
	2017	2030	2017	2030	2017	2030	
CHP – natural gas [A]	1 300	1 200	30 000	27 800	4.5	4.2	25
CHP – biomass [A]	3 700	3 500	158 400	144 000	3.8	3.8	25

([72]) The Danish Energy Agency catalogue of technology data for energy technologies. Available online: https://ens.dk/en/our-services/projections-and-models/technology-data

CHP – biogas [A]	6 700	6 000	96 500	87 400	5.8	5.8	25
Boilers – natural gas [B]	60	50	2 000	1 900	1.1	1	25
Boilers – biomass [B]	700	650	32 800	31 200	1	1	25
Solar collectors [B]	615	530	2 780	3 130	5	0	25
Heat pumps [B]	700	590	2 000	2 000	3.3	3.7	25
[A] – **Electric power (MW_e) and production of electric power (MWh_e)**							
[B] – **Heat output (MW_h) and production of thermal energy (MWh_h)**							

The main assumptions with regard to fuel costs are given in Table 4.8. The increase in natural gas by 2030 is based on European Commission recommendations, which cite an average of 4.5 % annually, while for biomass and biogas the authors assumed an annual price increase of 2 %. After 2030, the same rate of increase has been assumed for all energy sources, of 1 % per year.

In Latvia, the use of natural gas is subject to excise tax, which, as of 2017, is EUR 1.65 per MWh of fuel. Since changes to the excise tax after 2020 have not been confirmed in legislation, the baseline scenario assumes the tax to stay unchanged throughout the simulation period, whereas the EE scenario assumes that the excise tax could be increased by 8 % per year. That would mean that by 2050 the excise tax on natural gas would be EUR 22.5/MWh.

TABLE 4.8. FUEL COSTS

	Fuel costs, EUR/MWh	**Annual increase of costs (up to 2030), EUR/year**	**Annual increase of costs (after 2030), EUR/year**
Natural gas	20.8	4.5	1
Biomass	10.67	2	1
Biogas	12.4	2	1

Use of natural gas is also subject to the natural resources tax on generated CO_2 emissions, except equipment included in the emission trading system and subject to ETS quota conditions. Until 2020 the natural resources tax on generated CO_2 emissions was EUR 4.5/t CO_2, while a new tax rate of EUR 9/t CO_2 has been applied as of 2020. The rates for 2021 and 2022 have also been approved, and will be EUR 12/t and EUR 15/t CO_2, respectively. The baseline scenario assumes that the tax rates approved up to 2022 are applied with the natural resources tax remaining at the 2022 level thereafter, while in the EE scenario the natural resources tax is gradually increased after 2022 up to the emission quota trading (ETS) level, reaching EUR 72/t in 2050 (see Figure 4.22). The model assumes the ETS emission quota price based on the values recommended by the European Commission.

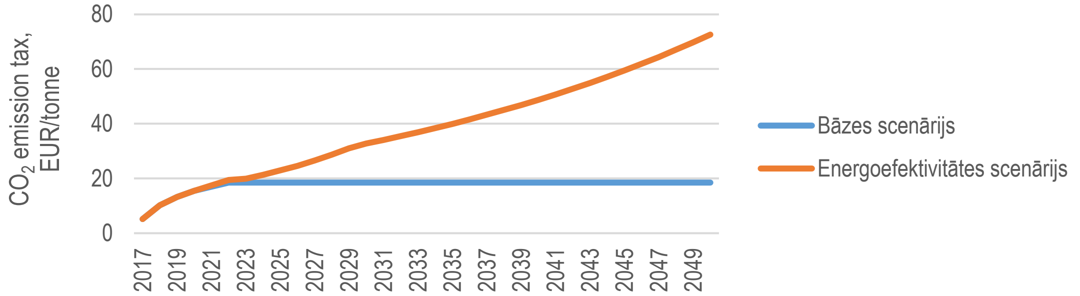


Figure 4.22. Changes in taxation for generated CO_2 emissions used in the analysis

Bāzes scenārijs - Baseline scenario; Energoefektivitātes scenārijs - Energy efficiency scenario

The main revenue flows in the financial analysis are comprised of the reduction of fuel costs and avoided CO_2 costs. The avoided CO_2 costs are calculated assuming that the amount of thermal energy produced from RES

was to be produced using natural gas. The avoided CO_2 emission costs are obtained by multiplying the amount of avoided CO_2 emissions by modelled CO_2 emission prices (taxes) in the relevant year.
In addition, the economic analysis also takes into consideration the avoided environmental costs, which are determined vis-à-vis the production of thermal energy at natural gas powered plants. The environmental costs are determined based on previously performed studies, which have identified the specific environmental costs of various technologies per amount of thermal energy produced (see Table 4.9). As for solar thermal power technologies, heat pumps and the integration of residual heat, it is assumed that no external environmental costs are incurred.

TABLE 4.9. ENVIRONMENTAL COSTS USED IN THE CALCULATIONS ([73])

Technological solution	Specific environmental costs, EUR/MWh
Biomass CHP plants	4.3
Natural gas CHP plants	11.7
Natural gas boiler houses	17.9
Biomass boiler houses	11.2

The calculated environmental costs and savings identified through the comparison of both analysed scenarios are aggregated and discounted in order to determine the current financial and economic values. The financial discount rate applied in the calculation is 4 %, while the social discount rate is 5 %.

4.3.1. Use of biomass

The cost and revenue flows for use of biomass are given in Figure 4.23. The accumulated value for the analysed period from 2020 to 2050 is given in Figure 4.24. It can be seen that in the EE scenario the main investments are made in 2030, with financial support for integration of RES becoming available. In the EE scenario, the identified fuel savings and avoided CO_2 emission costs also increase significantly, as this scenario predicts an increase in the costs of natural gas and CO_2 due to changes in tax policy. The EE scenario assumes slightly higher operational and maintenance costs, and slightly larger benefits from avoided environmental costs.

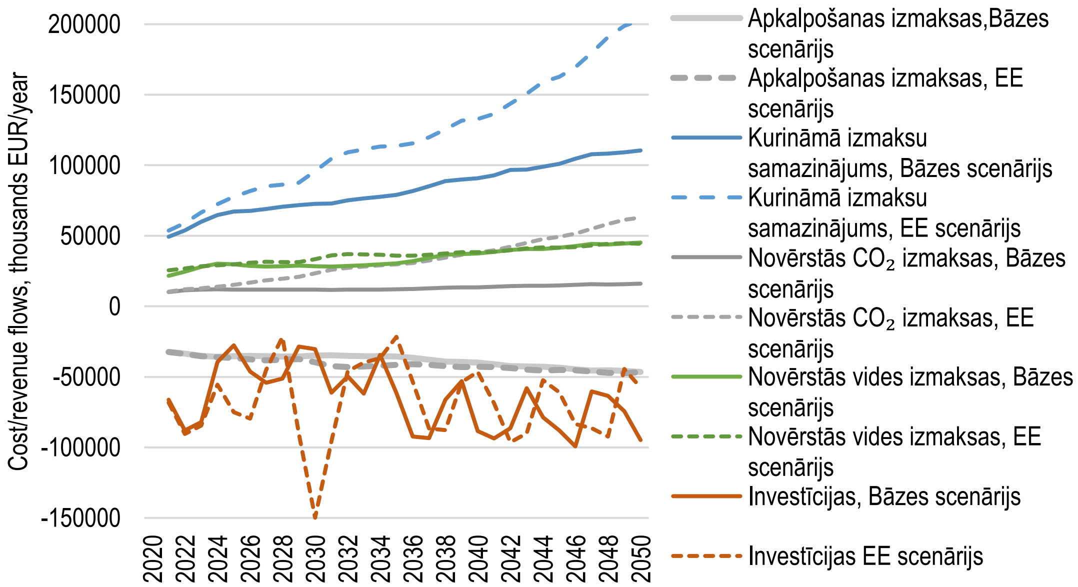


Figure 4.23. Estimated cash flows with regard to use of biomass in the analysed scenarios

([73]) Subsidies and costs of EU energy. An interim report, 2014. Available online: https://ec.europa.eu/energy/sites/ener/files/documents/ECOFYS%202014%20Subsidies%20and%20costs%20of%20EU%20energy_11_Nov.pdf

Apkalpošanas izmaksas, Bāzes scenārijs - Maintenance costs, Baseline scenario; Apkalpošanas izmaksas, EE scenārijs - Maintenance costs, EE scenario; Kurināmā izmaksu samazinājums, Bāzes scenārijs - Reduction of fuel costs, Baseline scenario; Kurināmā izmaksu samazinājums, EE scenārijs - Reduction of fuel costs, EE scenario; Novērstās CO2 izmaksas, Bāzes scenārijs - Avoided CO_2 costs, Baseline scenario; Novērstās CO2 izmaksas, EE scenārijs - Avoided CO_2 costs, EE scenario; Novērstās vides izmaksas, Bāzes scenārijs - Avoided environmental costs, Baseline scenario; Novērstās vides izmaksas, EE scenārijs - Avoided environmental costs, EE scenario; Investīcijas, Bāzes scenārijs - Investments, Baseline scenario; Investīvijas, EE scenārijs - Investments, EE scenario

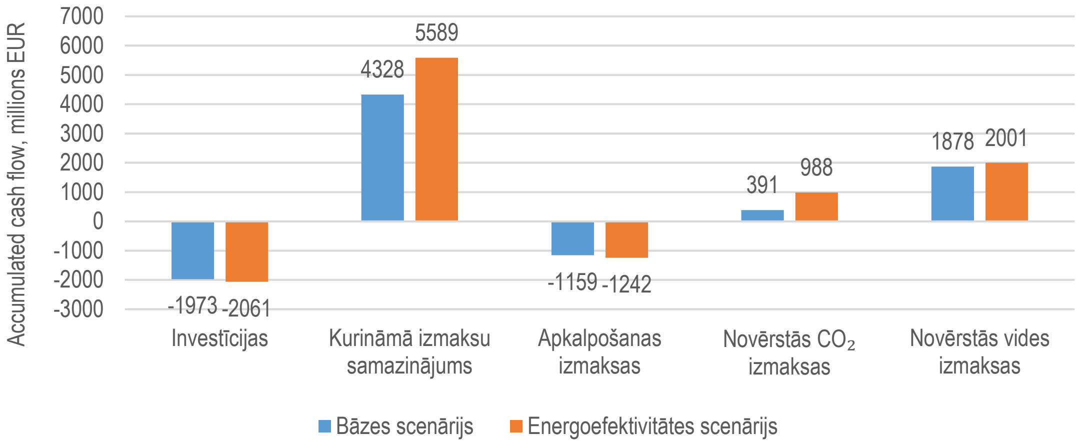


Figure 4.24. Accumulated values with regard to use of biomass in analysed scenarios

Baseline scenario Energy efficiency scenario

Investīcijas - Investments; Kurināmā izmaksu samazinājums - Reduction of fuel costs; Apkalpošanas izmaksas - Maintenance costs; Novērstās CO2 izmaksas - Avoided CO_2 costs; Novērstās vides izmaksas - Avoided environmental costs

In order to assess the costs and benefits within the EE scenario, an economic and financial analysis was performed to calculate key indicators, net present value (NPV) and internal rate of return (IRR). The values obtained are given in Table 4.10. In the EE scenario, NPV is EUR 610 million.

TABLE 4.10. RESULTS OF THE FINANCIAL AND ECONOMIC ANALYSIS

	NPV, m EUR	IRR, %
Financial analysis	610	11.2 %
Economic analysis	578	13.0 %

By including the avoided environmental costs in the DH assessment for biomass integration, as well as the social discount rate, the calculated NPV is EUR 578 million in the analysed period up to 2050. As compared to the baseline scenario, in the financial analysis the internal rate of return is 11.2 %, while the IRR in the financial analysis is given as 11.2 %.

4.3.2. Integration of solar thermal power

The cost and revenue flows for use of solar thermal power technologies are given in Figure 4.25. The accumulated value for the analysed period from 2020 to 2050 is given in Figure 4.26.

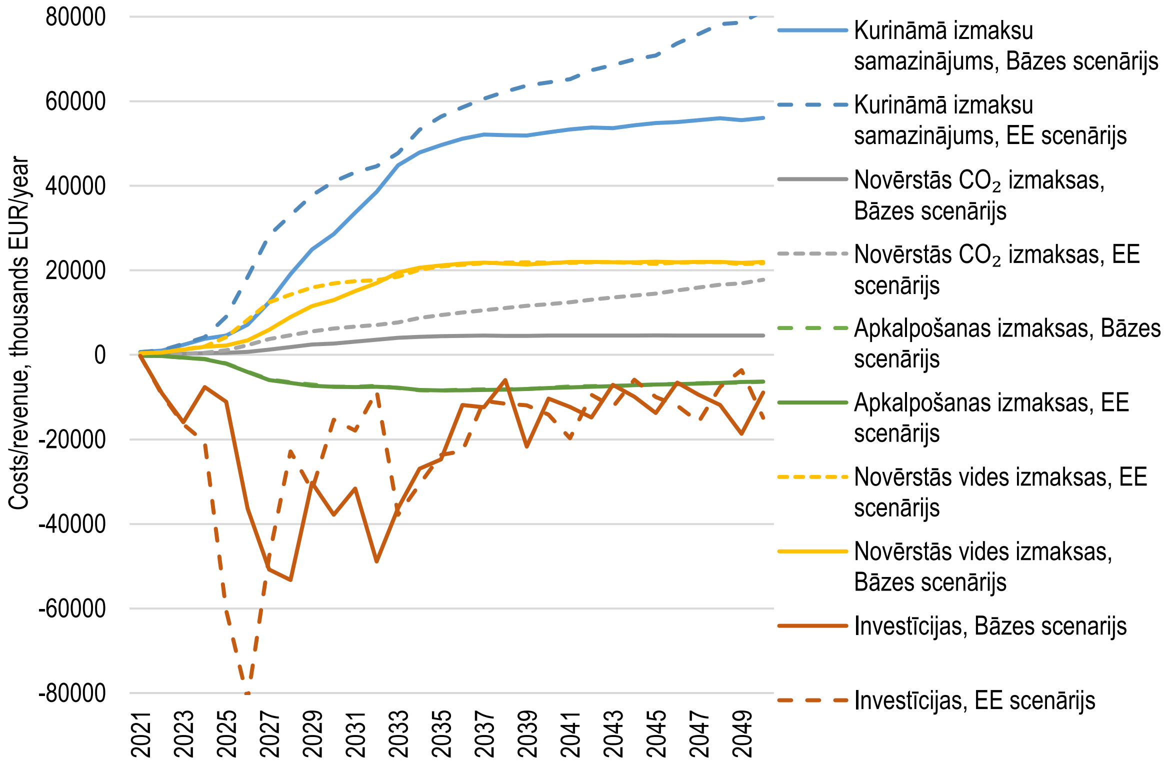


Figure 4.25. Costs and revenue with regard to use of solar thermal energy as included in the economic analysis

Apkalpošanas izmaksas, Bāzes scenārijs - Maintenance costs, Baseline scenario; Apkalpošanas izmaksas, EE scenārijs - Maintenance costs, EE scenario; Kurināmā izmaksu samazinājums, Bāzes scenārijs - Reduction of fuel costs, Baseline scenario; Kurināmā izmaksu samazinājums, EE scenārijs - Reduction of fuel costs, EE scenario; Novērstās CO2 izmaksas, Bāzes scenārijs - Avoided CO_2 costs, Baseline scenario; Novērstās CO2 izmaksas, EE scenārijs - Avoided CO_2 costs, EE scenario; Novērstās vides izmaksas, Bāzes scenārijs - Avoided environmental costs, Baseline scenario; Novērstās vides izmaksas, EE scenārijs - Avoided environmental costs, EE scenario; Investīcijas, Bāzes scenārijs - Investments, Baseline scenario; Investīvijas, EE scenārijs - Investments, EE scenario

It can be seen that in the EE scenario, the main investments are made in 2026, with financial support for integration of RES becoming available. In the EE scenario, the identified fuel savings and avoided CO_2 emission costs also increase significantly, as this scenario predicts an increase in the cost of natural gas and CO_2 due to changes in tax policy. The EE scenario assumes slightly larger benefits from avoided environmental costs in the first years of the introduction of the technology.

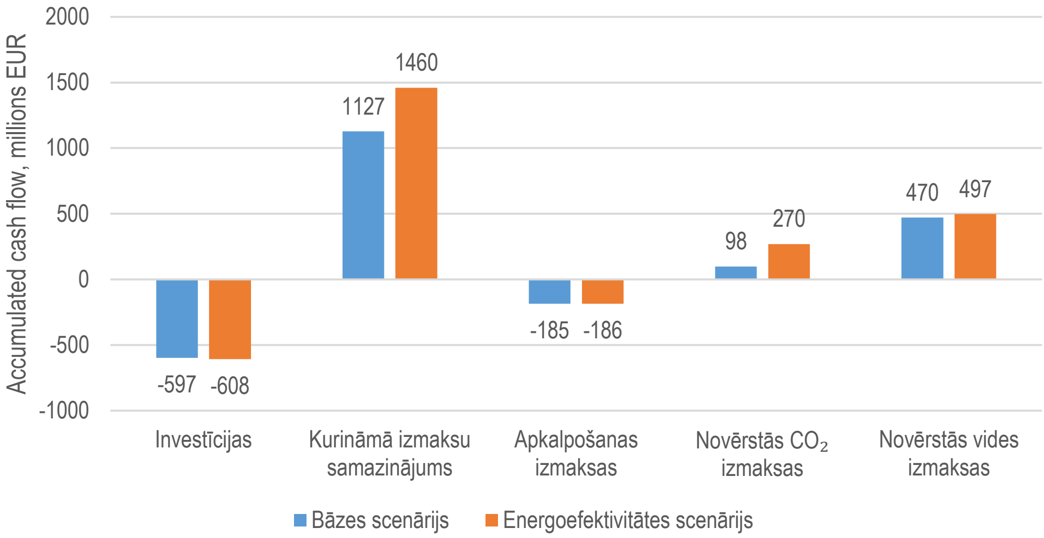


Figure 4.26. Accumulated values regarding the use of solar thermal energy within the analysed scenarios

Bāzes scenārijs - Baseline scenario; Energoefektivitātes scenārijs - Energy efficiency scenario

Investīcijas – Investments; Kurināmā izmaksu samazinājums - Reduction of fuel costs; Apkalpošanas izmaksas - Maintenance costs; Novērstās CO2 izmaksas - Avoided CO_2 costs; Novērstās vides izmaksas - Avoided environmental costs

In order to assess the costs and benefits within the EE scenario, an economic and financial analysis was performed to calculate key indicators, net present value (NPV) and internal rate of return (IRR). The values obtained are given in Table 4.11.

TABLE 4.11. RESULTS OF THE FINANCIAL AND ECONOMIC ANALYSIS OF INTEGRATING SOLAR THERMAL ENERGY

	NPV, m EUR	IRR, %
Financial analysis	206	19 %
Economic analysis	393	21 %

By including the avoided environmental costs in the DH assessment for the integration of solar thermal energy, the calculated NPV reaches EUR 393 million over a 20-year period. Compared to the baseline scenario, the internal rate of return in the economic assessment reaches 21 %, while the IRR in the financial assessment is 19 %.

4.3.3. Integration of heat pumps

The option of integrating heat pumps to produce thermal energy using residual RES electric power during periods of low demand for electric power is being examined as an additional energy resource for DH. Figure 4.27 illustrates the main costs and benefits of integrating heat pumps.

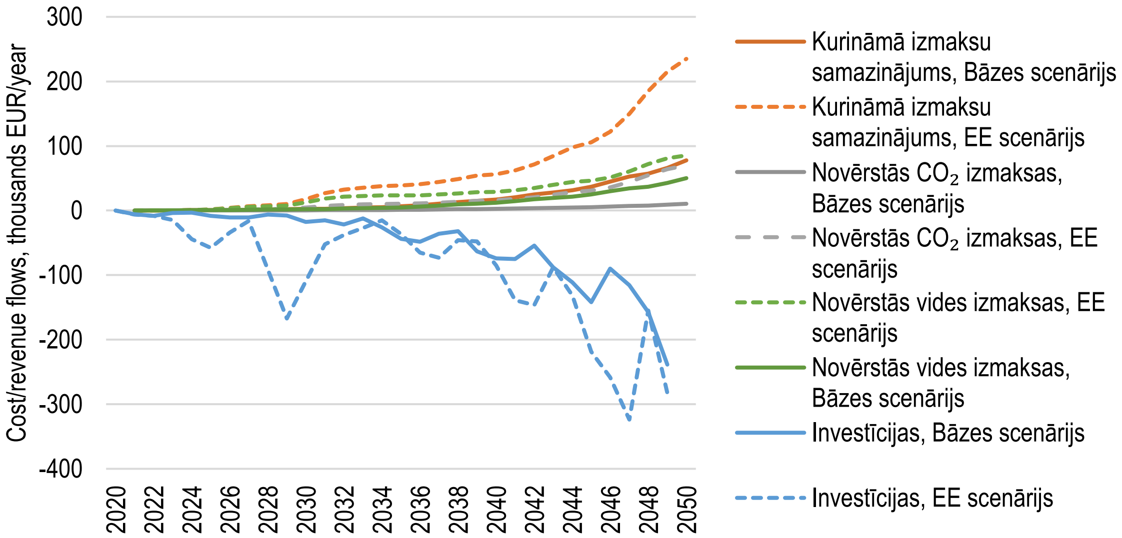


Figure 4.27. Costs and revenues included in the economic analysis of integrating heat pumps

Kurināmā izmaksu samazinājums, Bāzes scenārijs - Reduction of fuel costs, Baseline scenario; Kurināmā izmaksu samazinājums, EE scenārijs - Reduction of fuel costs, EE scenario; Novērstās CO2 izmaksas, Bāzes scenārijs - Avoided CO_2 costs, Baseline scenario; Novērstās CO2 izmaksas, EE scenārijs - Avoided CO_2 costs, EE scenario; Novērstās vides izmaksas, Bāzes scenārijs - Avoided environmental costs, Baseline scenario; Novērstās vides izmaksas, EE scenārijs - Avoided environmental costs, EE scenario; Investīcijas, Bāzes scenārijs - Investments, Baseline scenario

The transition from the use of natural gas CHP plants to the use of wind power for the production of electric power takes place over an extended period, therefore use of heat pumps in DH increases more steeply in the period from 2030 until 2050. Figure 4.28 demonstrates that the main investments in the EE scenario are made in 2030 and 2048. Thus, the majority of benefits will also be felt after 2050 with the use of heat pumps increasing within DH. In determining the reduction of fuel costs, the cost of electricity needed for operating the heat pumps was also taken into consideration.

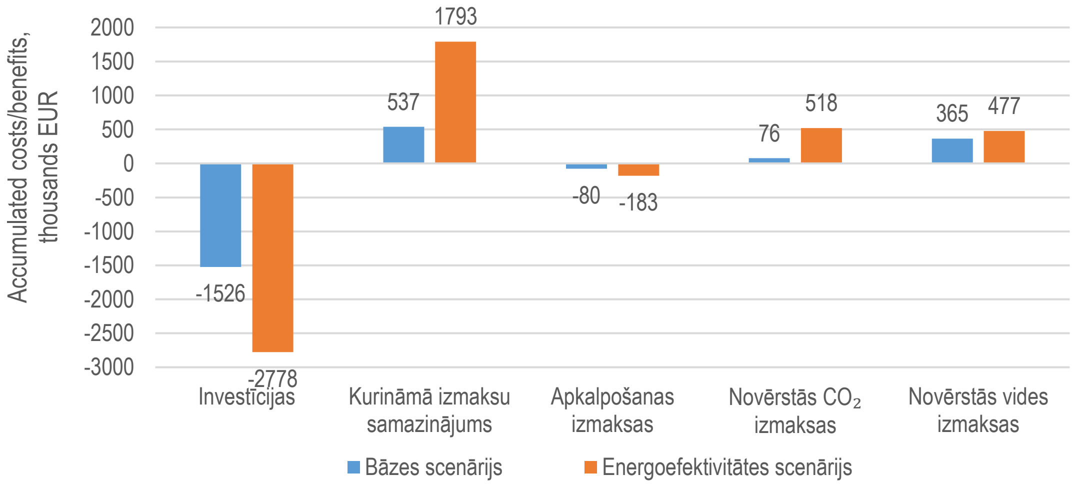


Figure 4.28. Accumulated values regarding use of heat pumps within the analysed scenarios

Bāzes scenārijs - Baseline scenario; Energoefektivitātes scenārijs - Energy efficiency scenario

Investīcijas – Investments; Kurināmā izmaksu samazinājums - Reduction of fuel costs; Apkalpošanas izmaksas - Maintenance costs; Novērstās CO2 izmaksas - Avoided CO_2 costs; Novērstās vides izmaksas - Avoided environmental costs

In order to assess the costs and benefits within the EE scenario, an economic and financial analysis was performed to calculate key indicators, net present value (NPV) and internal rate of return (IRR). The values obtained are given in Table 4.12.

TABLE 4.12. RESULTS OF THE FINANCIAL AND ECONOMIC ANALYSIS OF THE INTEGRATION OF HEAT PUMPS

	NPV, thousands EUR	IRR, %
Financial analysis	247	-15 %
Economic analysis	622	3 %

By including the avoided environmental costs in the DH assessment for the integration of heat pumps, the calculated NPV reaches EUR 622 thousand over a 20-year period. Compared to the baseline scenario, the internal rate of return in the economic assessment reaches 3 %, while the IRR in the financial assessment is negative.

4.3.4. Integration of residual heat

The economic potential of the integration of residual heat was examined through system dynamics modelling. The amount of residual heat was determined for the whole territory of Latvia by analysing overall production processes and the amount of thermal energy produced, and considering limitations as to the use of residual heat. The key assumptions as to the potential of residual heat are based on the obtained mapping results – the average potential residual heat at companies, the distance to the nearest boiler house and compatibility with the heating capacity of the boiler house.

With regard to the integration of residual heat, two development scenarios are examined: a baseline scenario where the integration of residual heat is analysed without any additional support mechanisms and an EE scenario where financial support for connections with industrial businesses for the integration of residual heat into the DH is considered. Figure 4.29 demonstrates the development trends regarding the integration of residual heat up to 2050. In the baseline scenario, the amount of residual heat integrated into the DH increases up to 16.4 GWh, while in the EE scenario it reaches 80 GWh per year.

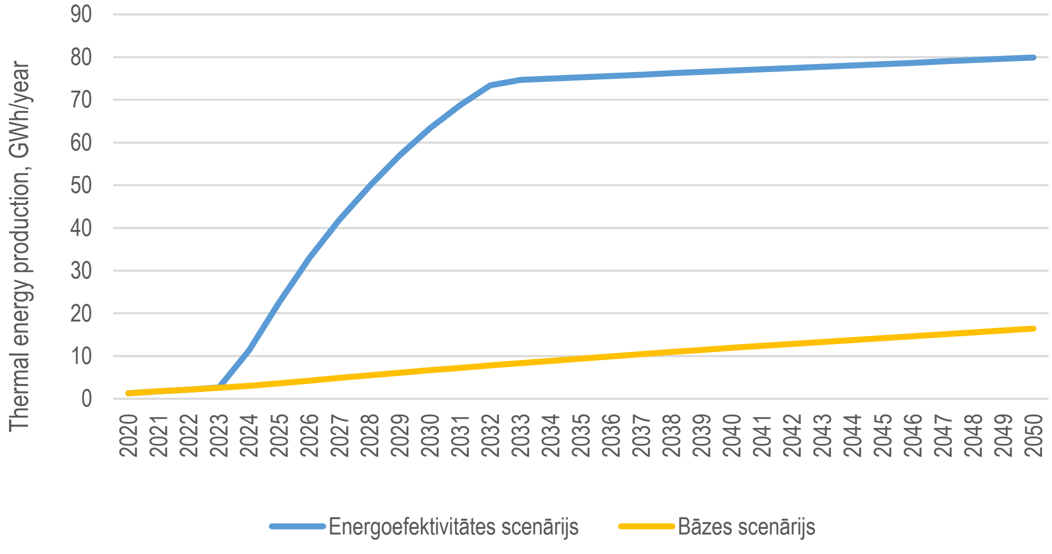


Figure 4.29. Estimated integration of residual heat

Energoefektivitātes scenārijs - Energy efficiency scenario; Bāzes scenārijs - Baseline scenario

Figure 4.30 demonstrates the calculated amount of investments for the integration of residual heat. In the baseline scenario, this number is EUR 2.575 million in the period up to 2050, whereas in the EE scenario it is EUR 13.250 million.

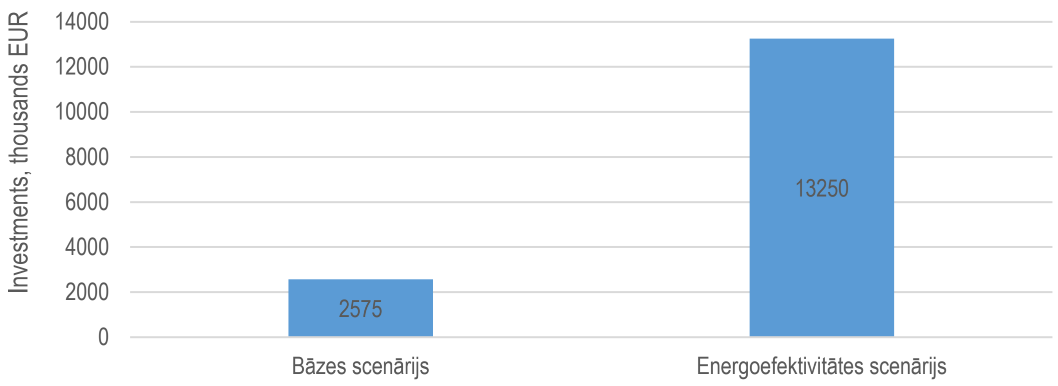


Figure 4.30. Accumulated necessary investments for the integration of residual heat

Energoefektivitātes scenārijs - Energy efficiency scenario; Bāzes scenārijs - Baseline scenario

The main revenue flow after the integration of residual heat is comprised of revenue from selling heat to consumers. In order to calculate the potential revenues, an estimated average tariff for heat production was used assuming an increase from an average of EUR 47.10/MWh to EUR 54.31/MWh in the baseline scenario and to EUR 62.33/MWh in the EE scenario. Figure 4.31 demonstrates revenue and costs calculated within the financial analysis of both scenarios. Revenue from the sale of residual heat is approximately five times lower in the baseline scenario. Additional revenue arises from the reduction of the cost of CO_2 emissions. The economic analysis also takes into consideration revenue from avoided environmental costs that would occur if thermal energy obtained from residual heat would no longer have to be produced by natural gas boilers.

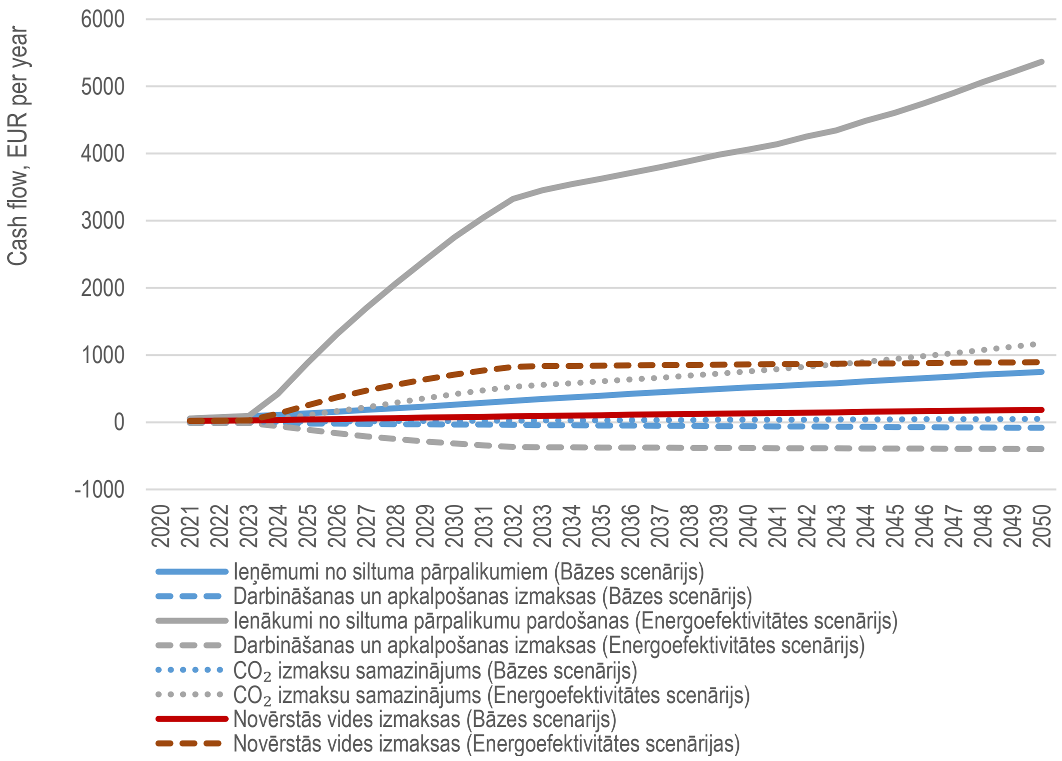


Figure 4.31. Differences in revenue and cost cash flows for the analysed scenarios

Ieņēmumi no siltuma pārpalikumiem (Bāzes scenārijs) - Revenues from residual heat (baseline scenario); Darbināšanas un apkalpošanas izmaksas (Bāzes scenārijs) - Operating and maintenance costs (baseline scenario); Ienākumi no siltuma pārpalikumu pārdošanas (Energoefektivitātes scenārijs) - Revenues from sale of residual heat (energy efficiency scenario); Darbināšanas un apkalpošanas izmaksas (Energoefektivitātes scenārijs) - Operating and maintenance costs (energy efficiency scenario); CO2 izmaksu samazinājums (Bāzes scenārijs) - Reduction of CO_2 costs (baseline scenario); CO2 izmaksu samazinājums (Energoefektivitātes scenārijs) - Reduction of CO_2 costs (energy efficiency scenario); Novērstās vides izmaksas (Bāzes scenārijs) - Avoided environmental costs (baseline scenario); Novērstās vides izmaksas (Energoefektivitātes scenārijs) - Avoided environmental costs (energy efficiency scenario)

In order to assess the costs and benefits within the EE scenario, an economic and financial analysis was performed to calculate key indicators, net present value (NPV) and internal rate of return (IRR). Figure 4.32 demonstrates the discounted cash flows identified in the financial and economic analysis.

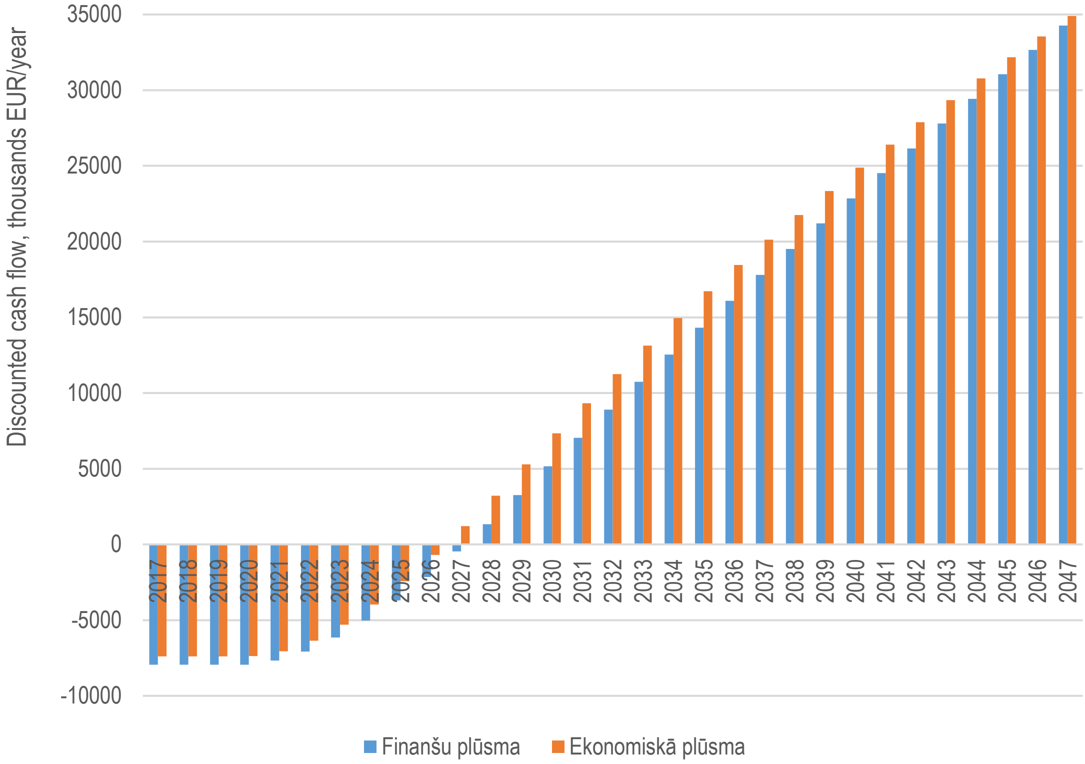


Figure 4.32. Comparison of discounted cash flows of the financial analyses of the scenarios

Finanšu plūsma - Financial flow; Ekonomiskā plūsma - Economic flow

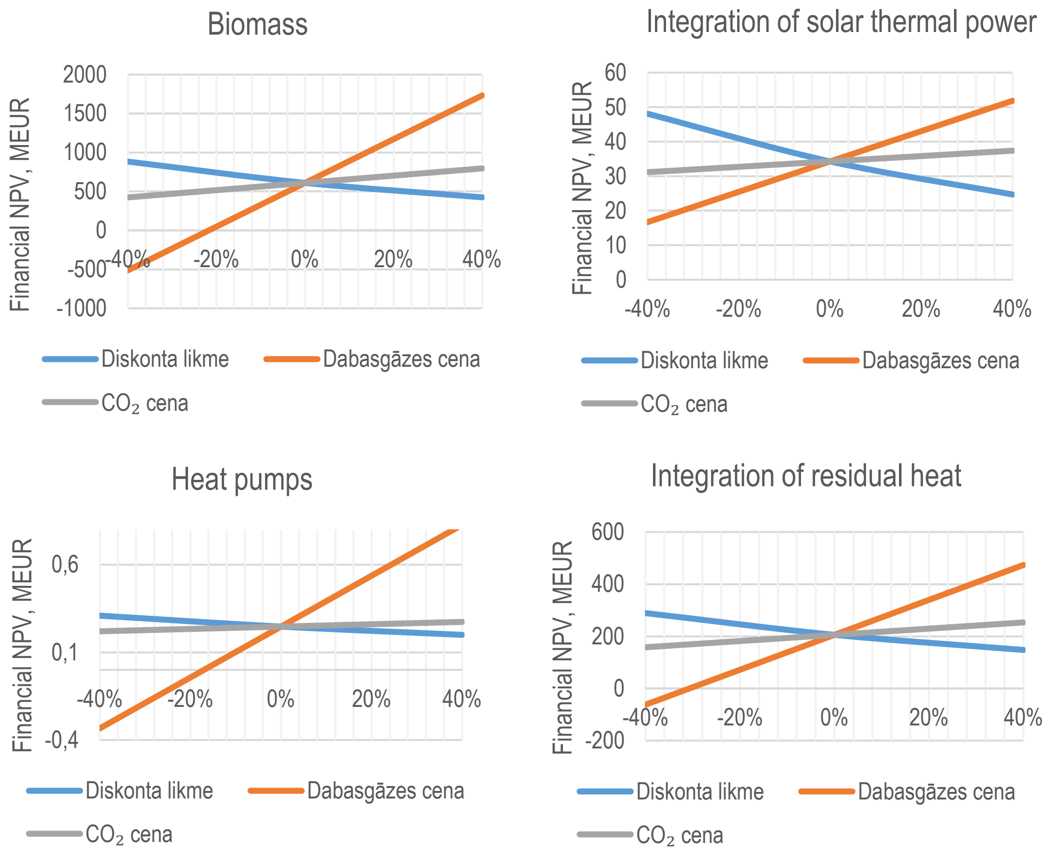
TABLE 4.13. FINANCIAL ANALYSIS INDICATORS CALCULATED FOR THE ANALYSED SCENARIOS

	NPV, thousands EUR	IRR, %
Financial analysis	34	9.6 %
Economic analysis	38	10.1 %

Table 4.13 provides a summary of the financial indicators of both analysed scenarios. Under the assumptions made regarding the necessary investments and revenue, integration of residual heat provides a high internal rate of return within the EE scenario.

4.3.5. Sensitivity analysis

To assess the effect of the main assumptions on the obtained results of the financial analysis, a sensitivity analysis has been carried out. Figure 4.33 demonstrates changes in the financial NPV if the cost of natural gas is increased or reduced, the discount rate applied in the calculation and the price of CO_2 emissions.



4.33. Results of sensitivity analysis of various directions of development

Diskonta likme - Discount rate; Dabasgāzes cena - Price of natural gas; CO2 cena - Price of CO_2

Table 4.14 summarises the calculated financial NPVs at various values of the criteria. For the purposes of the sensitivity analysis, the price of natural gas in the EE scenario is increased from EUR 33/MWh to EUR 46/MWh in 2020 and to EUR 94/MWh in 2050. In turn, at a 40 % reduction in the price of natural gas, the price is EUR 20/MWh in 2020 and EUR 40/MWh in 2050. The analysed discount rate ranges from 2 % (at a 40 % reduction) to 6 % (at a 40 % increase). The rate of increase of CO_2 costs as applied in the calculation at a 40 % increase in the EE scenario is increased from EUR 72/t CO_2 to EUR 101/t CO_2 in 2050. In turn, in case of lower CO_2 costs, the price of a tonne of CO_2 in 2050 is EUR 43.5.

TABLE 4.14. CHANGES IN FINANCIAL NPV (MILLIONS OF EUR) FOLLOWING CHANGES IN RELEVANT CRITERIA

Criterion changes	-40 %	0 %	40 %
Discount rate changes			
Increased share derived from biomass	884	610	425
Integration of heat pumps	0.31	0.25	0.20
Integration of solar thermal power	289	206	148
Use of residual heat	48	34	25
Price of natural gas			
Increased share derived from biomass	-513	610	1 733
Integration of heat pumps	-0.33	0.25	0.83
Integration of solar thermal power	-62	206	474
Use of residual heat	17	34	52
Price of CO_2			
Increased share derived from biomass	424	610	796
Integration of heat pumps	0.22	0.25	0.27
Integration of solar thermal power	158	206	253
Use of residual heat	31	34	37

It is evident that the greatest changes arise from an increase or reduction in the price of natural gas, which is used as the reference value for calculating the gains from RES and residual heat. Changes in the discount rate have a greater effect on solar thermal energy technologies, which the EE scenario estimates will take place after 2030.

4.4. Integration of renewable energy sources into individual heating

A system dynamics modelling method was used to assess the economic potential of integrating RES into individual heat supply. The RES potential was assessed with respect to the energy sources and technological solutions currently being employed in various sectors, with a view to long-term development up to 2050. A cost-benefit analysis of RES integration was performed, taking into consideration the costs and benefits for individual thermal energy producers and society at large in terms of a reduction in environmental impact. Based on current development trends, three energy sources have been analysed as the main RES to be used for individual heat supply: biomass, which over the previous decade has increasingly been used to substitute fossil fuels; solar thermal power through the installation of solar collectors, which can be considered a potential energy source for hot water supply, and ground and air source heat pumps, which use electricity for the production of thermal energy.

A system dynamics model was employed to assess the most financially advantageous method of thermal energy production for the relevant year, taking into consideration the cost of fuel, technologies, operation and the available policy support. Therefore, a two-tier economic assessment is provided with the most suitable type of fuel and technology selected within the system dynamics model, and the discounted costs-benefits compared within the financial and economic assessment.

The capital expenses for technologies, operation and maintenance costs, as well as the efficiency of the equipment are based on information from a Danish technology catalogue covering the main technologies used in local and individual heat supply. The key parameters used are given in Table 4.15. Capital expenses include both expenses for technologies and installation thereof. Two types of systems are examined in regard to local and individual heat supply, medium and small scale, based on the heat consumption of the user.

The main assumptions as to fuel costs and applicable tax rates are the same as described in Chapter 4.3. The assumptions used in the modelling of demand for individual heat supply and the breakdown of fuels by sector are described in Chapter 2.5.

TABLE 4.15. MAIN COSTS OF INDIVIDUAL AND LOCAL HEAT SUPPLY TECHNOLOGIES USED IN THE MODEL

	Capital expenses, EUR/MW		Fixed O&M, EUR/MW/year		Variable O&M, EUR/MWh		Lifetime, years
	2017	2030	2017	2030	2017	2030	
Natural gas (160 kW)	112 500	104 375	2 800	2 650	0.0	0.0	25
Biomass (160 kW)	337 500	312 500	7 220	6 980	0.0	0.0	20
Natural gas (10 kW)	320 000	300 000	20 900	19 900	0.0	0.0	20
Biomass (12 kW)	584 000	541 700	43 000	40 500	0.0	0.0	20
Diesel fuel (160 kW)	175 000	162 500	3 520	3 225	25.0	21.0	20
Diesel fuel (15 kW)	400 000	373 000	16 000	15 700	0.0	0.0	20
Heat pumps (160 kW)	662 500	560 000	2 500	2 115	0.5	0.4	20
Heat pumps (10 kW)	1 600 000	1 400 000	29 100	25 500	0.0	0.0	20
Solar collectors (140 kW)	580 000	478 570	2 780	3 130	0.0	0.0	25
Solar collectors (4.2 kW)	643 000	500 000	16 430	16 430	0.0	0.0	25

When analysing options for the development of individual heat supply, two scenarios are examined: a baseline scenario, which assumes development within the existing legislative and support framework, and an EE scenario, which envisages support for the implementation of EE measures (mostly thermal insulation of buildings with the aim of reducing heat consumption) in apartment buildings, commercial buildings, public buildings and industrial undertakings. Furthermore, the scenario also assumes that support is provided for the integration of RES into the local and individual heat supply. The amount of support has been taken from the values forecast for the period up to 2030, as set out in Annex 4 to the National Energy and Climate Plan of Latvia. Support is allocated for the period up to 2030, on condition that part of it can also be used after 2030, provided that the application for funding is received by 2030. Additional funding after 2030 is not considered. A summary of the main amounts of funding and aid intensities is provided in Table 4.16.

TABLE 4.16. SUPPORT FOR IMPROVING ENERGY EFFICIENCY OF BUILDINGS AND INTEGRATING RES

	Total amount of support, MEUR	Aid intensity, %
Residential buildings (energy efficiency)	1 200	30
Commercial sector buildings (energy efficiency)	300	30
Municipal buildings (energy efficiency)	100	30
Private buildings (energy efficiency)	100	30
Industrial sector (RES and energy efficiency)	225	20
Individual heat supply (RES)	267	20

The estimated breakdown of energy produced by energy source is given for the baseline scenario in Figure 4.34 and, for the EE scenario, in Figure 4.35. A continual increase in the use of biomass and solar energy for heating can be observed. The proportion of DH accounted for by biomass reaches 60 % in 2050 in the baseline scenario and 65 % in the EEF scenario. The EEF scenario foresees a slight increase in the potential of integrated solar energy, estimating it at 15 % of the total produced thermal energy within DH in 2050. Heat pumps provide a very small portion of thermal energy produced in both scenarios. The EE scenario predicts an overall decrease in the demand for thermal energy due to improved energy efficiency of buildings.

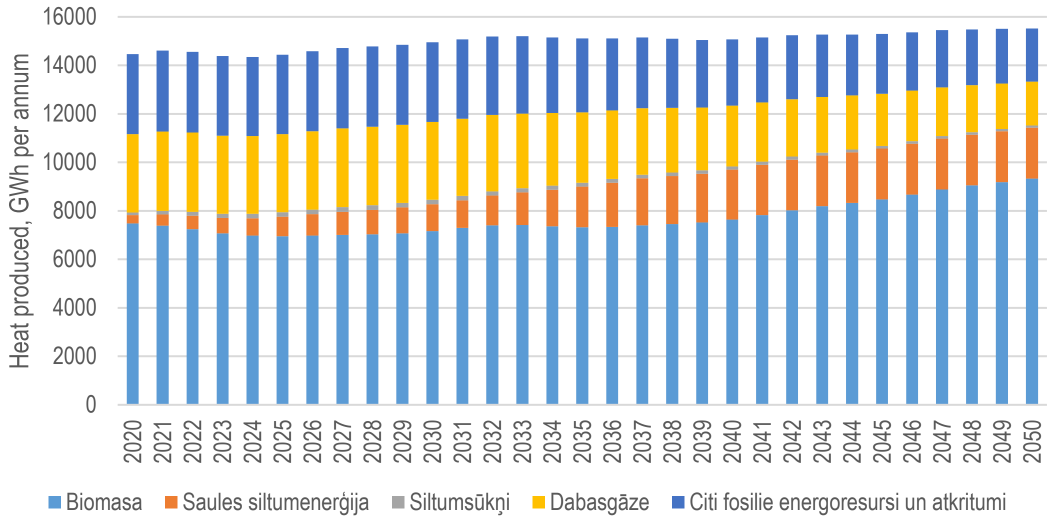


Figure 4.34. Fuels used for thermal energy production in individual heat supply within the baseline scenario

Biomasa - Biomass; Saules siltumenerģija - Solar thermal energy; Siltumsūkņi - Heat pumps; Dabasgāze - Natural gas; Citi fosilie energoresursi un atkritumi - Other fossil fuels and waste

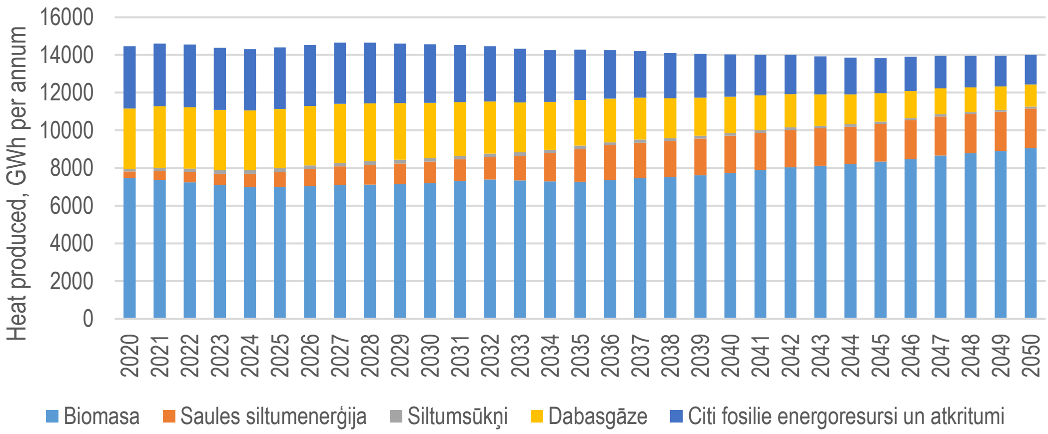


Figure 4.35. Fuels used for thermal energy production in individual heat supply within the energy efficiency scenario

Biomasa - Biomass; Saules siltumenerģija - Solar thermal energy; Siltumsūkņi - Heat pumps; Dabasgāze - Natural gas; Citi fosilie energoresursi un atkritumi - Other fossil fuels and waste

In order to perform a cost-benefit analysis for the broader use of RES in individual heat supply, the costs and benefits of each analysed energy source are determined, and these are then compared to the production of thermal energy in natural gas boiler houses. The costs of investments for the installation of technologies, as well as maintenance and service costs comprise the main expenses. Considering that investments are not simultaneous, the model was based on annually necessary investments discounted to determine the current value of total investments.

The cost and revenue flows for the use of RES are given in Figure 4.36. The accumulated values for the analysed period from 2020 to 2050 are given in Figure 4.37. The amount of investments is similar in both scenarios as the demand for thermal energy in individual heat supply decreases within the EEF scenario. In the EEF scenario, the identified fuel savings and avoided CO_2 emission costs also increase significantly, as this scenario predicts an increase in the costs of natural gas and CO_2 due to changes in tax policy. The EEF scenario assumes slightly higher operational and maintenance costs, and slightly larger benefits from avoided environmental costs, which, as in the case of DH, have been determined as compared to heat production using natural gas technologies.

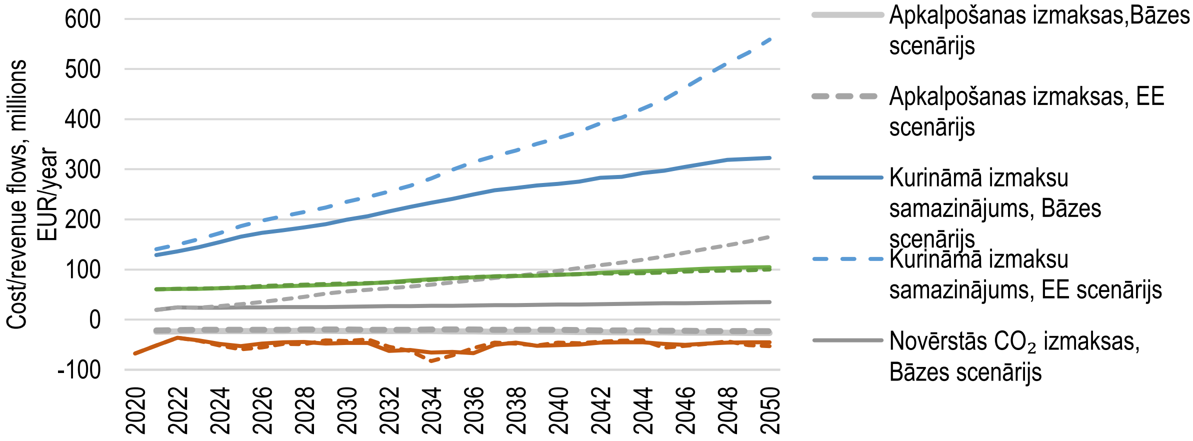


Figure 4.36. Estimated cash flows in the analysed scenarios with regard to the use of RES

Apkalpošanas izmaksas, Bāzes scenārijs - Maintenance costs, Baseline scenario; Apkalpošanas izmaksas, EE scenārijs - Maintenance costs, EE scenario; Kurināmā izmaksu samazinājums, Bāzes scenārijs - Reduction of fuel costs, Baseline scenario; Kurināmā izmaksu samazinājums, EE scenārijs - Reduction of fuel costs, EE scenario; Novērstās CO2 izmaksas, Bāzes scenārijs - Avoided CO_2 costs, Baseline scenario; Novērstās CO2 izmaksas, EE scenārijs - Avoided CO_2 costs, EE scenario; Novērstās vides izmaksas, Bāzes scenārijs - Avoided environmental costs, Baseline scenario

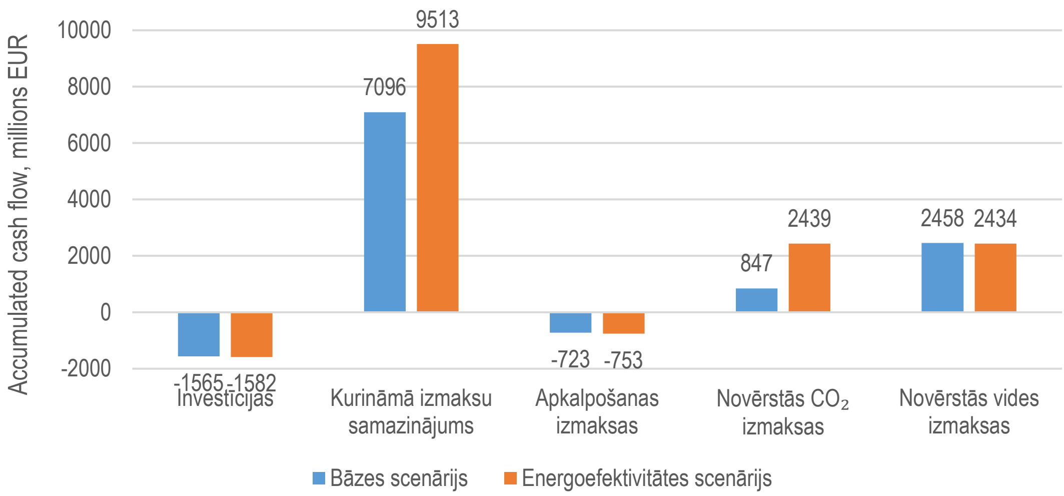


Figure 4.37. Accumulated values for the analysed scenarios

Bāzes scenārijs - Baseline scenario; Energoefektivitātes scenārijs - Energy efficiency scenario

Investīcijas – Investments; Kurināmā izmaksu samazinājums - Reduction of fuel costs; Apkalpošanas izmaksas - Maintenance costs; Novērstās CO2 izmaksas - Avoided CO_2 costs; Novērstās vides izmaksas - Avoided environmental costs

In order to assess the costs and benefits of the EE scenario, an economic and financial analysis was performed to calculate NPV and IRR. The values obtained are given in Table 4.10. In the EE scenario, NPV is EUR 1.680

billion. By including the avoided environmental costs in the economic assessment of increasing the share of RES, as well as the social discount rate, the calculated NPV reaches EUR 1.378 billion in the analysed period up to 2050. Both the financial and economic internal rate of return is higher in the EE scenario than the baseline scenario.

TABLE 4.17. FINANCIAL ANALYSIS INDICATORS CALCULATED FOR THE ANALYSED SCENARIOS

	NPV, million EUR	IRR, %
Financial analysis	1 680	> 20 %
Economic analysis	1 378	> 20 %

To assess the effect of the main assumptions on the obtained results of the financial analysis, a sensitivity analysis has been carried out. Figure 4.38 demonstrates changes in the financial NPV if the cost of natural gas is increased or reduced, the discount rate applied in the calculation and the price of CO_2 emissions. The main assumptions regarding the social discount rate are the same as described in Chapter 4.3.

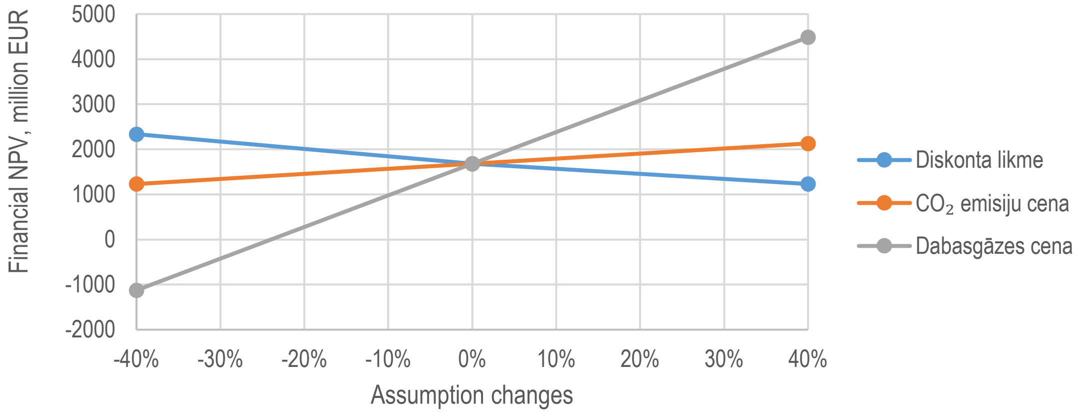


Figure 4.38. Results of the sensitivity analysis

Diskonta likme - Discount rate; CO2 emisiju cena - Price of CO_2 emissions; Dabasgāzes cena - Price of natural gas

It is evident that the greatest changes arise from the increase or reduction of the price of natural gas, as it is used as the reference value for calculating the benefits provided by RES. Changes in the discount rate have a greater impact on solar thermal energy technologies, which the EE scenario sees as being installed and producing the most energy after 2030.

5. POTENTIAL NEW STRATEGIES AND POLICY MEASURES

Potential new strategies and policy measures have been assessed based on methods of which the algorithms are illustrated in Figure 5.

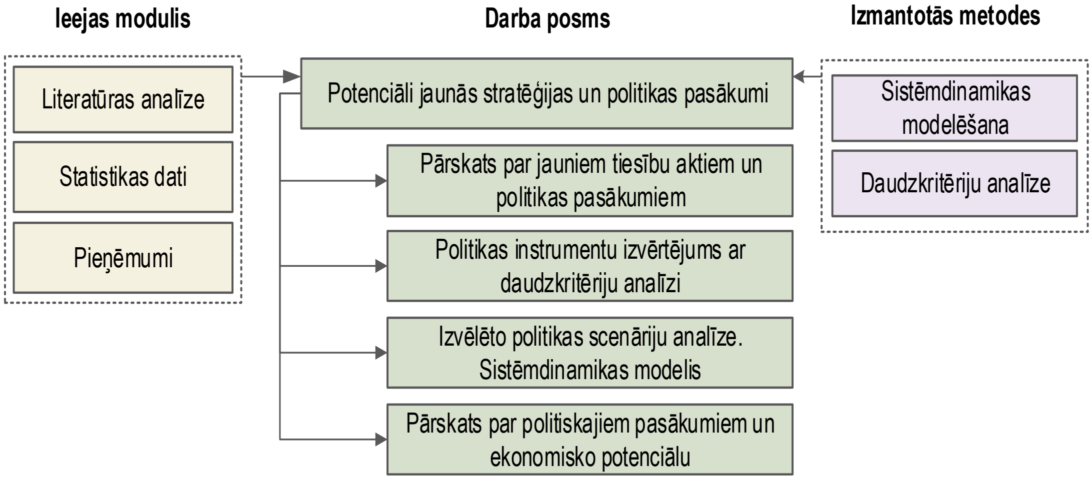


Figure 5. Algorithm of methods for assessing potential new strategies and policy measures [*for translation, see (30) in accompanying document*]

The assessment is based on a method encompassing the analysis of publications to obtain an overview of new legislative acts and policy planning documents. The assessment also examines potential new political support and an assessment of the scenarios using two scientific methods. The TOPSIS multi-criteria decision analysis method was used to assess policy instruments and the prioritisation thereof. A system dynamics model was used for analysing selected policy scenarios, which provides for the possibility to create an overview of policy measures and their economic potential.

5.1. Overview of new legislative acts and policy measures

Policy instruments

The introduction and viability of DH solutions are affected by various factors relating to energy demand, the operation and regulation of the market, legislation, and heat supply and energy policy in general. However, the key factor in the sustainability of DH as an efficient energy system is policy instruments that can either promote or hinder the operation and development of DH.

By establishing a low carbon economy or even a zero carbon economy as the target, policymakers are creating an environment that promotes the broader use of renewable and inexhaustible energy sources across all sectors of the economy, especially in energy and transport, which both have a significant impact on GHG emissions. Support for the broader use of RES in the production of electricity also promotes the introduction and operation of DH systems. A typical and ideal example: a supported biomass CHP plant produces thermal and electric power; the electric power is injected into the grid, while the thermal power is delivered to heating consumers through the DH network. Support for a specific technological solution is granted based on the installed electrical power output or the amount of power injected into the grid. Cross-subsidies from revenue generated from production of electric power are not permitted for thermal power, however, heat production is supported indirectly as a decision has been taken to invest into the specific technological solution (the CHP plant). The output of the CHP plant is determined by the minimum heating output needed during summer months to ensure efficient use of the technology. Electric power produced through cogeneration is a by-product of heat production (74).

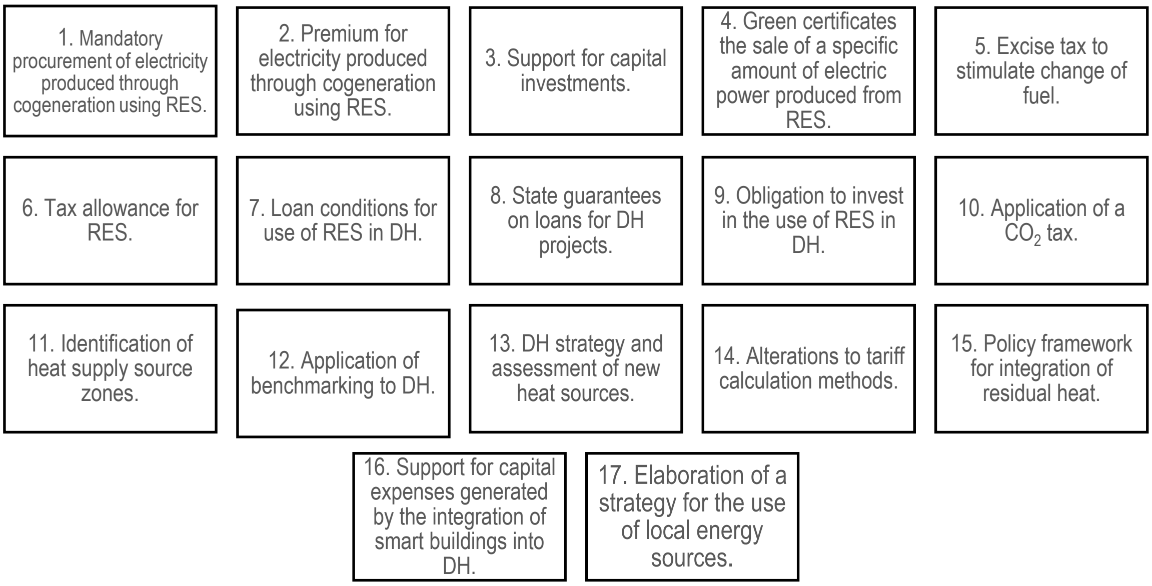


Figure 5.1. Policy instruments for direct and indirect support of broader use of RES in DH

In assessing what types of policy instruments could promote the creation, maintenance and preservation of DH, it needs to be taken into consideration that there are policies that affect DH, although their primary objective is the promotion of the use of renewable and inexhaustible energy sources. Furthermore, policy instruments are linked to solutions for reducing CO_2 emissions, including by ensuring switching to other fuels. Policy instruments identified below (see Figure 5.1 and the description of policy instruments given afterwards) may have an effect on district heating.

In planning and selecting policy instruments for promoting district heating, factors such as the objective of the policy instrument, the potential reduction of GHG emissions, possible primary energy savings, effects on high-efficiency cogeneration, effects on the share of RES in the national energy portfolio, the heating and cooling supply, the relationship with financial planning and the potential to reduce budget expenditure and energy costs for market players, the potential need for public support, and the impact on the budget and type of possible support must be considered.

(74) Kristina Difs, National energy policies: Obstructing the reduction of global CO_2 emissions? An analysis of Swedish energy policies for the district heating sector, Energy Policy 38. 2010. 7775-7782.

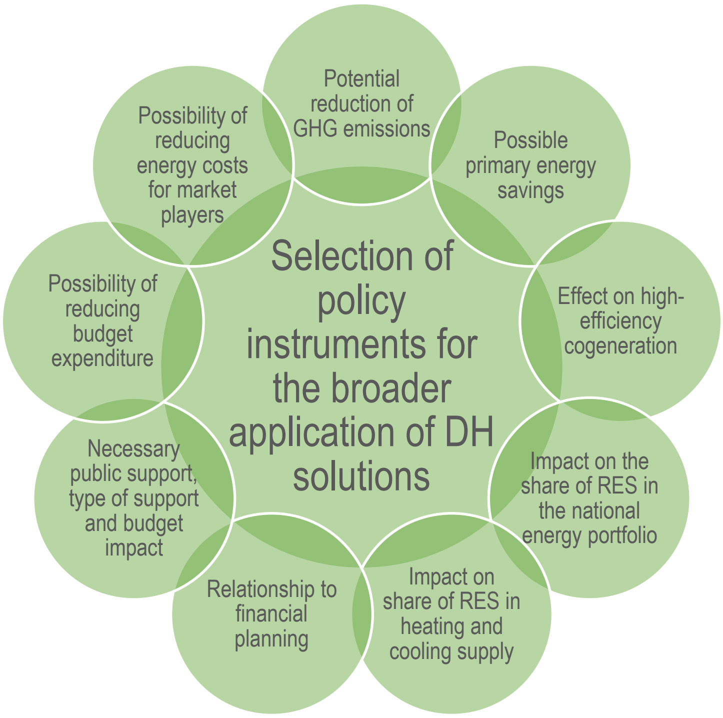


Figure 5.2. Factors affecting choice of policy instruments

Various factors play a crucial role in the development of DH systems. The ideological framework for the introduction and maintenance of DH is the creation of sustainable energy systems by reducing the consumption of fossil fuels in energy production and energy consumption per se and implementing EE measures both on the supplier and consumer side. The shift from fossil fuels to renewable energy sources in heat production is a means of reducing GHG emissions.

Each of the analysed policies shown in Figure 5.1 promotes the EE aspects of DH: a reduction in GHG emissions, primary energy savings, an increase in the share derived from high-efficiency cogeneration, an increase in the share derived from RES, and cost savings for the public sector budget and market players (see Table 5.1). Nearly all the analysed policies have a positive effect on the reduction of GHG emissions and the increase in the share derived from RES.

TABLE 5.1. IMPACT OF ANALYSED POLICIES ON VARIOUS ASPECTS OF DH

Expected aspect	No of policy (from Figure 5.1) that has an impact
Reduction in greenhouse gas emissions	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 17
Primary energy savings	1, 2, 3, 4, 8, 12, 15, 16, 17
Impact on share derived from high-efficiency cogeneration	1, 2, 3, 4, 8, 17
Impact on share derived from RES in the national energy source structure and heating and cooling sector	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 17
Relationship to national financial planning and cost savings for the public sector budget and market players	5, 6, 11, 12, 13, 14, 15, 16, 17

Mandatory procurement of electricity produced through cogeneration using RES (MP RES)

This policy instrument is intended to stimulate broader use of RES in the production of electric power. MP RES is categorised as a stable and predictable policy instrument which is used to promote investment in technologies while guaranteeing returns on investments and consumption of the energy produced. The MP provides a fixed amount of support for produced electric power regardless of the market price of electric power, and this support instrument creates the smallest burden, relatively, on the consumers of electricity, whose payments fund the support instrument. MP RES has the potential to especially promote biomass and biogas cogeneration in order to supply the DH network with thermal power.

Premium for electricity produced through cogeneration using RES (RES premium)

The policy instrument is intended to stimulate the use of RES in production of electric power. The premium above market price is considered to be a stable support instrument, which, as compared to the MP, is, to a higher degree, based on market principles as it does not provide a guaranteed, fixed payment for electric power, but rather covers the difference between the net price of producing electric power and the market price. Such an approach reduces the costs of the support system and the burden on the consumers who have to fund the support mechanism.

Green certificates for the sale of a specific amount of RES electric power (GC RES)

Green certificates are sold separately from produced electric power, and they certify that the buyer is paying for electric power produced from RES. As opposed to the MP RES and RES premium, GC RES is a support instrument based even more on market principles, and it is not directly linked to the electric power produced by a specific producer. With electric power being produced through cogeneration using biomass, it can be assumed that, as a support system, the GC RES also indirectly supports DH solutions. In the GC RES system market players (producers, suppliers (merchants), network operators) have an obligation to purchase and cancel electric power certificates every year. The number of green certificates that each market player must purchase is determined by the value of the green energy quota of the given year multiplied by the amount of electric power (in megawatt-hours) supplied to consumers during the year. This creates a demand for green certificates, which the producers then sell to obtain additional revenue from the sale of electric power.

Support for capital investments

Many technologies require major initial investments. DH solutions where energy is produced using renewable or inexhaustible sources need clear rules to depend on in taking investment decisions. Especially significant costs are to be expected if a DH system needs to be recreated from scratch due to a lack of a functioning DH system, which could be supplemented with new sources for thermal energy production or where existing sources could be replaced. In this support model, investors are compensated for their capital investment, while the production and sale of electric power follows market principles and investors do not receive additional payment for the energy.

Excise tax to stimulate change of fuel

The use of fiscal instruments (such as taxes) can stimulate a shift in the sources used for energy production. For example, by increasing the excise tax on natural gas, while reducing it for biomass or biogas, the competitiveness of natural gas as a source and technologies using natural gas is reduced as compared to biomass and biogas.

Tax allowance for RES

If excise tax on fossil energy sources is increased in order to reduce the competitiveness of fossil fuels as compared to renewable and inexhaustible sources, then the application of lower tax rates (such as excise taxes) or a zero applied rate temporarily or until certain criteria are fulfilled serves to raise the competitiveness of renewable and inexhaustible energy sources as compared to fossil fuels (natural gas).

Loan conditions for use of RES in DH

Loans taken to finance investments may be partially compensated or support for their repayment may be provided, such as by compensating loan interest payments. Such a solution makes loans more accessible and serves to promote capital investments, which are especially important in case of the creation and development of DH and DC systems, as these require major initial investments, and also incur regular maintenance costs.

State guarantees on loans for DH projects

Since the state holds an interest in the broader use of RES, including within DH and DC systems, such financial stimuli could be considered as state guarantees on loans for RES projects, with the scope of the instrument narrowed and applied only to DH and DC projects, if necessary.

Obligation to invest in the use of RES in DH

In order to ensure the broader use of RES in energy production in general and specifically for DH needs, fiscal policy instruments may be combined with other stimuli, such as the obligation for energy producers to invest in renewable energy sources and RES technologies.

Application of a CO_2 tax

The application of a CO_2 tax to all economic activities would result in a situation where the largest producers of CO_2 would incur higher operational costs than those producing less CO_2 or none at all. This would also serve as an incentive in the energy sector to opt for solutions with the smallest possible CO_2 footprint or a carbon neutral lifecycle.

Identification of heat supply source zones

The Energy Law (EL) provides everyone with the right to choose the type of heating best suited for their building. In turn, Article 51 of the EL stipulates that local governments may specify the development of heating supply and issue binding regulations, taking into account the provisions of environmental protection and the protection of cultural monuments, and also the possibilities for the use of local energy sources and co-generation and the evaluation of the safety of heating supply and long-term marginal costs ([75]).

For example, pursuant to Article 14(2) of the Law on Pollution and Article 51(2) of the Energy Law, the Riga City Council has issued binding regulation No 167 on the territorial zoning of air pollution and the selection of a type of heating supply ([76]). This regulation identifies specific zones and relevant requirements regarding the choice of a type of heating supply therein. For example, in Zone 1, where the annual average concentration of pollutants NO_2 and PM10 particles exceeds the legal limit and is more than 40 $\mu g/m^3$, only district heating or autonomous heating is permitted without fuel combustion (electric power, heat pumps, solar panels, including solar batteries and solar collectors).

Zoning can be used for areas identified as having a high thermal energy consumption density where connecting to an energy efficient DH system into which renewable energy sources have been integrated could provide benefits to the DH system operator, as well as the environment.

Application of benchmarking to DH

In several European countries (such as Germany, Finland, Estonia and others) the primary energy factor of each DH system is identified taking into consideration the efficiency of production of thermal energy, the structure of consumption of fuel and other ([77]) factors. In turn, building EE requirements is aimed at attaining specific levels of primary energy consumption. Thus, the owner

([75]) Energy Law. Latvijas Vēstnesis 1998; 273/275.

([76]) Riga City Council binding regulation No 167 on the territorial zoning of air pollution and selection of a type of heating supply. Latvijas Vēstnesis, 37 (5609), 23.02.2016.

([77]) Latõšov E., Kurnitskia J., Thalfeldta M., Volkova A. Primary energy factors for different district heating networks: An Estonian example. Energy Procedia 96; 2016; 674–684.

or developer of a building has a choice of several options by which they can fulfil the EE requirements: by investing in the reduction of losses through dividing structures, opting for individual renewable energy sources, or connecting to a DH system with a specific primary energy factor. Application of the benchmark method is based on the comparison and assessment of the techno-economic indicators of commercial operators. Such a system incentivises DH operators to aim for the lowest possible primary energy factor to therefore incentivise new customers to connect to DH. The EE requirements currently in force in Latvia apply only to the heating consumption of buildings, while the type of energy source used for this consumption is not taken into consideration.

DH strategy and assessment of new heat sources

With regard to the principles of DH market regulation, Article 15 of the Law on Local Authorities provides that one of the autonomous functions of local authorities is to organise the provision of utilities (including heat supply) to residents. Furthermore, Article 51 of the Law on Energy lays down that local authorities organise the supply of heating within their administrative territory and promote energy efficiency and competition on the heating supply and fuel market, whilst also taking account of possibilities for the use of local energy sources and cogeneration , and evaluate the safety of the heating supply and long-term marginal costs, thus determining how the heating supply develops. Permits for the installation of new equipment may be refused only on technical or environmental grounds, rather than on the basis of fundamental principles of economic or sustainable development or in order to protect consumer rights. This situation is justified by the need to provide consumers with the opportunity to choose from among various alternatives, and to increase competitiveness.

As a result, any investor may build a new thermal energy production device, participate in tenders run by the public operator, and expect the price of thermal energy offered to be the lowest to ensure a return on their investment. In this case, a strategically planned fourth generation heat supply system can be crucially affected or even destroyed due to the new location of the heat source. This alters the key parameters of the DH (transmission and distribution distances, input and output temperatures, pressure losses, etc.), which have been carefully planned to provide consumers with the most benefits.

To avoid such a situation, legislative amendments covering the following aspects are necessary:

- environmental protection;
- protection of consumer interests, which are not contradictory to the interests of thermal energy producers;
- fundamental aspects of a free and regulated market;
- the scope of responsibility and competence of local governments in implementing the most suitable DH solution;
- the responsibility of the national government to improve EE DH in line with national and EU law;
- a strategic approach to state support payments;
- harmonised and justified heating costs for consumers after the introduction of DH as an optimal heating source in the municipality.

A sustainable development strategy elaborated for each DH system would provide guidelines as to the most suitable investments in the thermal energy production sector, whilst also serving as a benchmark for the assessment of the efficiency of new heat production projects. A construction permit can be issued if the cost-benefit analysis, which includes an analysis of climate considerations, the existing situation, economic justification and the technical compliance of the solution, shows that the new project is equal or better than what is indicated in the guidelines. Otherwise, the assessment performed and the guidelines can serve as legal grounds to refuse a construction permit due to economic and consumer protection aspects.

Alterations to tariff calculation methods

The objective of these methods is to provide adequate profits, whilst also promoting a balance between the interests of the user and/or service provider. Differentiated tariffs ought to be introduced allowing for discounts, advance and customised payments, as well as other price mechanisms that are usually considered to be attractive to consumers so as to promote the transition to the use of low-potential thermal energy for heating and water heating.

Policy framework for integration of residual heat

The use of residual heat within DH plays a crucial role in a forward-looking energy policy. Recommended policy directions:

- promoting new (thermal) electric power plants and industrial equipment that produce residual heat in locations where the maximum available amount of residual heat will be recovered;
- locating new residential areas or new industrial equipment that uses heat in its production process in places where the available residual heat could help satisfy heating demand;
- connecting thermal power plants, industrial equipment that creates residual heat, waste incineration plants and other devices that transform waste into energy to the local DH network ([78]).

The aforementioned analysis of the potential for cogeneration and DH notes that, in Latvia, the placement of energy producers and industrial heat sources near existing DH networks has to be examined on a case by case basis.

A definition of residual heat is given in the amendments to the Energy Law. The DH operator and various thermal energy producers are successfully cooperating to collect information on the energy produced and consumed at various establishments, including industrial establishments, based on the fundamental principles of the open market, however, this practice has not been established in all DH systems. Therefore, the need to examine the opportunities for the use of residual heat prior to installing new thermal energy production capacity or renovating existing heat sources should be defined at the national or local level.

Support for capital expenses generated by the integration of smart buildings into DH

A crucial element in the efficient and flexible use of DH systems is smart grids and smart buildings, which, being part of a single energy system, provide remote or automated management of heating and cooling, water heating, various devices and lighting based on the time of year and time of day, humidity, outside air temperature and occupancy or operating capacity of the building. Automatic management of building energy demands allow consumers to participate in the so-called flexible demand system by adapting their energy consumption to fluctuations in the price of electric power or heating capacity. Solutions that allow consumers to optimise their energy expenses provide an opportunity to more efficiently integrate renewable and inexhaustible energy sources into the energy system, e.g. by using photovoltaic electric power as an additional energy source for cooling premises during peak demand ([79]). Small-scale DH systems using RES

([78]) Sarah Broberg, Sandra Backlund, Magnus Karlsson, Patrik Thollander, Industrial excess heat deliveries to Swedish district heating networks: Drop it like it's hot, Energy Policy 51(2012)332–339.

([79]) European Commission, An EU Strategy on Heating and Cooling, Brussels, 16.2.2016, COM(2016) 51 final.

technologies ensure that energy is produced relatively close to the consumer; this reduces energy losses and improves the resilience of the system against energy supply risks ([80]).

Elaboration of a strategy for the use of local energy sources

Although Latvia's objective is to increase the share of RES in energy supply as much as possible, energy systems wherein all energy is produced from RES do possess certain limitations that must be taken into account when planning the development of DH systems. Therefore, a strategy for using local RES needs to be elaborated at national or local government level.

The use of biomass in energy systems where 100 % of energy is produced from renewable sources presents challenges. Buildings also account for the majority of energy consumption in 100 % RES-based energy systems. It must be taken into account that the thermal energy production sector can reduce biomass consumption, leaving more biomass to be used by other sectors, whilst still maintaining a 100 % RES-based energy system. An analysis of heating technologies demonstrates that DH systems play an important role in reducing dependency on biomass and creating flexible and risk-resilient, cost-effective heating solutions. In heating systems in which heat is provided by large amounts of variable heat sources, DH helps to efficiently use fuel and accumulate heat in a cost-effective manner ([81]). The use alongside biomass of such RES as solar thermal energy (solar collectors), high-capacity heat pumps, geothermal energy, industrial residual heat and waste incineration helps reduce the consumption of biomass. District heating is also a prerequisite for the efficient use of cogeneration technologies. At the same time, in order for DH to be an economically viable solution in places with insufficient density of building energy consumption, geothermal heat pumps and biomass could be used for local or individual heating, as these have a broader application beyond heat production only for DH purposes ([82]).

At a political level, more and more countries are defining increasingly ambitious targets for the use of renewable energy sources in energy production. Denmark, which has already been mentioned previously in this document as an example of the creation of an efficient DH system, has, through the use of RES, achieved a broad political agreement that 100 % of energy must be produced from RES by 2050 and that heating and electric power must be produced solely from RES by 2035.

As in many other countries, in Denmark the majority of primary fuel source demand is created by the energy consumption of buildings. As the use of RES in energy supply expands, there is a risk that the use of biomass in heating could start to compete with its usage for other purposes, thus creating pressure on the land use and food production sectors. Biomass, as well as wind, wave, tidal and solar energy all have certain advantages and disadvantages. The uniqueness of biomass as a renewable energy source is that it can directly replace fossil fuels in combustion, being delivered to small-scale decentralised generation cogeneration plants, as well as centralised, energy supplying power plants. The fact that use of other RES carries the risk of variable availability only serves to enhance the uniqueness of biomass as an energy source. For example, solar and wind energy have variable availability and efficiency, even though the technologies linked to these energy sources are considered to be the most cost-efficient with guaranteed

([80]) Aleksandrs Zajacs, Anatolijs Borodiņecs, Assessment of development scenarios of district heating systems, Sustainable Cities and Society 48 (2019) 101540.

([81]) Henrik Lund, Poul Alberg Østergaard, David Connolly, Brian Vad Mathiesen, Smart energy and smart energy systems, Energy 137 (2017) 556–565.

([82]) Brian Vad Mathiesen, Henrik Lund, David Connolly, Limiting biomass consumption for heating in 100 % renewable energy systems, Energy 48 (2012) 160–168.

support from dedicated policy instruments gradually being reduced or discontinued altogether. Furthermore, depending on its aggregate state, biomass can be used as an energy source in various sectors, from the production of electric and thermal power to fuel for vehicles. Paradoxically, the main risk with regard to biomass is actually the broad application of this energy source. Since there is such a variety of applications for biomass, its availability could begin to decline, thus also affecting the cost of using this resource and the ROI schedules of selected energy technologies.

The development of technologies and DH infrastructure management flexibility presents increasingly more opportunities to implement DH systems where the heating system is supplied with thermal energy not only by a customary single source and technology (a CHP plant or boiler house), but from other sources as well. Increasingly more attention is being paid to the use of solar collectors within the framework of improving existing heating systems and planning new DH systems in order to improve efficiency ([83]). A solar collector park opened in September 2019 by heating company Salaspils Siltums can deliver up to 20 % of the total heating capacity needed for the heating system serviced by the company. Denmark is the leading country in Europe in terms of integrating solar energy into DH systems. Over the course of eight years (from 2008 to 2016) the solar collector surface area used by DH systems in Denmark increased from 64 000 square metres to 1.3 million square metres, with another 270 000 square metres planned to be installed. Denmark has several reasons for expanding the use of solar collectors within their DH systems. First of all, there is the low cost of thermal energy produced by solar collectors. The high costs of thermal energy produced by natural gas and electricity-operated boiler houses have created a situation in which solar heating is extremely competitive in the opinion of consumers. Second, DH companies are mostly owned by the final consumers of thermal energy, who favour the increased use of solar energy in heating, therefore, financial resources are being invested in DH thermal plants using solar energy. Furthermore, land for building solar collector thermal plants is available at good prices. Third, well-developed DH networks with many final consumers help reduce the cost of investment in solar energy DH. 64 % of Danish households are connected to district heating. Fourth, solar collector technologies are installed by a trusted supplier (*Arcon-Sunmark AS*), whose equipment is used by more than 70 % of all solar thermal power plants. High efficiency and a guaranteed long lifespan of large-scale solar collector systems have also won the confidence of the participants of the solar thermal energy market with regard to the future of solar power within district heating. Solar fields in Denmark have an efficiency of up to 40 %.

It can be concluded that the development of DH systems using solar thermal energy in Denmark's heating market is driven by such factors as a well-developed heating network, relatively cheap land, the cost-effectiveness of ground-mounted collectors, the high efficiency of the collectors, the long lifespan of the collectors, high energy taxes on natural gas, competitive heat production costs, and interaction with a liberalised electricity market ([84]).

The advantages of the use of solar thermal power in DH systems increase along with efforts to reduce and completely exclude use of fossil fuels, replacing them with RES. DH companies strive to provide their customers with the lowest possible price and costs. To this end, a comprehensive approach is needed, especially in light of an increasing variety of options for the production of thermal energy. The size of solar fields, storage volumes for heated water and dynamic shifts in

([83]) Elisa Guelpa, Aldo Bischi, Vittorio Verda, Michael Chertkov, Henrik Lund, Towards future infrastructures for sustainable multi-energy systems: A review, Energy 184 (2019) 2–21.
([84]) Henrik Lund, Anders N. Andersen, Poul Alberg Østergaard, Brian Vad Mathiesen, David Connolly, From electricity smart grids to smart energy systems e A market operation based approach and understanding, Energy 42 (2012) 96-102.

annual heating demand are interrelated factors. In order to achieve high cost-efficiency of solar collector DH systems, all three of these factors must be optimised. If the DH system lacks sufficiently large storage volumes for heated water, then the size of solar fields is limited by low demand for thermal energy during the summer.

In turn, cooling at night can be used as a means to reduce overproduction of heat by solar collectors during the hottest days of summer. If DH plants have cost-efficient means of seasonally storing thermal energy, the share of solar energy used in the DH system can be significantly increased ([85]). Another technology-based solution for the prevention of heat overproduction is to use what are known as solar trackers, which can be unfocused during the hottest days of summer when less thermal energy is needed. This solution also precludes the need to install large storage facilities.

Similar to Denmark, a significant portion of the final consumers of heating in Latvia are also connected to DH systems. In this indicator Latvia ranks alongside Denmark, Sweden, Finland, Estonia, Lithuania and Poland, countries that all have a high share of DH in the heat supply. Thus, due to similar accessibility to consumers, Latvia and other countries with a large share of DH in heat supply are advised to consider several recommendations derived from the Danish experience in the use of solar thermal energy to implement DH with low carbon emissions.

Firstly, in order to strengthen the confidence of the final consumers of thermal energy in the use of solar thermal energy in district heating, tested equipment with a long warranty delivered by a trusted supplier must be installed in projects using solar collectors. Secondly, the design and management of any DH system using solar thermal energy must be performed professionally and carefully. Thirdly, the current and estimated future costs of solar thermal energy and fossil energy systems (e.g. natural gas boiler houses) need to be examined and compared when calculating potential benefits. Fourthly, information needs to be provided to the final consumers of thermal energy, policymakers and advisors throughout the lifespan of solar thermal energy projects.

5.2. Assessment of implemented policy instruments through multi-criteria analysis

In order to rank the analysed policy instruments and support measures, a multi-criteria analysis was used (the method and formulas are provided in Subchapter 2.2.1).

In this case, 17 alternatives or policy instruments were selected for assessment based on four criteria: technological, economic, social, and climate and environmental aspects.

TABLE 5.2. THE DECISION-MAKING MATRIX AND ASSESSMENT OF POLICY INSTRUMENTS

No	**Policy instrument**	**Aspects**			
		Technological	Economic	Social	Climate and environment
1.	Mandatory procurement of electricity	4	3	3	4
2.	Premium on RES electricity	4	3	2	3
3.	Support for capital investments.	5	5	4	4
4.	Green certificates	4	4	3	3
5.	Excise tax	4	5	4	5
6.	Tax allowance for RES.	4	4	4	4
7.	Facilitated loans for RES	4	4	3	4
8.	State guaranteed loans	4	4	2	4
9.	Obligation to invest in RES	3	3	3	4
10.	CO_2 tax	5	4	5	5

([85]) Jelena Ziemele, Armands Gravelsins, Andra Blumberga, Dagnija Blumberga, The effect of energy efficiency improvements on the development of 4th generation district heating, Energy Procedia 95 (2016) 522–527.

11.	Heating source zoning	4	5	3	4
12.	Benchmarking heating tariffs	4	5	3	4
13.	Assessment of DH strategies	4	4	3	4
14.	Improving tariff calculation methods	4	4	3	4
15.	Integration of residual heat	5	5	5	5
16.	Support for investments for the integration of smart buildings into DH	4	4	5	3
17.	Elaboration of a strategy for the use of local energy sources	4	4	4	4

The result is a value demonstrating how closely the alternative comes to being an ideally positive solution and how far it is from being an ideally negative solution.
The results of the analysis show that one policy instrument fits the positive ideal solution. The reason for this is that this instrument obtained the highest score in all four aspects. This instruments is the integration of residual heat. The next best policy instrument with a major difference in rating is CO_2 tax (0.79). This is followed by excise tax (0.74) and support for capital investments in RES (0.71). These policy instruments are followed (by a difference of 0.10 points) by support for investments in the integration of smart buildings into DH (0.60), tax discounts for RES (0.58) and the development of a strategy for the use of local energy sources (0.58). Heating source zoning (0.53) and benchmarking heating tariffs (0.53) are closer to the ideally positive solution than the ideally negative one. The results of the analysis are presented in Figure 5.3.

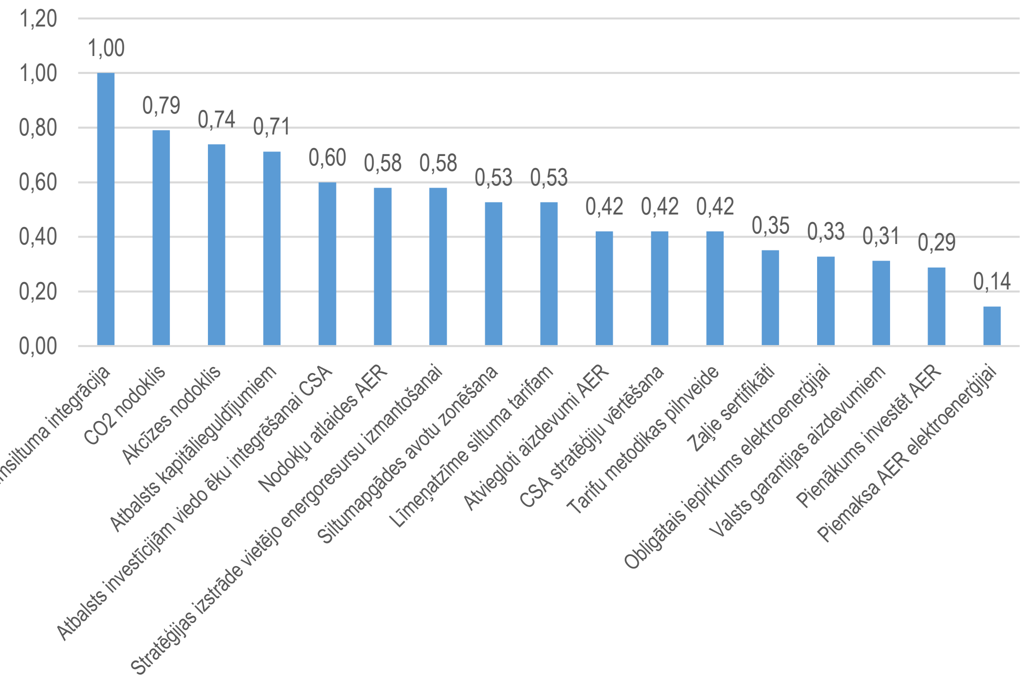


Figure 5.3. Results of TOPSIS analysis

Atlikumsiltuma integrācija - Integration of residual heat; CO2 nodoklis - CO_2 tax; Akcīzes nodoklis - Excise tax; Atbalsts kapitālieguldījumiem - Support for capital investments; Atbalsts investīcijām viedo ēku integrēšanai CSA - Support for investments for integrating smart buildings into DH; Nodokļu atlaides AER - Tax discounts for RES; Stratēģijas izstrāde vietējo energoresursu izmantošanai - Elaboration of a strategy for using local energy sources; Siltumapgādes avotu zonēšana - Heating source zoning; Līmeņatzīme siltuma tarifam - Benchmarking heating tariffs; Atviegloti aizdevumi AER - Facilitated loans for RES; CSA stratēģiju vērtēšana - Assessment of DH strategies; Tarifu metodikas pilnveide - Improving tariff calculation methods; Zaļie sertifikāti - Green certificates; Obligātais iepirkums elektroenerģijai - Mandatory procurement of electric power; Valsts garantijas aizdevumiem -

State guaranteed loans; Pienākums investēt AER - Obligation to invest in RES; Piemaksa AER elektroenerģijai - Premium on RES electricity

It must be noted that, for the purposes of this analysis, each policy instrument was rated separately. The best results could be achieved by combining several policy instruments with the highest scores. This method allowed the policy support measures to be ranked and integrated into the system dynamics model, and scenarios to be developed.

5.3. Analysis of selected policy scenarios. System dynamics model

Four different scenarios were analysed using the system dynamics model:

- a baseline scenario;
- a fossil fuel taxation scenario;
- a RES support scenario;
- a combined policies scenario.

Baseline scenario. This scenario looked at the development of the heat supply system if no policy instruments are applied. The excise tax remains at the 2017 level, as the current legislation does not provide for a future increase of the tax. The natural resources tax on generated CO_2 emissions increases according to the schedule set forth in legislative acts until 2022, with no further increase after that time. Funding for improving EE is allocated and used by 2023. The amount of support is in line with the amount intended for the promotion of EE that has been approved and allocated to Latvia up to 2020. After the current funding is used up, new funding for promoting EE is no longer allocated. Financial support is not allocated for the integration of renewable energy sources in heat supply, the replacement of DH networks, or for transitioning to low-temperature heating.

Fossil fuel taxation scenario. The excise tax and the natural resources tax on generated CO_2 emissions are increased. EE measures are implemented on the energy consumer side using the funding approved up to 2023. After 2023, additional funding is allocated based on the support amounts indicated in Latvia's National Energy and Climate Plan. This funding is allocated up to 2030. After 2030, additional funding for EE measures is not planned. Financial support is not allocated for the integration of renewable energy sources into heat supply, the replacement of DH networks, or for transition to low-temperature heating.

Renewable energy sources support scenario. A tax increase on fossil fuels is not envisioned. The excise tax remains at the 2017 level, as the current legislation does not envision and approve a future increase of the tax. The natural resources tax on generated CO_2 emissions increases according to the schedule set forth in legislative acts until 2022, with no further increase after that time. EE measures are implemented on the energy consumer side using the funding approved up to 2023. After 2023, additional funding is allocated based on the support amounts indicated in Latvia's National Energy and Climate Plan. This funding is allocated up to 2030. After 2030, additional funding for EE measures is not planned. Financial support is allocated for the integration of renewable energy sources into district and individual heating, and funding is also available for the replacement of DH networks and the promotion of the transition to low-temperature district heating. The amount of funding is based on the support amounts indicated in Latvia's National Energy and Climate Plan and it is allocated up to 2030. Additional funding is not allocated after 2030.

Combined policies scenario. This scenario combines the fossil fuel taxation and RES support scenarios. The excise tax and the natural resources tax on generated CO_2 emissions are increased. EE measures are implemented on the energy consumer side using the funding approved up to 2023. After 2023, additional funding is allocated based on the support amounts indicated in Latvia's National Energy and Climate Plan. This funding is allocated up to 2030. After

2030, additional funding for EE measures is not planned. Financial support is allocated for the integration of renewable energy sources into district and individual heating, and funding is also available for the replacement of DH networks and the promotion of the transition to low-temperature district heating. The amount of funding is based on the support amounts indicated in Latvia's National Energy and Climate Plan and it is allocated up to 2030. Additional funding is not allocated after 2030.

TABLE 5.3. COMPARISON OF SCENARIOS

	Excise tax increase, % per year	**CO_2 tax increase**	**Support level for EE measures, %**	**Support level for integration of RES in DH, %**	**Support level for integration of RES in individual heat**	**Support level for network replacement, %**
Baseline scenario	0	0 ([86])	0	0	0	0
Fossil fuel taxation scenario	8	up to the ETS quota price	30	0	0	0
Subsidy scenario	0	0	30	40	20	40
All policies scenario	8	up to the ETS quota price	30	40	20	40

Six different policy instruments were used in the model:

- Increased excise tax on natural gas;
- Increased natural resources tax on generated CO_2 emissions;
- Support for implementing EE measures on the consumer side;
- Support for the integration of renewable energy sources into district heating;
- Support for the integration of renewable energy sources into local and individual heating;
- Support for the replacement of DH networks and the promotion of the transition to low-temperature heating.

Excise tax. As of 2017, the excise tax on natural gas as fuel is EUR 1.65/MWh, while the tax on natural gas used as fuel for industrial manufacturing and other manufacturing-related processes is EUR 0.55/MWh. The current legislation does not envision a future increase of the excise tax on natural gas. It remains unchanged in the baseline scenario, whilst the fossil fuel taxation and the combined policies scenarios assume that the tax could increase by 8 % annually. That would translate to an increase from EUR 1.65/MWh in 2017 to EUR 22.5/MWh in 2050.

Increased natural resources tax (NRT) on generated CO_2 emissions. Until 2020, the NRT rate for generated CO_2 emissions was EUR 4.5/t_{CO_2}. Rates for 2020, 2021 and 2022 have also been approved in legislative acts and are EUR 9/t_{CO_2}, EUR 12/t_{CO_2} and EUR 15/t_{CO_2}, respectively. ([87]) The NRT is only applicable to equipment not included in the ETS system. ETS equipment is subject to ETS conditions, and the emission costs are determined by the emission quota price. The NRT does not apply to households. In the baseline scenario, the NRT rate increases according to the schedule indicated in legislation until 2022, afterwards remaining at the 2022 level. In the fossil fuel taxation and the combined policies scenarios, the NRT is gradually increased after 2022 to reach the ETS quota price level. The ETS quota price is assumed based on European Commission recommendations, which predict an increase of the quota price to

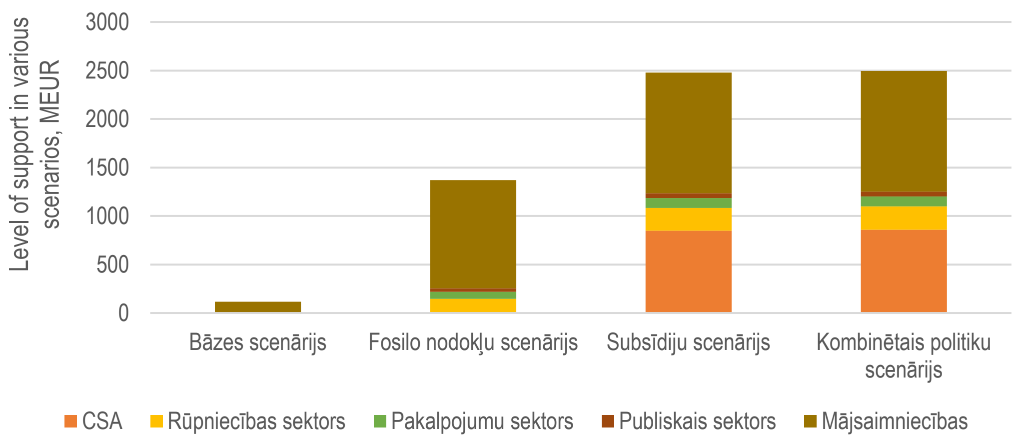
([86]) After 2022
([87]) Natural Resources Tax Law. Available online: https://www.vestnesis.lv/op/2019/240.5

approximately EUR 50 per quota in 2040. Based on this, the quota price in 2050 is calculated to be around EUR 70 per quota. One quota is equal to one tonne of CO_2 emissions.

Support for implementing energy efficiency measures on the consumer side. The model takes into account funding available for the renovation of apartment buildings in the period from 2016 to 2023. This funding is allocated in the baseline scenario, as well as in all of the other scenarios, and is used in full, thus coinciding with the actual performance of the system. ([88]) According to Annex 4 of the National Energy and Climate Plan, in the period up to 2030 funding is planned to be allocated for the improvement of EE in the household, manufacturing, service and public sectors. The total amounts of funding and the support level have been presented in Table 5.4. Support for EE is allocated in all scenarios, except for the baseline scenario. In analysing the development of renewable energy sources within heat supply, EE measures are taken into account in order to best forecast future demand for heating. Since Latvia and other EU member states have set certain EE targets, the development of heat supply and the use of renewable energy sources cannot be modelled on the basis of current consumption, but rather have to be modelled based on future consumption. The main focus of the project is the development of heating and cooling systems, therefore, several EE scenarios have not been modelled for the consumption side. Only one such scenario is examined, which is based on the policies and estimated funding described in Annex 4 of the National Energy and Climate Plan.

TABLE 5.4. AMOUNT OF SUPPORT AND SUPPORT LEVEL UP TO 2030

	Sector	Available funding, MEUR	Level of support, %
Energy efficiency of buildings	Commercial sector	300	30
	Public sector	100	30
	Multi-apartment buildings	1 200	30
	Private buildings	100	30
Renewable energy sources	Households and the public sector	267	20
	Manufacturing	225	20
	District heating	550	40
Transition to low-temperature DH		60	40



([88]) On increasing the energy efficiency of multi-apartment buildings. Available online: https://www.em.gov.lv/lv/jaunumi/26713-nosledzas-pieteikumu-pienemsana-daudzdzivoklu-maju-atjaunosanas-projektiem

Figure 5.4. Level of support in various scenarios by sector

Bāzes scenārijs - Baseline scenario; Fosilo nodokļu scenārijs - Fossil fuel taxation scenario; Subsīdiju scenārijs - Subsidy scenario; Kombinētais politiku scenārijs - Combined policies scenario

CSA – DH; Rūpniecības sektors - Manufacturing sector; Pakalpojumu sektors - Services sector; Publiskais sektors - Public sector; Mājsaimniecības - Households

Support for the integration of renewable energy sources into district heating. According to Annex 4 to the National Energy and Climate Plan, an approximate amount of financing is earmarked for increasing the EE of DH and integrating RES. The total financing allocated for DH development is EUR 550 million, and it is assumed that approximately 10 % could be used for the integration of renewable energy sources, with the rest being used for promoting the implementation of EE measures. Funding is available for the integration of biomass, solar collectors, heat pumps and residual heat into DH systems, and the support level is 40 %. Funding will be granted up until 2030. Support for the integration of renewable energy sources into DH will no longer be offered after 2030. Support is allocated within the RES support and combined policies scenarios, but not in the baseline and fossil fuel taxation scenarios.
Support for the integration of renewable energy sources into local and individual heating. According to Annex 4 to the National Energy and Climate Plan, an approximate amount of financing is earmarked for the integration of RES into local and individual heating. The total amount of planned financing for RES integration into households and the public sector is EUR 267 million, with another EUR 225 million earmarked for the promotion of improved EE and the integration of RES into the manufacturing sector. Funding is available for the integration of biomass, solar collectors and heat pumps into local and individual heating systems, and the support level is 20 %. Funding will be granted up until 2030. Support for integrating renewable energy sources into local and individual heating systems will no longer be offered after 2030. Support is allocated within the RES support and combined policies scenarios, but not in the baseline and fossil fuel taxation scenarios.
Aid for the replacement of DH networks and the promotion of the transition to low-temperature heating. In addition to EE and RES support policies, a policy instrument aimed at renovating heating networks and promoting the transition to low-temperature district heating is also considered. The amount of funding planned up to 2030 totals EUR 60 million, and the support level is 40 %. After 2030, support for the renovation of heating networks and the promotion of the transition to low-temperature district heating is no longer allocated. Support is allocated within the RES support and combined policies scenarios, but not in the baseline and fossil fuel taxation scenarios.

5.4. Overview of policy measures and economic potential

The previous chapters (5.1-5.3) have provided an overview of potential new policy measures, ranking them to identify the correlated potential of heating systems and policy instruments.
Priority policy instruments were modelled using a system dynamics approach with the obtained results used to assess district and individual heat production by energy source within the baseline scenario (described in Chapter 5.2). Currently, as per the baseline scenario, approximately 8 000 GWh/year of thermal energy is produced, yet medium- and long-term trends show that the amount of thermal energy produced within district heating will decrease to 7 000 GWh/year. Even though the amount of thermal energy produced within district heating will decrease, an increase in the medium- and long-term is expected in individual heat supply. It is estimated that currently approximately 14 000 GWh/year of thermal energy is being produced in individual heating, and this may reach up to 16 000 GWh/year by 2050.

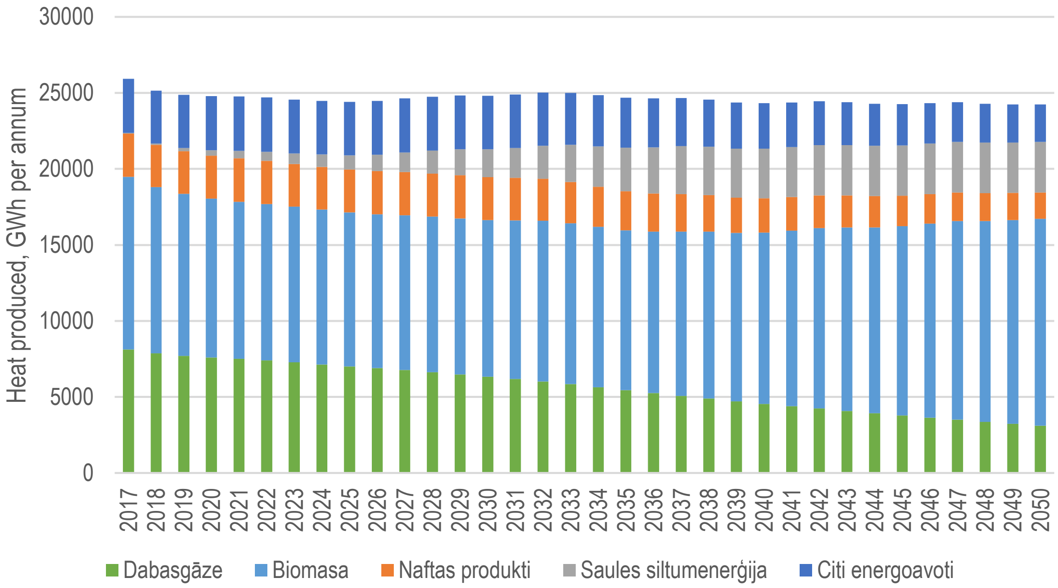


Figure 5.5. Thermal energy produced by energy source within overall heat supply in the baseline scenario

Dabasgāze - Natural gas; Biomasa - Biomass; Naftas produkti - Petroleum products; Saules siltumenerģija - Solar thermal energy; Citi energoavoti - Other energy sources

An analysis of the use of energy sources within heating in general (Figure 5.5) shows that the use of fossil fuels will decrease with biomass becoming increasingly important. In turn, over the next 5-10 years, the use of solar energy in heat production will become an increasingly important issue.

The thermal energy produced in individual heating, as broken down by energy source used, differs from the DH system. It can be observed that the reduction of fossil fuels in individual heating is not as significant as it is in DH. Even though it is expected that with bioeconomy issues coming to the forefront, the amount of quality wood available for the production of thermal energy will decrease, the share of biomass used in district and individual heating in the baseline scenario is large, which illustrates the current situation and political support.

If new policy instruments are adapted to the system and support is provided for EE measures and the integration of RES, then the production of thermal energy for district and individual heating differs significantly from the baseline scenario. The combined policies scenario combines the fossil fuel taxation and RES support scenarios. The excise tax and the NRT on generated CO_2 emissions are increased. EE measures are implemented on the energy consumer side (a description and analysis of these measures is given in Chapter 5.2). The results given in Figure 5.6 demonstrate that in the combined policies scenario, the amount of thermal energy produced for district heating will decrease from 8 500 GWh/year to 6 000 GWh/year. Solar thermal energy and biomass will be the main energy sources used in the production of thermal energy for DH. The combined policies scenario assumes that heat pumps and biogas will also be used to produce thermal energy. The use of residual heat and its integration into the district heating system is also mentioned in the combined policies scenario, however, the amounts are insignificant, as the potential of this energy source is yet to be explored. The use of fossil fuels fall significantly in this scenario: from approximately 5 000 GWh/year to 230 GWh/year. In the combined policies scenario, individual heating shows a reduction in fossil fuel usage, while the use of biomass and solar thermal energy continues to grow. The amount of thermal energy produced is estimated at just above 14 000 GWh/year.

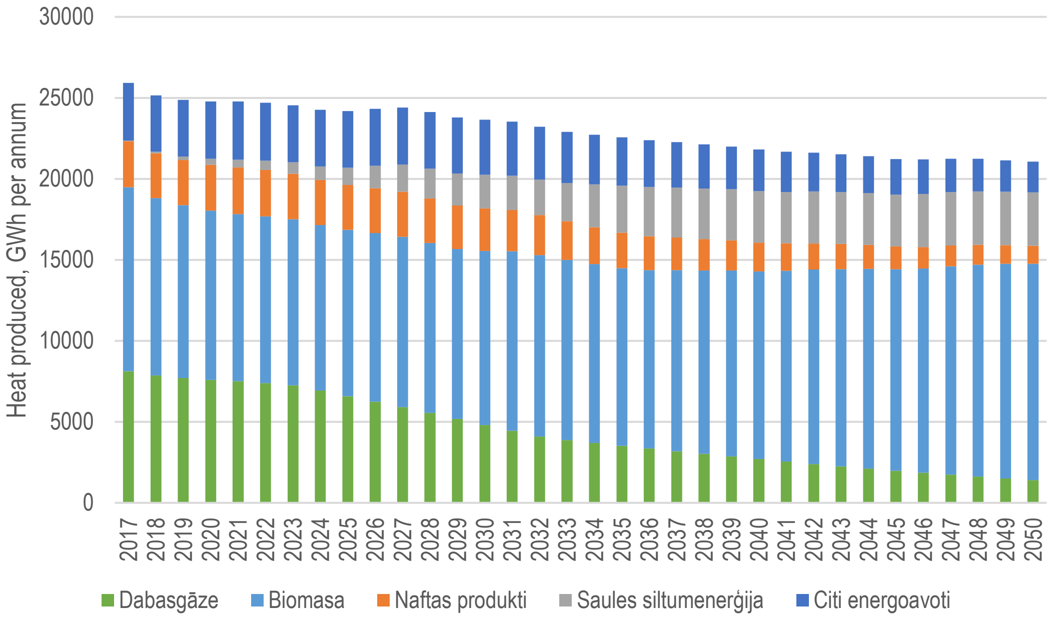


Figure 5.6. Thermal energy produced by energy source within overall heat supply in the combined policies scenario

Dabasgāze - Natural gas; Biomasa - Biomass; Naftas produkti - Petroleum products; Saules siltumenerģija - Solar thermal energy; Citi energoavoti - Other energy sources

By combining changes in tax policy and financial support in the form of subsidies, a significant reduction of fossil energy sources within the overall heat supply can be achieved. However, this is mostly due to the broader use of biomass. In order to efficiently use the wood resources available in Latvia, additional regulation or a long-term strategy for the area is needed.

5.4.1. Primary energy savings

Improving EE is a crucial prerequisite for sustainable economic development. One indicator, by which to strive towards better EE, is fulfilling the EE target (primary energy savings). The requirements of Directive 2012/27/EU are generally aimed at creating a national EE system that allows the state to save energy in all areas of the energy sector: in production, transmission and final consumption. Specific tools for achieving these savings have not been identified. By developing a system dynamic model and various scenarios, three development directions have been identified in addition to the existing baseline scenario, and their impact on primary energy source consumption (in terms of GWh/year) has also been determined.

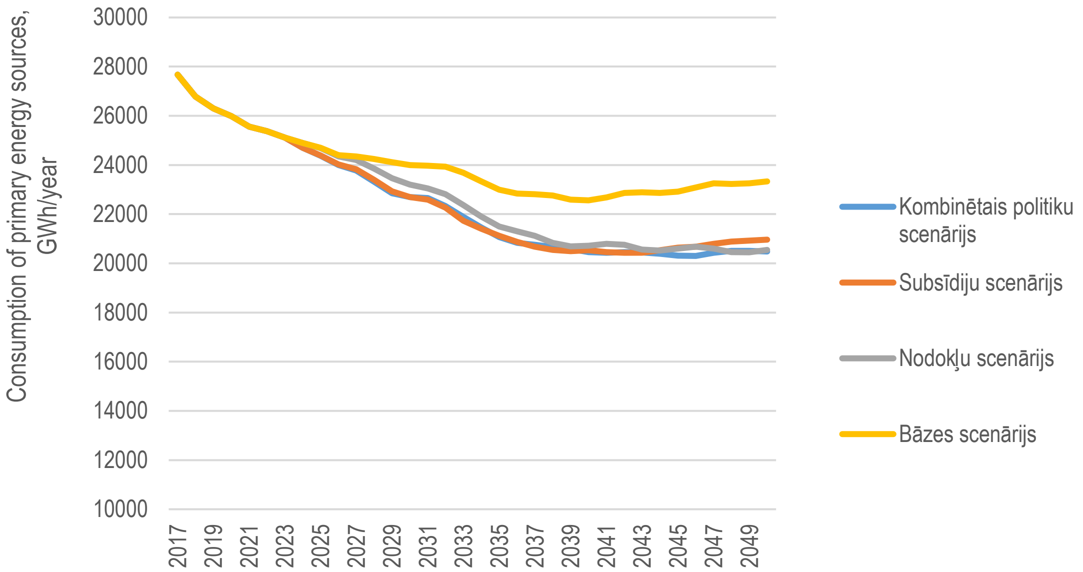


Figure 5.7. Consumption of primary energy sources in analysed policy scenarios

Kombinētais politiku scenārijs - Combined policies scenario; Subsīdiju scenārijs - Subsidy scenario; Nodokļu scenārijs - Taxation scenario; Bāzes scenārijs - Baseline scenario

Up until 2027, the reduction of primary energy source consumption appears to be similar in all scenarios. After 2027, the reduction of primary energy source consumption remains unchanged for the next five years in the baseline scenario, while in the combined policies scenario, the subsidy scenario and taxation scenario consumption could decrease further. The amount of savings until 2050 is similar in the combined policies, subsidy and taxation scenarios with no clear leader emerging.

5.4.2. Impact on share of renewable energy sources within the national energy source structure and the heating and cooling sector

A precondition for increasing the share of RES is the development of a long-term policy and targets to promote the broader use of RES. The 2030 target share of RES in heating and cooling production in Latvia is set at 57.59 %, which is higher than the total share within the final consumption of energy (50 %). The share of RES achieved in district and individual heating, and in heat supply in general nationally differs. Currently and in the baseline scenario, the share of RES in district and individual heating ranges from 47 to 55 %. Even though the results of the modelling show that the use of RES will increase in the baseline scenario, nearing 60 % by 2030, in the combined policies scenario the share of RES could reach as high as 80 % in DH and 62 % in individual heating.

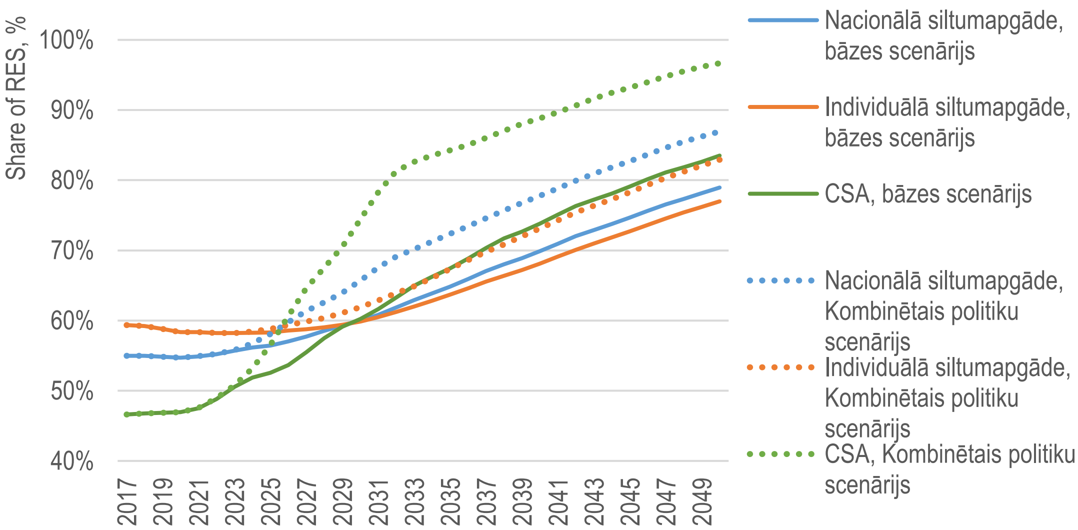


Figure 5.8. The share of RES achieved in district and individual heating, and in heat supply in general nationally

Nacionālā siltumapgāde, bāzes scenārijs - Heat supply nationally, baseline scenario; Individuālā siltumapgāde, bāzes scenārijs - Individual heating, baseline scenario; CSA, bāzes scenārijs - DH, baseline scenario; Nacionālā siltumapgāde, Kombinētais politiku scenārijs - Heat supply nationally, Combined policies scenario; Individuālā siltumapgāde, Kombinētais politiku scenārijs - Individual heating, Combined policies scenario; CSA, Kombinētais politiku scenārijs - DH, Combined policies scenario

In turn, the share of RES in heat supply nationally would be 66 % in 2030, which is 8 % more than planned in the decarbonisation dimension of the RES NECP. From the perspective of the selected scenarios, the highest share of RES could be achieved by applying the combined policies scenario.

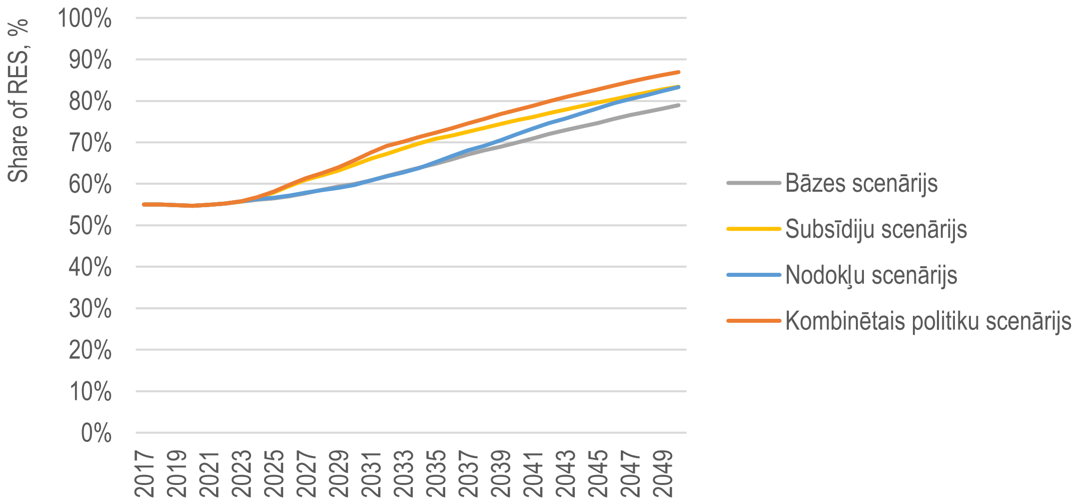


Figure 5.9. Share of RES in heat supply in general as achieved in various policy scenarios

Bāzes scenārijs - Baseline scenario; Subsīdiju scenārijs - Subsidy scenario; Nodokļu scenārijs - Taxation scenario; Kombinētais politiku scenārijs - Combined policies scenario

In analysing the achieved share of RES in various scenarios, it can be seen that the share that could be achieved in the baseline scenario increases mostly due to the gradual increase of the use of biomass and solar thermal energy. However, by applying various policy instruments, an even higher share of RES could be achieved, thus furthering progress towards climate neutrality in heating.

5.4.3. Impact on share of high-efficiency cogeneration

Over the past 10 years, the share of thermal energy produced at cogeneration plants has increased by 20 %, reaching 71 % in 2018. In analysing the thermal energy produced for DH at cogeneration plants using biomass and natural gas in various policy scenarios, it can be seen that the amount of thermal energy produced at biomass plants increases. In turn, the amount of thermal energy produced (in terms of GWh/year) at natural gas plants decreases.

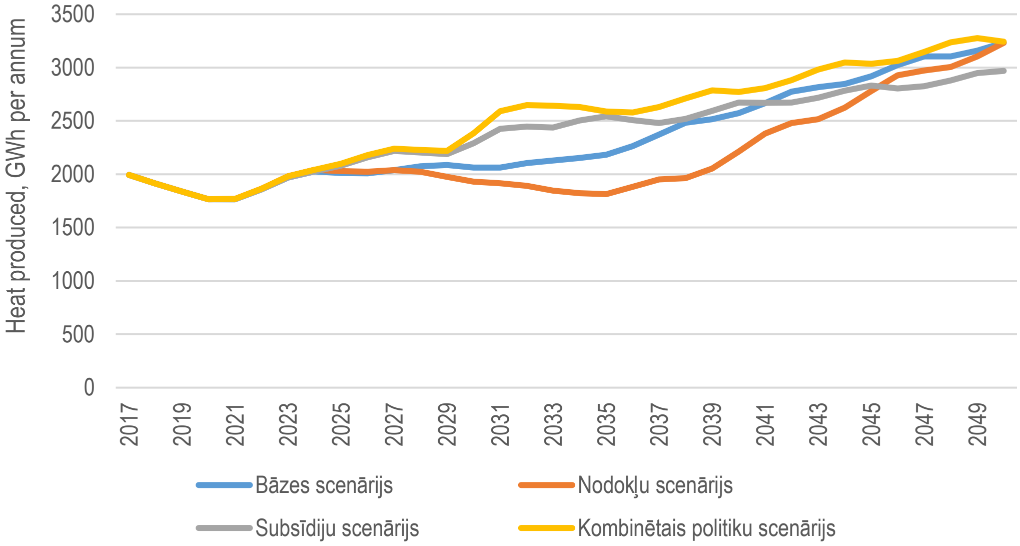


Figure 5.10. Thermal energy produced for DH at cogeneration plants using biomass in various policy scenarios

Bāzes scenārijs - Baseline scenario; Subsīdiju scenārijs - Subsidy scenario; Nodokļu scenārijs - Taxation scenario; Kombinētais politiku scenārijs - Combined policies scenario

The most favourable scenario is the combined policies scenario. It is estimated that in the case of the combined policies scenario, the amount of thermal energy produced will increase up to 3 243 GWh/year.

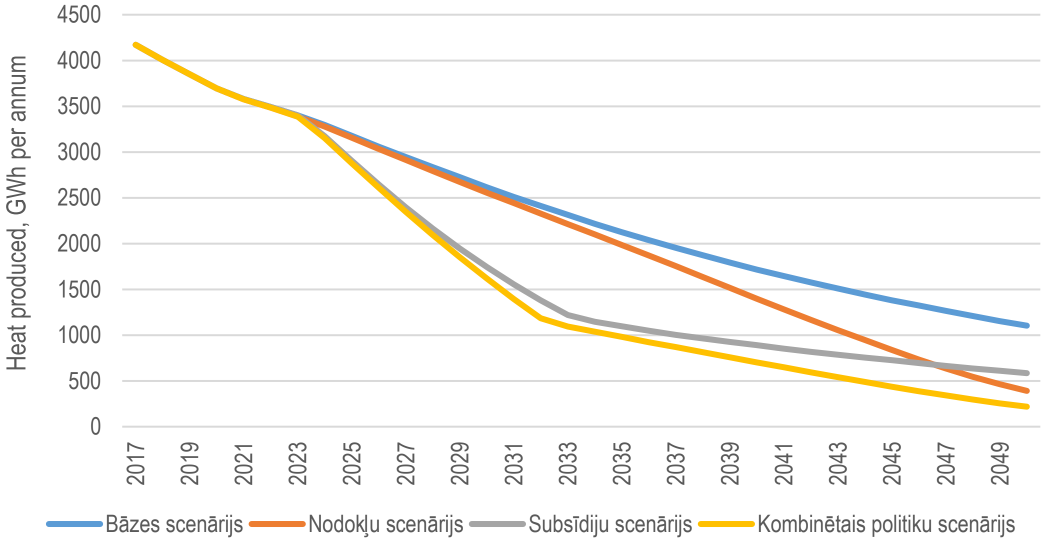


Figure 5.11. Thermal energy produced for DH at cogeneration plants using natural gas in various policy scenarios

Bāzes scenārijs - Baseline scenario; Nodokļu scenārijs - Taxation scenario; Subsīdiju scenārijs - Subsidy scenario; Kombinētais politiku scenārijs - Combined policies scenario

Various development scenarios demonstrate that the amount of thermal energy produced for DH at natural gas cogeneration plants will decrease in the coming years. In the case of the combined policies scenario, the amount of thermal energy produced will decrease from 4 000 GWh/year to 218 GWh/year in 2050. A greater decrease could be achieved in the subsidy and combined policies scenarios, where excise tax and the NRT on generated CO_2 emissions are increased.

Electric power produced at natural gas cogeneration plants is expected to be replaced with power produced at wind farms, which will increase the share of RES in the total energy supply.

5.4.5. Reduction of greenhouse gas emissions

An important indicator characterising the system and how it strives towards EE is the amount of avoided and reduced GHG emissions. The reduction in CO_2 emissions can be assessed by taking into consideration EE measures within system elements, i.e. at the source, during transmission and at consumption, and creating development scenarios. In 2017, emissions were 2 400 thousand tonnes

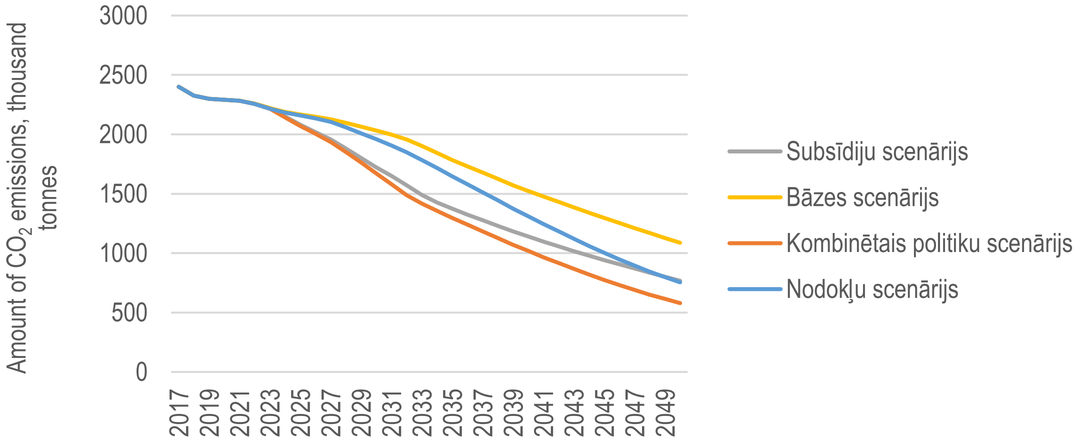


Figure 5.12. Amount of CO_2 emissions generated in heating in general in various analysed scenarios

Subsīdiju scenārijs - Subsidy scenario; Bāzes scenārijs - Baseline scenario; Kombinētais politiku scenārijs - Combined policies scenario; Nodokļu scenārijs - Taxation scenario;

An emissions reduction of up to 579 thousand tonnes could be achieved through the application of various development policies, such as the combined policies scenario. Implementation of the subsidy and taxation scenario would also have a positive effect on the reduction of CO_2.

5.4.6. Public support measures

The link with national financial planning and cost savings in the public sector and market participant budgets pertains to total costs. As total costs decrease, heat production costs decrease for all stakeholders both in district and individual heating.

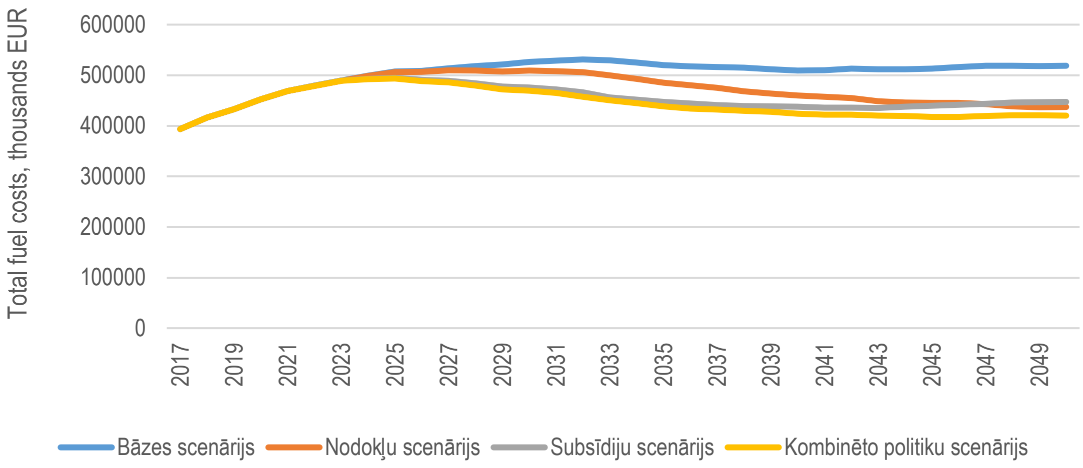


Figure 5.13. Total fuel costs in heating in general in the analysed scenarios

Bāzes scenārijs - Baseline scenario; Nodokļu scenārijs - Taxation scenario; Subsīdiju scenārijs - Subsidy scenario; Kombinētais politiku scenārijs - Combined policies scenario

The amount of support and support intensity in various sectors and development scenarios is demonstrated in Subchapter 5.3 (Table 5.4 and Figure 5.4).

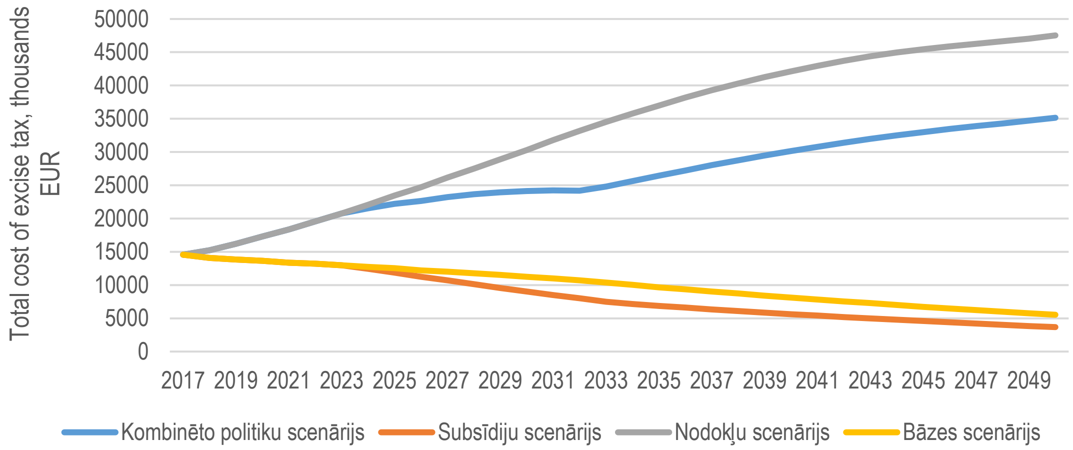


Figure 5.14. Cost of excise tax in heating in general in the analysed scenarios

Kombinētais politiku scenārijs - Combined policies scenario; Subsīdiju scenārijs - Subsidy scenario; Nodokļu scenārijs - Taxation scenario; Bāzes scenārijs - Baseline scenario

By raising the excise tax in the taxation and combined policies scenarios, the producer of thermal energy in district and individual heating will incur costs, while the total state budget will receive revenue.

6. RECOMMENDATIONS

In the light of the study *Determination of Heating and Cooling Efficiency Potential In Latvia under Directive 2012/27/EU on Energy Efficiency*, and following an assessment of the current situation with regard to heating and cooling systems, demand, targets, strategies and policy measures, an analysis of the cost-benefit potential of various development alternatives and an assessment of potential new strategies and policy measures, the following recommendations are proposed:

1. The review of heating and cooling systems has made available general information about the thermal energy produced at boiler houses and cogeneration plants and the amount and type of fuel consumed, but there is no detailed information available on district, individual and local heating. To make a comprehensive assessment of the existing system, annual statistical reports ought to include additional information and data on thermal energy consumption and fuels consumed in the production of thermal energy. At the moment, comprehensive statistics or reports on heating, which would allow for the current situation to be assessed, are unavailable.
2. At the moment, there is no data available in Latvia on the cooling energy consumed and the technologies used to produce it. To determine the potential for district cooling, further research is needed and territories with high cooling energy consumption need to be identified by performing a case study and developing a methodology.
3. A basic methodology for identifying residual heat has been developed, but in order to determine the economic potential of residual heat in Latvia, further research is needed in the form of a case study and the identification of specific costs and savings.
4. The economic potential of heating efficiency could be improved by promoting the transition to a lower heat transfer agent temperature, which would help reduce losses in transmission and investments in heating network renovation (e.g., by using cheaper pipelines made of plastic).
5. With the thermal energy consumption of buildings decreasing, the existing DH systems working with high-temperatures will become inefficient as the specific transmission costs will increase by more than 50 %. In order to incentivise owners of renovated or newly constructed buildings to connect to the DH system, heating tariffs need to be decreased or differentiated, taking advantage of cheaper energy sources and/or reducing transmission costs.
6. The analysis of the current situation in heating and the assessment of the economic potential show that the use of RES, especially wood, translates into a reduction in heat production costs. Although wood is being increasingly used in production of thermal energy, the price of wood is expected to rise in the coming years as it will begin to be used in the bioeconomy for the production of products with a high added value. Therefore, in the next decades it will be necessary to consider diversification of heat sources by including the use of solar energy, as well as integrating residual heat into district and local heating systems.
7. The study analysed various policy measures and their long-term effects. The results of the modelling performed show that support in the form of subsidies has a greater impact on key indicators as compared to higher taxes. Targets and policy measures pertaining to the development of heat supply need to be assessed and implemented as a package, rather than separate targets and policies.

8. Development of district and local heating and the transition of DH to a fourth generation system must be incorporated into strategic long-term planning documents.

Annexes

Overview of climate conditions during the heating season

The start of the heating season is determined by the outside air temperature: when the average daily air temperature is no more than 8 °C for at least three consecutive days. In legislation, the duration of the heating season is established in Cabinet of Ministers Regulation No 432 Rules on Latvia's Building Code LBN 003-19 'Building Climatology'. In order to assess changes in climate conditions in Latvia over the course of the past several years, the changes in the outside air temperature and the duration of the heating season in Riga representing the average weather conditions in Latvia have been analysed.

The duration of the heating season in Riga is 192 days per year and the average outside air temperature during the heating season is 1.1 °C. The actual duration of the heating season in Riga in the period from 2015 until 2020 is illustrated in Table 1 (data provided by Rīgas Siltums). Data on the average outside air temperature during the heating season was obtained from the Latvia's Environment, Geology and Meteorology Centre (LEGMC).

Table 1

Duration of the heating season and average air temperature (°C)

Year	Duration of heating season, days	Average outside air temperature during the heating season, °C
Code	192	1.1
2015	207	3.8
2016	202	1.7
2017	218	2.8
2018	201	1.8
2019	211	3.9
2020	206	4.8

The lowest average daily temperature in the 2015-2020 period was registered in 2016: -17.7 °C, while the highest average daily temperature of 27.4 °C was also recorded in 2016. Figure 1 shows the average outside air temperature, which changed by 1.8 °C during the 2015-2020 period.

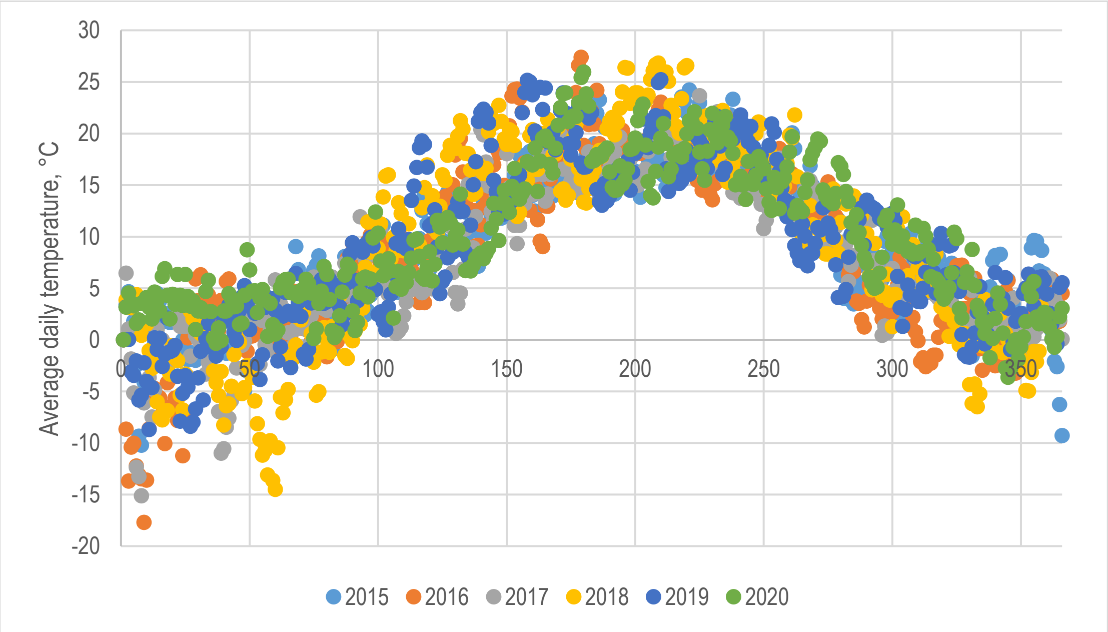


Figure 1. Comparison of the average daily temperature from 2015 until 2020

Table 2 shows the duration of outside air temperatures in hours and the average value for the five-year period (2015-2020). Based on the five-year average value, the outside air temperature mostly ranges from 0 °C to 5 °C, accounting for an average of 2,224 hours per year. Table 2 demonstrates that outside air temperatures below -25 °C have not been recorded, while temperatures below -20 °C occur for only a couple of hours per year. This must be taken into consideration when designing new heating device outputs to ensure that they operate at optimum capacity.

Table 2

Hours of outside air temperature

Outside air temperature, °C	Duration, hours						
	2015	2016	2017	2018	2019	2020	Average
< -25	0	0	0	0	0	0	0
-25 to -20	0	3	0	0	0	0	1
-20 to -15	0	33	16	36	0	0	14
-15 to -10	23	180	105	112	20	0	73
-10 to -5	111	280	169	543	260	0	227
-5 to 0	735	782	874	1 221	948	407	828
0 to 5	2 241	2 492	2 592	1 547	1 978	2 494	2 224
5 to 10	1 922	1 289	1 471	1 031	1 614	2 008	1 556
10 to 15	1 703	1 298	1 538	1 247	1 514	1 453	1 459
15 to 20	1 460	1 564	1 453	1 504	1 464	1 659	1 517
20-25	469	702	500	1 032	736	609	675
> 25	94	159	40	378	195	144	168

Figure 3 provides an illustration of the outside air temperature in 2015-2020 and the duration of each specific temperature per year. It can be seen that the temperature has changed over the course of this five-year period, as the outside temperature in 2020 did not fall below -5 °C, whereas the lowest temperature in previous years reached at least -10 °C.

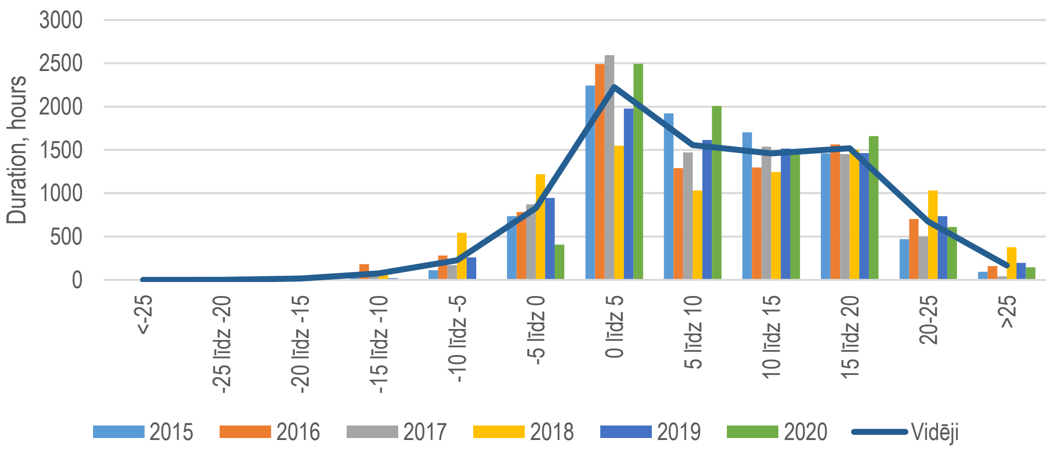


Figure 3. Hours of outside air temperature

līdz - until

Overview of heating networks and renovations thereof in the biggest cities in Latvia

Riga

Rīgas Siltums AS delivers thermal energy through a heating network of approximately 818 km. The total length of the heating network owned by the company as of 2019 is 695.49 km, including 280.82 km of ductless heating mains ([89]). The first heating mains was placed into operation in November 1958, and was extended to a length of 2.3 km within a year.

70 % of heating in Riga is purchased from the Latvenergo CHP plant, the rest is produced by five thermal plants and several dozen small and medium-sized boiler houses; the main fuel used for the production of thermal energy is natural gas and wood chips.

Since 2010, 14 % (115 km) of the total heating network in Riga have been renovated.

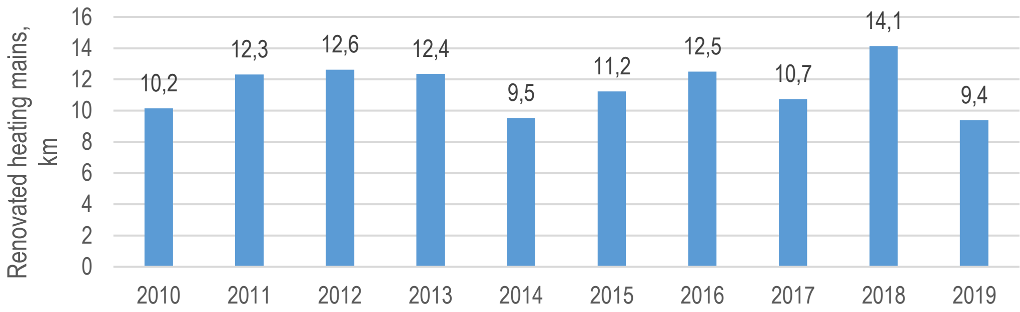


Figure 1. Renovated heating mains in Riga, 2010-2019 ([90])

Daugavpils

According to the 2019 report, the total length of the heating network in Daugavpils is 120 km. ([91]) According to data from 2016, there are five natural gas CHP plants, six fossil fuel and two biomass boiler houses operating in Daugavpils. Extensive improvements of the heating network were performed in the period from 2004 to 2015 with four new boiler houses built, four others renovated with new boilers installed, 19.06 km of heating mains renovated, and the length of heating mains was reduced by 6.6 km as a result of optimisation. Renovation of 14 km of heating mains is planned by 2020, but approximately 78 km of heating mains have as of yet not been renovated. ([92])

From 2011 to 2019, 11.6 km or 9 % of the total length of heating mains were renovated.

([89]) Annual Report 2019 of Rīgas siltums AS. Available online: https://www.rs.lv/sites/default/files/page_file/rs_gada_parskats_2019.pdf
([90]) Annual reports of Rīgas siltums AS.
([91]) Public report by the City of Daugavpils. 2019 Available online: https://www.daugavpils.lv/assets/upload/dokumenti/2020/Publiskais_parskats_2019.pdf
([92]) Daugavpils City Sustainable Energy Action Plan 2016-2020. 2016 Available online: https://www.daugavpils.lv/assets/upload/dokumenti/IERP_Daugavpils_v7_10%2011%202016_prec_1.pdf

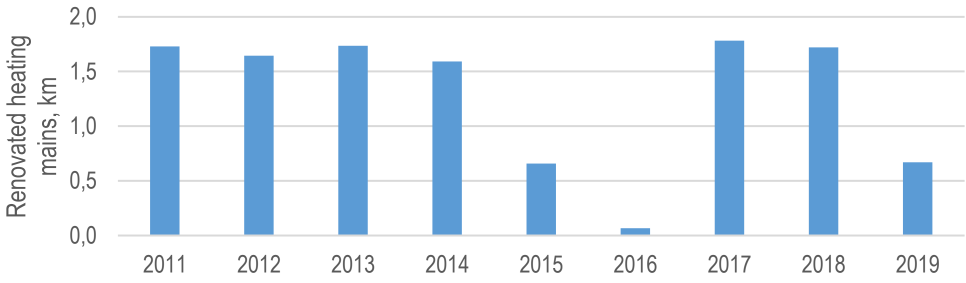


Figure 2. Renovated heating mains in Daugavpils, 2011-2019 (93)

Liepāja

According to data from 2020, there are two CHP plants and 13 boiler houses operating in Liepāja, and the total length of the heating pipelines is 102.5 km (93). By 2018, only 3 % of the heating network had not yet been renovated, yet in 2019, 99 % of the network had already been renovated. The remaining heating mains are scheduled to be renovated and upgraded by 2020.

31 % (31.7 km) of the heating network was renovated in the period from 2015 to 2019 (94).

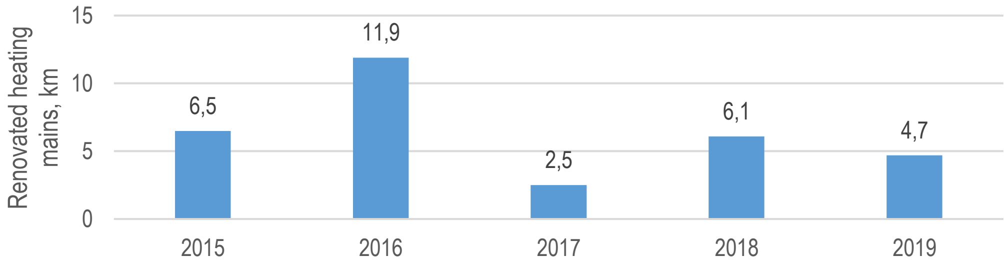


Figure 3. Renovated heating mains in Liepāja, 2015-2019 (95)

Jelgava

The length of the DH network in Jelgava is 72 km and it is operated by Fortum (95). Fortum Jelgava SIA built a heating main under the Lielupe River in Jelgava, which was the first project of this kind in Latvia. The total length of this pipe is 1.4 km, of which 380 m run under the river. From 2008 to 2014, Fortum renovated 12.41 km of heating mains. (96)

Jūrmala

The length of the heating mains in Jūrmala is 60 km, and there are 12 heat sources (97). The renovation of 8 km of heating mains is planned for completion by 2021 (98).

(93) Liepāja City Sustainable Energy and Climate Action Plan 2020-2030. Available online: https://faili.liepaja.lv/Dokumenti/Dokumentu-biblioteka/Strat%C4%93%C4%A3ijas-nozaru-pl%C4%81ni/Ilgtspejigas_Energetikas_un_klimata_ricibas_plans_2020_2030.pdf
(94) Annual energy reports for Liepāja.
(95) Biomass CHP plant in Jelgava. Available online: https://www.fortum.lv/par-fortum/par-mums/fortum-latvija/biomasas-kogeneracijas-stacija-jelgava
(96) Fortum is beginning the implementation of a new project. 2014. Available online: https://www.jelgava.lv/lv/jaunumi/zinu-arhivs/-fortum-sak-istenot-jaunu-projektu/
(97) About Jūrmalas siltums. Available online: https://jurmalassiltums.lv/par-jurmalas-siltums/
(98) 2019 Public Report by the Jūrmala City Council. 2020. Available online: https://jurmala.lv/docs/k20/x/L0261_pielikums.pdf

Ventspils

According to 2019 data, the length of the heating network in Ventspils is 50.2 km ([99]). A total of 7.4 km of heating mains were renovated in the period from 2012 to 2015 ([100]). All heating mains in the city had already been renovated by 2018 with work continuing on attracting new customers and constructing new heating mains. It is planned for the total length of the heating network in Ventspils to be 54.2 km by December 2020. ([104])

Rēzekne

Heating for the city of Rēzekne is provided by two CHP plants and one boiler house ([101]). According to 2019 data, the total length of the heating network is 38.9 km, of which 38 % or 14.8 km have been renovated. ([102])

Valmiera

According to 2015 data, the total length of the heating network in Valmiera is 64.6 km ([103]). District heating in Valmiera is provided by Valmieras ūdens SIA, which purchases thermal energy from Valmieras enerģija AS (84.16 %), Valmieras piens AS (14.32 %), ITA SIA (1.52 %), according to 2019 data ([104]).

Ogre

The total length of the heating network in Ogre is 26.4 km, and there are six boiler houses in operation. By 2013, 12.7 km or 48 % of the total heating network had been renovated. ([105])

Jēkabpils

According to 2019 data, there are four boiler houses operating in Jēkabpils, and 62 % of the population uses district heating. The total length of the city's heating network is 25.2 km. 1.47 km of heating mains are planned for renovation in 2018-2020, with 7.2 km already renovated between 2011 and 2015. ([106])

([99]) 2019 Public Report of Ventspils siltums. Year 2020. Available online: http://ventspilssiltums.lv/sites/default/files/u2/images/vs_gada_parskats_2019.pdf
([100]) Ventspils siltums mid-term strategy 2018-2020. 2018. Available online: http://www.ventspilssiltums.lv/sites/default/files/u2/images/vs_strategija_2019-2022.pdf
([101]) Ownership structure of Rēzeknes siltumtīkli. Available online: https://rezeknessiltumtikli.lv/ipasuma-struktura/
([102]) 2019 Annual Report of Rēzeknes siltumtīkli. 2020. Available online: https://rezeknessiltumtikli.lv/wp-content/uploads/2020/05/GP2019.pdf
([103]) Report on the operation of Valmieras ūdens SIA in 2015. Available online: http://www.valmierasudens.lv/attachments/article/152/SIA%20Valmieras%20%C5%ABdens%20prezent%C4%81cija%20_2015.pdf
([104]) 2019 Public Report by the Valmiera City Council. 2020. Available online: https://www.valmiera.lv/images/userfiles/cits/GP_2019_28052020_DOMEI.pdf
([105]) Heating by Ogres namsaimnieks. Available online: http://94.100.6.202/siltumapgade
([106]) Jēkabpils City Development Plan 2020-2026. 2019 Available online: https://www.jekabpils.lv/sites/default/files/universalais/2013/01/974-attistibas-programma/1-pasreizejas-situacijas-raksturojums_0.pdf

List of identified industrial residual heat

Establishment	Location	Indicative residual heat, MWh/year (107)	No on the map
STORA ENSO PACKAGING SIA	Riga	1 631	1
A.C.B. AS	Riga	492	2
RĪGAS PIENA KOMBINĀTS AS	Riga	1 739	3
Latvijas Finieris AS, Furnieris	Riga	15 895	4
GRINDEKS AS	Riga	3 743	5
Lenta-12	Riga	227	6
Baltic Agro SIA	Riga	1 620	7
Pellet 4Energia	Riga	769	8
Valdori SIA	Riga	592	9
VRV SIA	Riga	338	10
RĪGAS MĒBEĻU SERVISS SIA	Riga	154	11
KLIPPAN-SAULE SIA	Riga	905	12
RĪGAS PIENSAIMNIEKS SIA	Riga	2 104	13
SADZĪVES PAKALPOJUMI SIA	Riga	1 838	14
AIDANA SIA – TECĒJUMS, SIA	Riga	325	15
TTS SIA	Riga	311	16
Rīgas laku un krāsu rūpnīca SIA	Riga	358	17
Latvian Dairy, SIA	Riga	540	18
Latvijas balzams AS	Riga	2015	19
BALTTUR	Riga	172	20
TKF Latekss SIA	Riga	812	21
ILGEZEEM SIA	Riga	1 159	22
AKZ SIA	Riga	3 936	23
HGF Rīga SIA	Riga	839	24
Tehprojekts	Riga	259	25
MEŽROZE SIA	Riga	2 156	26
FONEKSS METĀLS SIA	Riga	1 284	27
VIA SIA	Riga	892	28
Rīgas kombinētās lopbarības rūpnīca SIA	Riga	155	29
BELKOVIT SIA	Riga	166	30
CEĻU PĀRVALDE AS	Riga	1 378	31
MOBIL ASFALTS SIA	Riga	889	32
OVI Rīga SIA	Riga	753	33
RĪGAS DZIRNAVNIEKS AS	Riga	988	34
Baltic Biogran	Riga	532	35
Industry Service Partner SIA	Riga	2 404	36
Man – Tess Tranzīts	Riga	166	37
Rīgas elektromašīnbūves rūpnīca AS	Riga	521	38
BMGS AS	Riga	372	39
Noliktavu Parks	Riga	377	40
KRONOSPAN Riga SIA	Riga	127 406	41
Cido Grupa	Riga	1 117	42

(107) Based on data on fuel consumption provided by the company and the average potential for residual heat in the sector

Rīgas kuģu būvētava AS	Riga	13 644	43
BLB Baltijas Termināls AS	Riga	33 408	44
IP VECMĪLGRĀVIS SIA	Riga	170	45
WT TERMINAL'SIA	Riga	1 741	46
Gamma A SIA	Riga	3 534	47
Fille 2000	Valmiera	6 977	48
V.L.T. SIA	Valmiera	1 154	49
VALPRO SIA	Valmiera	1 027	50
LPKS VAKS	Valmiera	740	51
Valmieras stikla šķiedra AS	Valmiera	14 189	52
Valmieras piens AS	Valmiera	9 017	53
Kurzemes granulas	Ventspils	4 454	54
DIANA SVECES SIA	Ventspils	295	55
BALTIC COAL TERMINAL	Ventspils	277	56
Malmar Sheet Metal SIA	Ventspils	264	57
VENTSPILS ZIVJU KONSERVU KOMBINĀTS	Ventspils	260	58
VENTAMONJAKS AS	Ventspils	194	59
Ventbunkers AS	Ventspils	10 209	60
KUREKSS	Tārgale civil parish	5 344	61
Nexis Fibers SIA	Daugavpils	1 603	62
Latgales Ceļdaris SIA	Daugavpils	1 135	63
Latgales Piens	Daugavpils	1 036	64
DAUGAVPILS DZELZSBETONS SIA	Daugavpils	469	65
DITTON PIEVADĶĒŽU RŪPNĪCA AS	Daugavpils	296	66
MEAT UNION SIA	Daugavpils	288	67
LATVIJAS MAIZNIEKS AS	Daugavpils	2 632	68
OŠUKALNS SIA	Jēkabpils	694	69
Sedumi SIA	Jēkabpils	561	70
REĀLS SIA	Jēkabpils	253	71
Gaujas koks SIA	Jēkabpils	14 153	72
PET Baltija AS	Jelgava	1 432	73
Zn metals SIA	Jelgava	1 363	74
Elagro Trade SIA	Jelgava	1 061	75
BRAKŠĶU ENERĢIJA SIA	Jelgava	383	76
Chocolette Confectionary SIA	Jelgava	151	77
LATVIJAS PIENS SIA	Jelgava	1 906	78
LODE SIA Āne factory	Ozolnieki Municipality	8 778	79
Fito-AL SIA	Jelgava Municipality	155	80
LIKTENIS SIA	Jūrmala	158	81
Baltic Transshipment Center SIA	Liepāja	345	82
Jensen Metal LSEZ SIA	Liepāja	264	83
DZELZSBETONS MB SIA	Liepāja	200	84
Trelleborg Wheel Systems Liepaja LSEZ SIA	Liepāja	186	85
LIEPĀJAS KAFIJAS FABRIKA SIA	Liepāja	179	86
Lauma Fabrics SIA	Liepāja	7 776	87
CTB SIA	Liepāja	724	88
Kolumbija LTD SIA	Liepāja	491	89
GI TERMINĀLS LSEZ SIA	Liepāja	460	90
CEĻI UN TILTI SIA	Rēzekne	892	91
Rēzeknes dzirnavnieks	Rēzekne	775	92

Vecā maiznīca	Rēzekne	277	93
Newfuels RSEZ SIA	Rēzekne	10 788	94
VEREMS, SIA	Rēzekne	6 834	95
BOVIS SIA	Rēzekne	6 202	96
Scandbio Latvia SIA		12 895	97
Dobeles Eko SIA	Dobele	9 817	98
I.S.D. SIA	Iecava	8 658	99
STORA ENSO LATVIJA AS	Launkalne civil parish,	7,122	100
Vika Wood SIA	Lauciene civil parish,	5 114	101
Olainfarm AS	Olaine	4 560	102
Dobeles dzirnavnieks AS	Dobele	4 161	103
DRUVAS UNGURI SIA	Saldus civil parish	2 984	104
CĒSU ALUS AS	Cēsis	2 771	105
Fazer Latvija	Ogre	2 769	106
TROLL Smiltene SIA	Smiltene	2 752	107
DAILE AGRO SIA	Glūda civil parish	2 711	108
Zaļā Mārupe SIA	Jaunmārupe	2 619	109
STAĻI SIA	Priekuļi civil parish	2 595	110
Vudlande	Launkalne civil parish	2 583	111
Rettenmeier Baltic Timber SIA	Inčukalns	12 166	112
BIODEGVIELA SIA	Jaunkalsnava	3 771	113
JELD-WEN LATVIJA SIA	Aizkraukle	2 477	114
SMILTENE IMPEX SIA	Launkalne civil parish	2 190	115
LATFOOD AS	Ādaži	2 159	116
RENETA SIA	Grobiņa	2 136	117
Smiltenes piens AS	Smiltene	1 900	118
GBM SIA	Ciemupe	1 641	119
BSW LATVIA SIA	Rumbula	1 633	120
SAULKALNE S SIA	Salaspils Municipality	1 627	121
LATRAPS, agricultural service cooperative union	Eleja	1 465	122
TUKUMA PIENS AS	Tukums	1 458	123
Sātiņi-LM SIA	Novadnieki civil parish	1 456	124
TENAPORS SIA	Dobele	1 436	125
8 CBR SIA	Smiltene	1 414	126
ADUGS SIA	Līvāni	1 321	127
Olaine chemical plant BIOLARS AS	Olaine	1 252	128
LIMBAŽU CEĻI SIA	Limbaži	1 239	129
LIELZELTIŅI SIA	Ceraukste civil parish	1 184	130
Orkla Confectionery & Snacks Latvija SIA	Ķekava civil parish	1 000	131
A Pieci SIA	Ķekava civil parish	910	132
AĻŅI AS SIA	City of Varakļāni	909	133
Puratos Latvia	Pūre civil parish	879	134
KRAUSS SIA	Cesvaine civil parish	877	135
Jaunpils pienotava	Jaunpils civil parish	765	136
DAIVA agricultural services coop. union	Jeru civil parish	751	137
AVOTI SWF SIA	Avoti	705	138
Baltic Dairy Board SIA	City of Bauska	691	139
KRK VIDZEME SIA	Alūksne Municipality	675	140
STRABAG SIA	Smārde civil parish	665	141
KONTO	City of Gulbene	662	142

BAUSKAS SADZĪVES PAKALPOJUMI SIA	City of Bauska	649	143
BALTIC CANDLES Ltd SIA	City of Dobele	614	144
UNDA SIA	Engure civil parish	611	145
KRĀSLAVAS PIENS AS	City of Krāslava	579	146
TMB ELEMENTS SIA	Salaspils Municipality	577	147
PS LĪDUMS SIA	Veģi	572	148
PNB Print SIA	Ropaži Municipality	571	149
ALMO HARDWOOD AS	Alsviķi civil parish	569	150
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UNION ASPHALTTECHNIK SIA	Mārupe Municipality	499	154
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TUKUMA STRAUME AS	Tume civil parish	371	172
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