COMPREHENSIVE ASSESSMENT STUDY OF THE NATIONAL HEATING AND COOLING POTENTIAL

November 2022

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND DEFINITIONS

Abbreviation	Explanation
RES	Renewable energy sources
RESD	Directive 2009/28/EC on the promotion of the use of energy from renewable sources
SEC	Secondary energy consumption
CPR or Common Provisions Regulation	Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action
CAGR	Cumulated annual growth rate
DC system	District cooling system
DH system	District heating system
NZEB	Nearly zero-energy building
OECD	Organisation for Economic Co-operation and Development
EIB	European Investment Bank
MoEne	Ministry of Energy
Energy balance	Fuel and energy balance
EPC	Energy performance class
EED	Directive 2012/27/EU on energy efficiency amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC
FEC	Final energy consumption
FF	Fossil fuels
SFF	Solid fossil fuels (coal, peat, coke, etc.)
LFF	Liquid fossil fuels
LTRS	Long-term renovation strategy
LR	Republic of Lithuania
LDHA	Lithuanian District Heating Association
National building stock	Building stock registered in the RPR database on 31 December 2020
NECAP	National Energy and Climate Action Plan for 2021-2030
UEC	Useful energy consumption
RPR	LR Real Property Register
Site	All buildings at one address
Amending Directive	Directive (EU) 2018/844 of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency
Building stock	Buildings within the national building stock that use thermal energy
PEC	Primary energy consumption
EPB	Energy performance of buildings
EPBD	Directive 2010/31/EU on the energy performance of buildings and Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency
RC	State enterprise Centre of Registers

SPSC	State enterprise Centre for Certification of Construction Products

Abbreviation	Explanation
CBA	Cost-benefit analysis
GHG	Greenhouse gases
Terms of reference	Terms of reference for procurement
NERC	National Energy Regulatory Council
Green Deal	The European Green Deal provides a roadmap for ensuring the sustainability of the EU economy, while turning climate and environmental challenges into opportunities across all policy areas and ensuring that the transition is fair and inclusive for all.

1. EXECUTIVE SUMMARY

This report has been drawn up in the framework of the Contract No 8-142 of 13 December 2021 (hereinafter referred to as 'the Contract') on the comprehensive assessment study of the national heating and cooling potential (hereinafter referred to as 'the Study').

Context, objectives and tasks of the Study

Energy efficiency is one of the most important long-term strategic objectives in the energy sector, both in Lithuania and on the EU level.

On the EU level the heating and cooling sector is the most significant final energy consumer consuming around 50% of the EU's total energy demand (approximately 80% of that energy is consumed in buildings). In order to identify the potential for enhancing efficiency in this sector, Directive 2012/27/EU ('the EED') obliges each Member State to carry out a comprehensive assessment of the potential for efficient heating and cooling, including a map of the entire territory of the country showing the sources and infrastructure of heating and cooling demand.

The main objectives of the Study:

1. To carry out a comprehensive assessment of the potential for efficient heating and cooling in Lithuania.
2. To collect and/or generate data necessary for the preparation of an interactive heating and cooling map.

The main tasks of the comprehensive assessment of Lithuania's potential for efficient heating and cooling are as follows:

- To assess the current demand for heating and cooling (Chapter 4).
- To make a long-term forecast of heating demand (Chapter 5).
- To make a long-term forecast of cooling demand (Chapter 6).
- To assess the current heating and cooling supply (Chapter 7).
- To make an assessment of the potential for efficient heating (Chapter 8).
- To make an assessment of the potential for efficient cooling (Chapter 9).
- To carry out an analysis of policy measures (Chapter 10).

1.1. Results of the assessment of the potential for efficient heating

To summarise the analysis of the strategic objectives for the energy sector, the following key objectives for Lithuania's energy sector for 2050 can be highlighted:

Objectives for Lithuania's energy sector for 2050

Sector	Objective	Target indicators (2050)
Lithuania, total	Decrease in PEC and FEC intensity (compared to 2017)	2.4-fold
	GHG emissions reduction (compared to 1990)	95%
	RES share in FEC	80%

Taking into account the long-term strategic objectives of the energy sector, the following objectives and target indicators are set for the heating sector:

Objectives for Lithuania's heating sector for 2050

Sector	Objective	Target indicators (2050)
Heating	T1. Decrease in FEC intensity	18.8 TWh
	T2. Decrease in PEC intensity	20.6 TWh
	T3. GHG emissions	0 kt CO_2

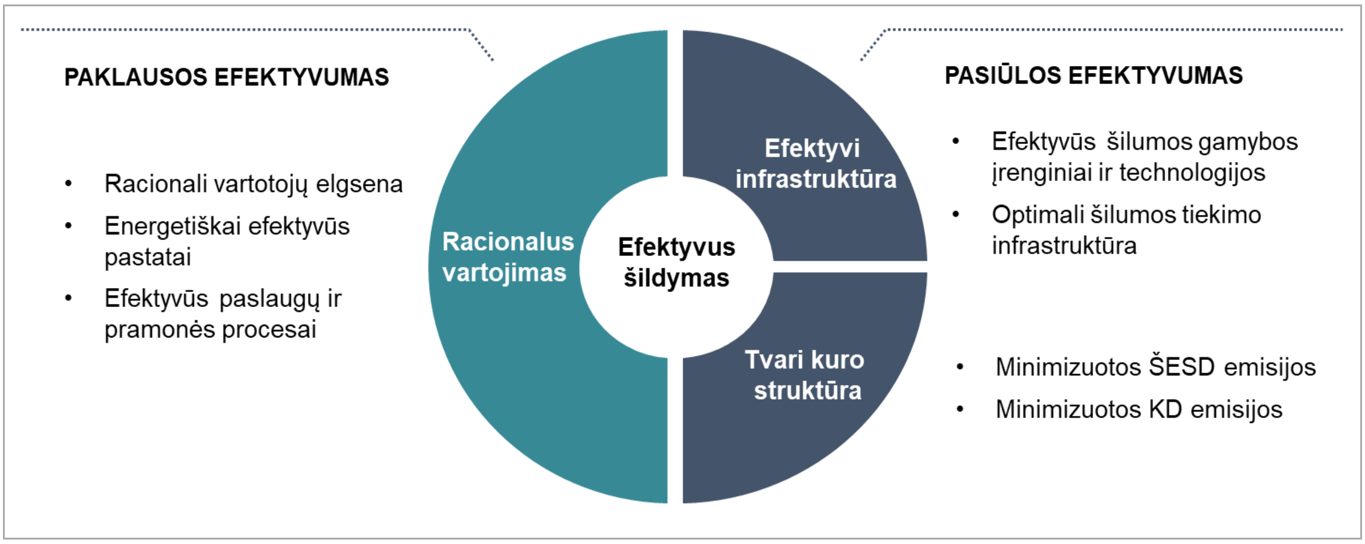
sector	T4. RES share in the DH sector	100%
	T5. RES share in the decentralised sector	90%

Taking into account the long-term objectives set for the heating sector, three main expectations are defined for the area of thermal energy efficiency:

- Rational consumption: a key measure to reduce FEC intensity.
- Efficient infrastructure: a key measure to reduce PEC intensity.
- Sustainable fuel mix: a key measure to reduce GHG emissions.

In terms of the energy supply chain, these expectations are divided into two groups: enhancing the efficiency of heating demand and enhancing the efficiency of heating supply.

Assessment model for the potential for efficient heating

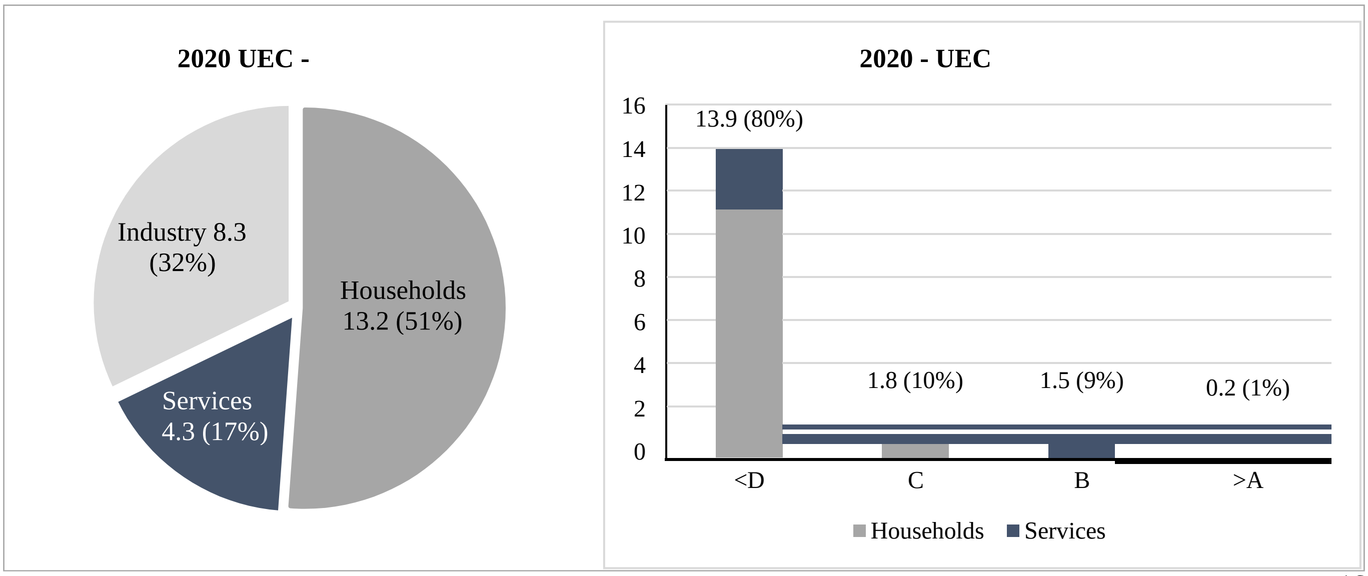


When assessing the potential for enhancing demand efficiency, solutions are sought to reduce the need for heating energy while maintaining the same quality parameters of the service (e.g. indoor temperature level). When assessing the potential for enhancing supply efficiency, technological solutions are sought to meet efficient heating demand with the lowest financial and economic (social) costs.

1. Potential for enhancing heating demand efficiency

An analysis of the heating demand structure has revealed that a major part of the demand (about 68%) is for heating buildings (households and the service sector) while the majority of buildings (about 80%) are low energy efficiency.

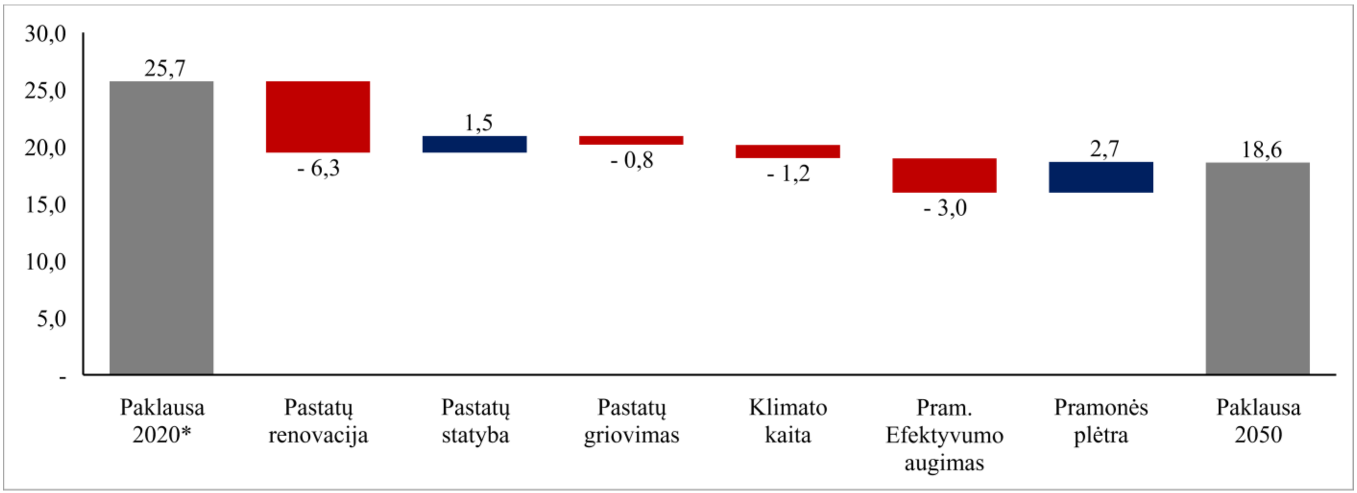
Lithuania's heating UEC in 2020, GWh



Accordingly, it can be concluded that the main potential for enhancing heating demand efficiency is in enhancing the energy efficiency of buildings (renovation).

It is estimated that full implementation of the objectives set in the Long-Term Renovation Strategy (LTRS) for 2050 would reduce the level of heat demand by about 6.3 TWh due to renovation measures. Taking into account all the factors influencing heating demand, it is projected that heating demand would decrease by 28% (from 25.7 TWh in 2020[1] to 18.6 TWh in 2050).

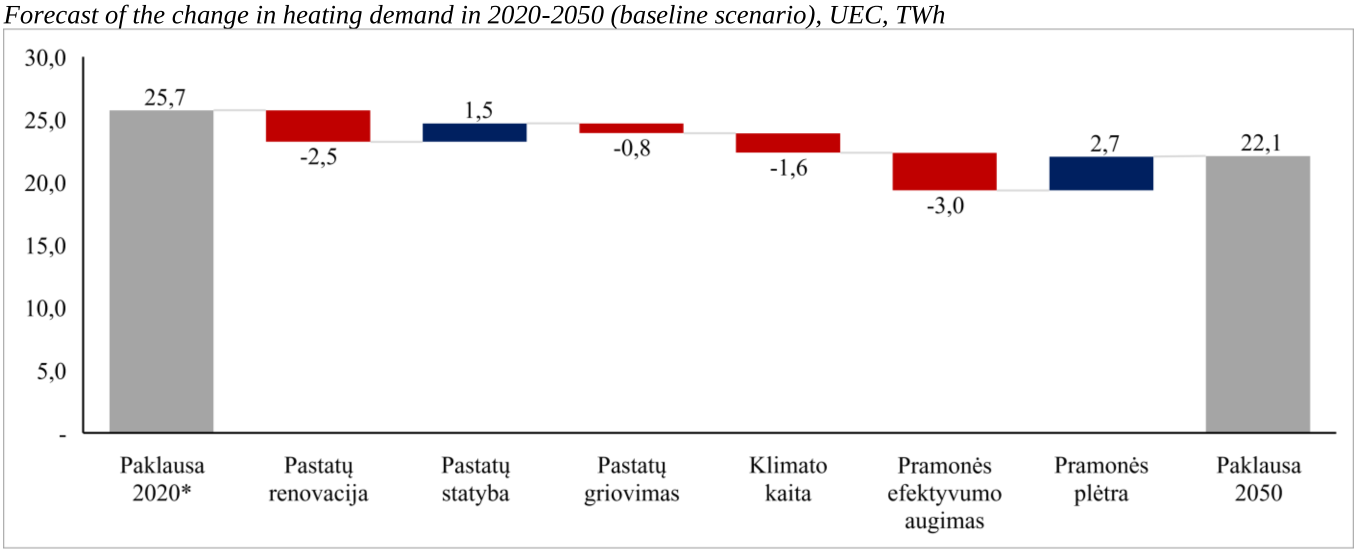
Forecast of the change in heating demand in 2020-2050 (LTRS100), UEC, TWh



In accordance with the precautionary principle and in order to be prepared for a less optimistic pace of renovation of the building stock, the scope of this Study is modelled on the premise that 40% of the surface area of buildings envisaged in the LTRS will be renovated by 2050. This solution allows for the development of the required policy measures to enhance supply efficiency, also in the event that the LTRS renovation targets are not fully met. In this way, even if the sectoral targets for reducing FEC and PEC intensity are not fully met, the GHG emission reduction targets would still be achievable.

Under the baseline scenario offering a forecast of heating demand, taking into account all the factors influencing heating demand, it is projected that heating demand would decrease by 14% (from 25.7 TWh in 2020 to 22.1 TWh in 2050).

Forecast of the change in heating demand in 2020-2050 (baseline scenario), UEC, TWh



[1] The reference year is calculated as the average for 2018, 2019 and 2021 (more details in Chapter 5.1).

2. Potential for enhancing heating supply efficiency

As described above, long-term strategic objectives for the energy sector shape two main strands of action for enhancing heating supply efficiency:

- Efficient infrastructure: a key measure to reduce PEC intensity.
- Sustainable fuel mix: a key measure to increase the RES share and to reduce GHG emissions.

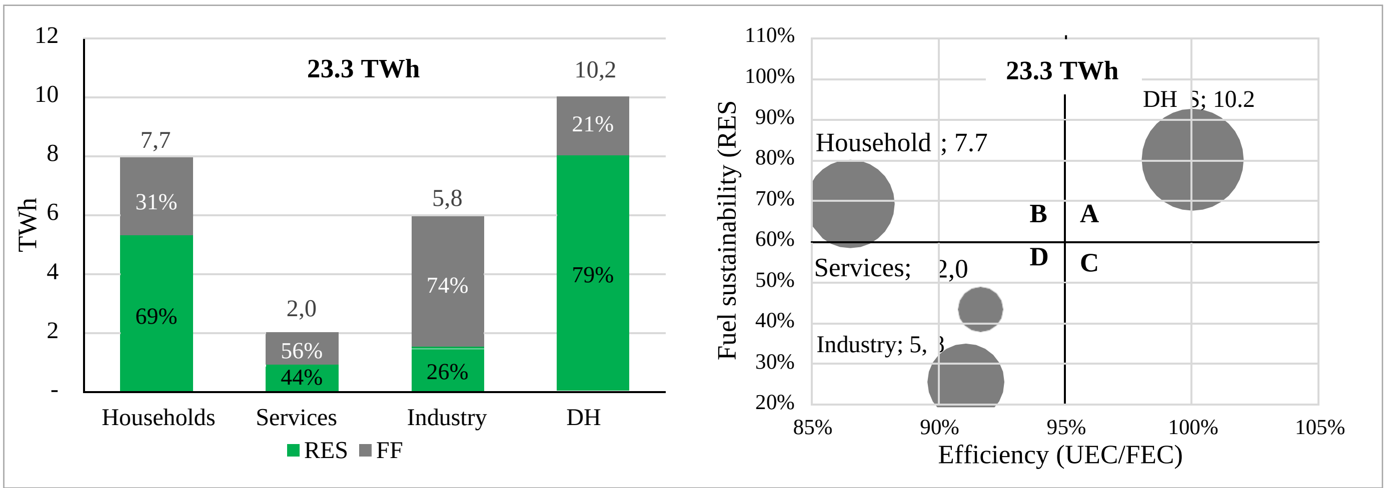
An analysis of the heating supply structure has revealed that when assessing fuel sustainability (the RES share in the fuel mix):

- The best indicators are in the district heating (DH system) segment where the RES share reaches 79%.
- The smallest RES share is in the industry sector: 26%.

In assessing the efficiency of manufacturing infrastructure:

- The best UEC to FEC ratio is also in the district heating segment (100%).
- The lowest efficiency is in the household segment (it is estimated that about 50% of biomass-fuelled boilers are inefficient[2]).

Heating supply efficiency indicators (2020)



As a significant part of the heating sector's fuel mix consists of natural gas (29% in 2020) and there is a steady increase in the share of electricity (5% in 2020), it is important to assess the most probable scenarios for the development of the gas and electricity sectors when setting targets for enhancing the efficiency of the heating sector.

Long-term scenarios for the development of the Lithuanian gas sector are not fully simulated in strategic planning documents. The Roadmap for the development of the gas transmission system published by the European Network of Transmission System Operators for Gas (ENTSOG)[3] offer projections for three fundamental scenarios for the configuration of the gas transmission system:

- Methane scenario (in combination with the CCUS[4] technology).
- Methane and hydrogen mix scenario (in combination with the CCUS technology).
- Hydrogen scenario.

It is estimated that by 2050 the gas sector configuration will be in line with the interim gas sector development scenario, i.e. natural gas will be blended with renewable gas (ratio 20/80) while CCUS technology will be used to control the remaining GHG emissions.

2 Functional operation factor (FOF) of approximately 77%.

3 https://www.entsog.eu/entsog-roadmap-2050.

4 Carbon Capture, Utilisation and Storage.

To sum up the long-term objectives set for Lithuania’s electricity sector, it can be concluded that the main goal for 2050 is for Lithuania to consume only domestic electricity produced from RES. The baseline scenario assumes that this strategic objective for the electricity sector will be achieved, i.e. in 2050, 100% of electricity consumed in the heat sector will be produced in Lithuania using RES.

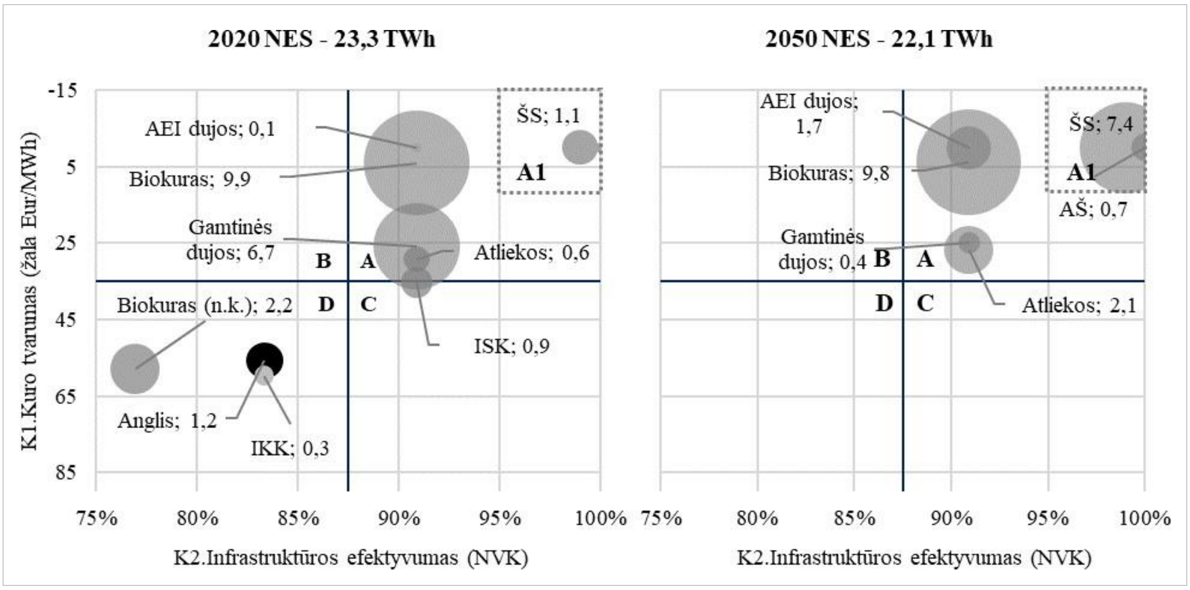
Taking into account the objectives set for the heating sector, the most probable scenarios for the development of the sectors concerned and the analysis of the current situation, the following priority strands of action for enhancing supply efficiency are established.

Strands of action for enhancing heating supply efficiency (summary)

Sector	Efficiency indicators (2020)		Strands of action for enhancing efficiency (2050)	
	Infrastructure efficiency	Fuel sustainability	Heating sector	Sectors concerned
District heating	high	high	• Rational development • Optimisation of the production structure • Reducing supply losses (4G network transformation) • Waste heat integration	• RES share in the electricity generation structure (100%) • RES share in the gas network (80%)
Decentralised heating – Households	Low	Medium	• Eliminating consumption of solid and liquid fossil fuels • Eliminating natural gas consumption • Eliminating inefficient biofuel production sources • Limiting biofuel consumption	
Decentralised heating – Service sector	Medium	Medium	• Eliminating consumption of solid and liquid fossil fuels • Eliminating natural gas consumption • Limiting biofuel consumption	
Decentralised heating – Industry sector	Medium	Low	• Eliminating consumption of solid and liquid fossil fuels • Reducing natural gas consumption • Implementing CCUS technology	

Source: authors of the Study

Implementation of energy efficiency measures by the year 2050 would rid the heating sector of supplies of relatively polluting and low-efficiency fuels, meaning that supply would migrate from Square D to Square A.



To sum up, under the baseline scenario:

- Consumption of solid and liquid fossil fuels is eliminated (2.5 TWh in 2020).
- Natural gas consumption is reduced significantly (from 6.7 TWh to 0.4 TWh) (both due to reduced gas consumption and gas sector transformation).
- Inefficient sources of biofuel production are eliminated (2.3 TWh in 2020).
- Thanks to the spread of heat pumps and waste heat integration, the share of ambient energy increases almost 7-fold (from 0.8 TWh to 5.9 TWh).

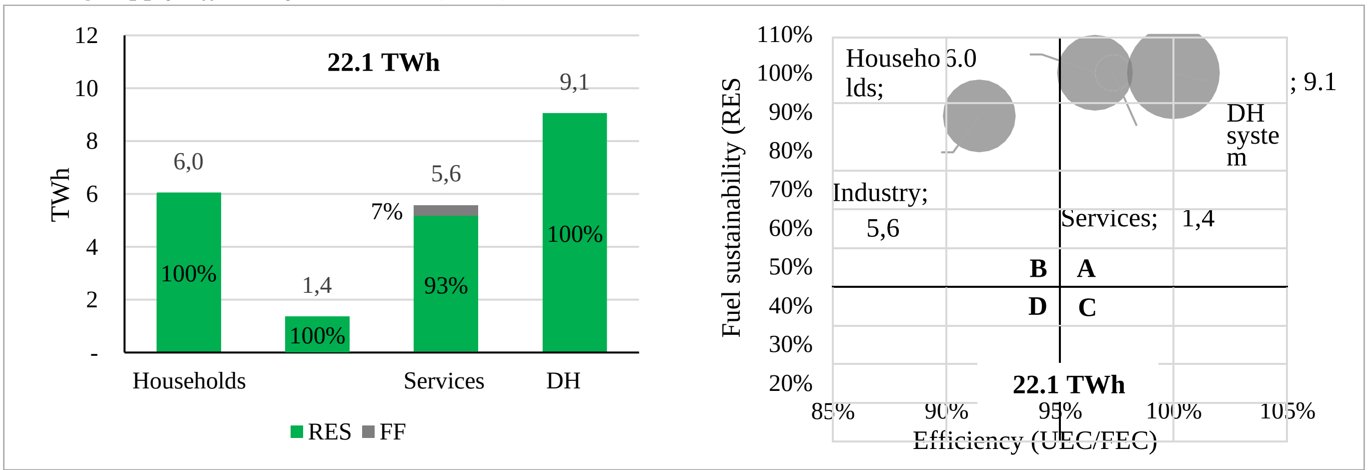
The sectoral change in the production structure under the baseline scenario for 2050 is disclosed in the table below.

Changes in the production structure in 2050 (summary)

Fuel	UEC in 2020	Change	UEC in 2050				
			Total	Households	Services	Industry	DH system
Coal	1.221	-1.221	-	-	-	-	-
Solid fuel	347	-347	-	-	-	-	-
Petroleum products	904	-904	-	-	-	-	-
Natural gas	6.743	-6.328	415	-	-	415	-
Total FF	**9.214**	**-8.799**	**415**	**-**	**-**	**415**	**-**
RES gas	96	+1.600	1.697	-	38	1.659	-
Biofuel	9.933	-170	9.762	2.164	335	2.318	4.945
Biofuel (n.k.)	2.232	-2.232	-	-	-	-	-
Waste	597	+1.473	2.070	-	-	825	1.245
Waste heat	89	+350	441	-	-	-	441
Solar collectors	-	+251	251				251
Electricity (HP)	419	+2.122	2.541	1.439	367	133	602
Ambience (HP)	712	+4.157	4.869	2.446	624	227	1.572
Total RES	**14.079**	**+7.552**	**21.631**	**6.049**	**1.364**	**5.162**	**9.056**
TOTAL	**23.292**	**-1.247**	**22.046**	**6.049**	**1.364**	**5.577**	**9.056**

A change in the production structure would allow achieving these 2050 heating supply indicators.

Heating supply efficiency indicators (2050)

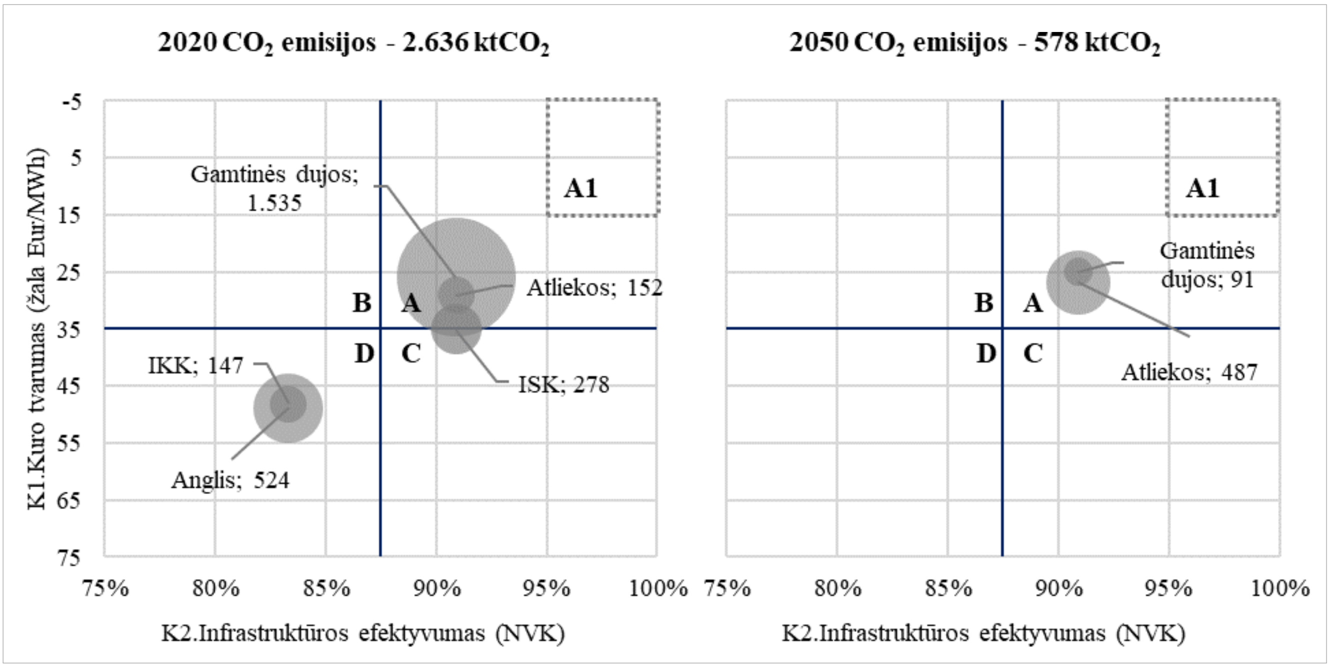


As one might notice, in 2050:

- The fuel mix in the sectors using heating energy for space heating (households, the service sector and the DH system) is dominated by RES fuel sources and the supply is in a zone of relatively high efficiency and fuel sustainability (Square A).
- The industry sector's supply, due to the relatively lower use of the heat pump technology, is within a less efficient zone (Square B).
- As most of the heating energy in the industry sector is not used for space heating but rather for production processes[5], it is projected that about 11% of the sector's fuel mix will consist of fossil fuels while the CCUS technology will be used to control the remaining GHG emissions.

This transformation of the heat production structure would reduce CO_2 emissions by more than 4 times.

Change in CO_2 emissions (2020-2050)



In the baseline scenario, upon taking full advantage of the possibilities for enhancing heating efficiency established in the Study, the following indicators would be achieved.

Projected indicators for the heating sector for 2050

Sector	Objective for 2050	Target indicators	Baseline scenario indicators
Heat sector	T1. Decrease in FEC intensity	18.8 TWh	22.8 TWh
	T2. Decrease in PEC intensity	20.6 TWh	24.5 TWh
	T3. GHG emissions	0 kt CO_2	578 kt CO_2
	T4. RES share in the DH sector	100%	100%
	T5. RES share in the decentralised sector	90%	97%

As can be seen, under the baseline scenario, the target indicators for Targets T1 and T2 (FEC 18.8 TWh and PEC 20.6 TWh) are not fully met. This indicator is mainly influenced by measures to enhance heating demand efficiency. In order to achieve the target, measures planned in the Long-Term Renovation Strategy (LTRS) to enhance demand efficiency should be implemented to the full extent.

5 A specific fuel type may be important for the production process, e.g. when the process requires a specific heat temperature or a specific chemical element is generated during combustion.

It is also important to note that while the target indicators for Targets T1 and T2 have not been fully met, their structure in 2050 shows a significant increase in the share of ambient energy.

NB: Under the baseline scenario, a significant part of primary energy consumption (PEC) and final energy consumption (FEC) in structural terms in 2050 (about 7.5 TWh, 30%) is thermal energy generated by heat pumps. The electricity used to produce this amount of thermal energy is about a third (approximately 2.5 TWh).

The target indicator for Target T3 (0 kt CO_2 emissions) is not fully met. The remaining share of the emissions comprises the following:

- Emissions from waste incineration plants (488 kt CO_2/year). The emissions come from three installations of high capacity and economic capacity participating in the ETS. The thinking therefore is that, with appropriate financial incentives (high cost of allowances), the remaining emission damage can be controlled with the CCUS technology. With the growing RES share in the waste composition, the need for CCUS technology would proportionately decrease.
- Emissions from natural gas (91 kt CO_2/year). The emissions come from the industry sector, which in the baseline scenario is projected to consume about 2 TWh of the gas mixture with low CO_2 footprint, 20% of which will be attributable to natural gas. As in the case of waste incineration plants, it is assessed that, with appropriate financial incentives (high cost of allowances), a major proportion of the remaining emission damage can be controlled with the CCUS technology.

In the baseline scenario, the indicators of the remaining objectives (T4 and T5) are fully met.

1.2. Results of the assessment of the potential for efficient cooling

Taking into account the long-term strategic objectives of the energy sector, the following objectives and target indicators are set for the heating sector:

Objectives for the cooling sector for 2050

Sector	Objective	Target indicators (2050)
Cooling sector	T1. Decrease in FEC intensity	-
	T2. Decrease in PEC intensity	-
	T3. GHG emissions	0 kt CO_2
	T4. RES share in the DH sector	100%
	T5. RES share in the decentralised sector	100%

The cooling sector is an emerging sector and constitutes an insignificant part of the energy sector. Accordingly, no objectives are set to reduce FEC and PEC indicators as compared to 2017 levels.

Like in the case of the heating sector, three main expectations are defined for the area of cooling energy efficiency:

- Rational consumption: a key measure for controlling FEC intensity.
- Efficient infrastructure: a key measure for controlling PEC intensity.
- Sustainable fuel mix: a key measure for controlling GHG emissions.

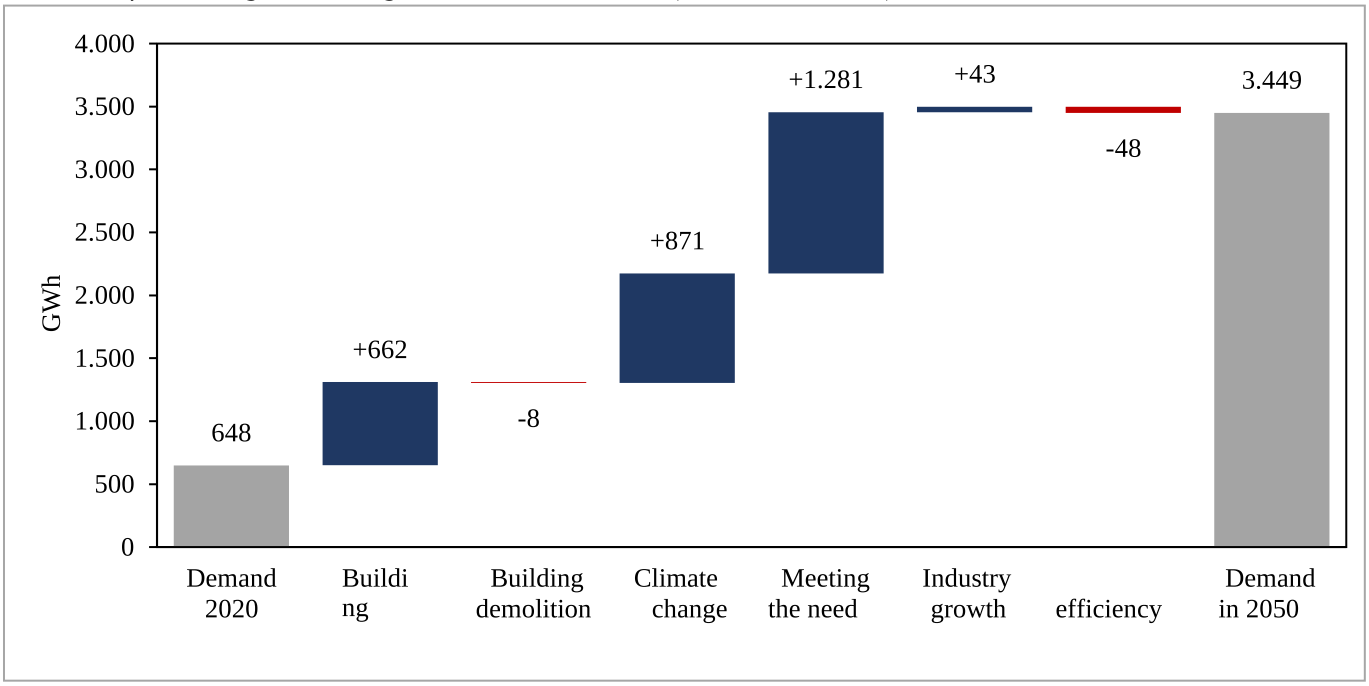
Like in the assessment of heating, in terms of the energy supply chain, these expectations are divided into two groups: increasing the efficiency of cooling demand and enhance the efficiency of cooling supply.

Potential for enhancing cooling demand efficiency

Cooling demand (UEC) in 2020 is estimated at 0.6 TWh. Unlike the heating sector, whereas heat during the cold season is indispensable in terms of servicing basic human needs, cooling in the climate zone concerned is still not an indispensable service. This is also confirmed by the assessment that a significant part of the need for cooling is unmet. Actual cooling consumption in the service sector is estimated at 10% while the need for cooling in households is estimated at only 1%.

It is the change in the level of meeting the need for cooling that constitutes the most significant part of the change in the projected cooling demand. The baseline scenario for projected cooling demand estimates that cooling demand will increase about fivefold in 2050 (from 0.6 TWh in 2020 to 3.4 TWh in 2050).

Forecast of the change in cooling demand in 2020-2050 (baseline scenario), UEC, TWh



Potential for enhancing cooling supply efficiency

As described above, long-term strategic objectives for the energy sector shape two main strands of action for enhancing heating supply efficiency:

- Efficient infrastructure: a key measure to control PEC intensity.
- Sustainable fuel mix: a key measure to control GHG emissions.

An analysis of the existing cooling supply structure has revealed that:

- Cooling is generated in a decentralised manner using high-efficiency technology (heat pumps).
- The technologies used will not generate GHG emissions by 2050 and will have the RES share of 100% in the production structure (in the most probable scenario for the development of the electricity sector).

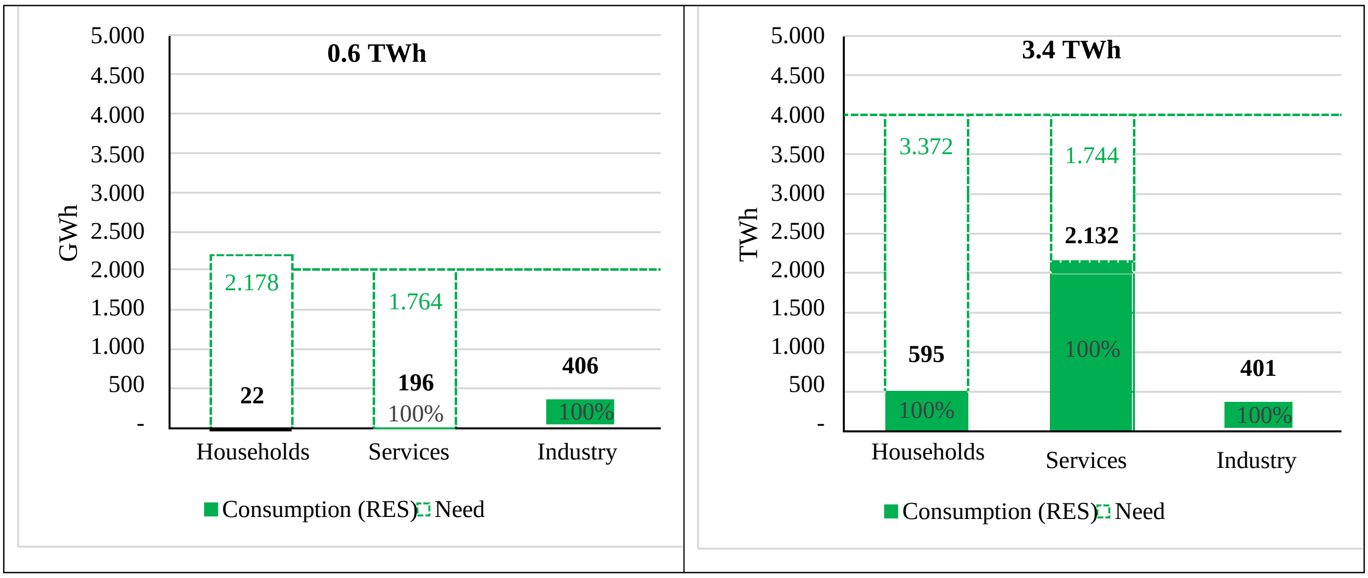
Taking into account the objectives set for the cooling sector, the most probable scenarios for the development of the sectors concerned and the analysis of the current situation, the following priority strands of action for enhancing supply efficiency are established.

Summary of supply efficiency targets

Sector	Efficiency indicators in 2020		Strands of action for enhancing efficiency (2050)	
	Infrastructure efficiency	Fuel sustainability	Cooling sector	Sectors concerned
Centralised cooling	-	-	• Rational development by increasing production efficiency	• RES share in the electricity generation structure (100%)
Decentralised cooling	High	High[6]	• Maintaining the RES share in the production structure	

Once the planned efficiency enhancing tasks have been completed, the following indicators for the cooling sector can be forecast for 2050.

Cooling demand and supply UEC in 2050



As can be seen, in the baseline scenario:

- The need for cooling energy is increasing (from 5.1 to 9.1 TWh);
- There is a significant increase in the level of meeting the need (from 13 to 38%) and, accordingly, in the demand for cooling (from 0.6 to 3.4 TWh);
- The RES share of 100% is maintained in the production structure.

In addition, an assessment of the potential of district cooling supply was carried out (for more information see Chapter 9.4.2), during which the preliminary potential of district cooling supply in Vilnius and Kaunas cities was established at up to 1 TWh. Forecasts for the cooling sector in the baseline scenario for 2050 are presented below.

Projected indicators for the cooling sector for 2050

Sector	Objective for 2050	Target indicators	Baseline scenario indicators
Cooling sector	T1. Decrease in FEC intensity	*Not set*	3.4 TWh
	T2. Decrease in PEC intensity	*Not set*	3.4 TWh
	T3. GHG emissions	0 kt CO_2	0 kt CO_2
	T4. RES share in the DH sector	100%	100%
	T5. RES share in the decentralised sector	100%	100%

In the baseline scenario, all target indicators set for the objectives (T3-T5) are fully met.

6 The most probable scenario for the development of the electricity sector

2. CONTEXT AND OBJECTIVES OF THE STUDY

Energy efficiency is one of the most important long-term strategic objectives in Lithuania's energy sector:

- Improve the financial situation of the country's population;
- Boost the competitiveness of businesses;
- Reduce greenhouse gas emissions;
- Improve ambient air quality (by reducing ambient air pollution).

The aim is to make enhanced energy efficiency and the use of renewable energy sources part of daily life of every household, business or industry purchasing electricity, gas, biofuels or other fuels or raw materials.

The goal of enhanced energy efficiency is defined in the National Energy Independence Strategy of Lithuania[7] (NEIS) and other strategic documents at national level regulating Lithuania's energy efficiency or renewable energy targets.

Given that the heating and cooling sector is the most important final energy consumption sector at EU level (consuming about 50% of total EU energy demand) and 80% of this energy is consumed in buildings, Article 14 of Directive 2012/27/EU ('the EED') requires each Member State to carry out and notify to the Commission a comprehensive assessment of the potential for efficient heating and cooling.

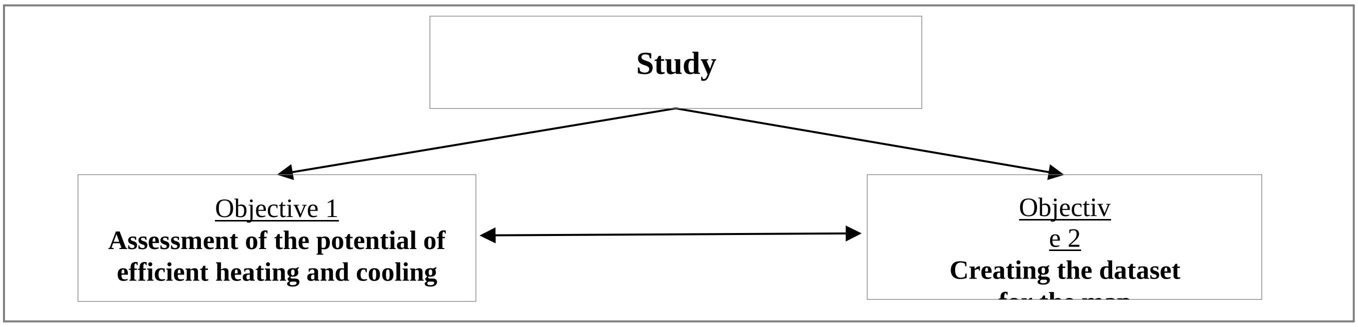
In addition, in accordance with Annex VIII to the EED, a comprehensive national assessment of the potential for efficient heating and cooling supply must include a map of the entire territory of the country showing the sources and infrastructure of heating and cooling demand ('the heating and cooling map').

The heating and cooling map as a tool is drawn up outside of the scope of this Study but it is planned that the dataset collected in the course of the Study will be the basis for the creation of the database for the interactive map.

Accordingly, the following main objectives of the Study are established:

1. To carry out a comprehensive assessment of the potential for efficient heating and cooling in Lithuania.
2. To collect and/or generate data necessary for the preparation of an interactive heating and cooling map.

Figure 1. Objectives of the Study



Source: authors of the Study

7 Approved by the Seimas of the Republic of Lithuania by Resolution No. XIII-1288 of 21 June 2018 approving the National Energy Independence Strategy.

Assessment of the potential of efficient heating and cooling

The design of the Study as much as feasible is in line with the recommended assessment design set out in the Commission Recommendation on the content of the comprehensive assessment of the potential for efficient heating and cooling under Article 14 of Directive 2012/27/EU ('the Recommendation')[8].

The main tasks of the comprehensive assessment of Lithuania's potential for efficient heating and cooling are as follows:

1. To assess the current demand for heating and cooling (Chapter 4);
2. To make a long-term forecast of heating demand (Chapter 5);
3. To make a long-term forecast of cooling demand (Chapter 6);
4. To assess the current heating and cooling supply (Chapter 7);
5. To carry out an assessment of the potential for efficient heating in order to identify optimal solutions for meeting heating demand (Chapter 8);
6. To carry out an assessment of the potential for efficient cooling in order to identify optimal solutions for meeting cooling demand (Chapter 9);
7. To conduct an analysis of policy measures in order to identify the need to revise existing policy measures or to introduce new ones with a view to creating preconditions for the implementation of optimal solutions to meet demand (Chapter 10).

At the beginning of each chapter, there is a summary of the essential provisions of the Recommendation that apply to a specific task.

Creating the dataset for the heating and cooling map

In accordance with Annex VIII of the EED, a map of a country's territory needs to show (with sensitive information being protected) the sources of heating and cooling demand and supply infrastructure, with a spatial dimension, in order to identify potential synergies. All information should be presented in separate layers, distinguishing between geographical and system boundaries, energy production and energy consumption.

Although the scope of this Study does not include the drawing up of a map as a tool, part of the map information is used directly in assessing the potential for efficient heating and cooling, e.g. geographical coordinates of buildings are used during the cost-benefit analysis in order to identify the development potential of district heating supply systems. Accordingly, the creation of the data set for the map is considered an integral part of the process of assessing the potential for enhancing heating and cooling efficiency and the synergies between consumers and potential suppliers.

Taking into account the requirements applicable to the dataset of the interactive heating and cooling map, the decision was taken to make the dataset based on the Real Estate Register ('NTR'), accumulating the required attributes and data at the level of each building.

8 Commission Recommendation (EU) 2019/1659 of 25 September 2019 on the content of the comprehensive assessment of the potential for efficient heating and cooling under Article 14 of Directive 2012/27/EU.

3. LIMITS AND KEY PARAMETERS OF THE STUDY

Limits of the Study

In accordance with point 1 of Annex VIII to the EED, Member States are required to provide final energy consumption (FEC) data for heating and cooling in household, service and industry sectors and in all other sectors, each of which accounts for more than 5% of total national useful heating and cooling demand (UEC).

In order to identify the level of heating and cooling demand in the sector, we carried out an analysis of Lithuania's fuel and energy balance in 2020 ('the energy balance'). The energy balance is the main statistical source of EU Member States' energy consumption data revealing information on the sources and consumption of the country's energy resources and forms of energy.

In accordance with the energy balance data, energy needs[9] in Lithuania in 2020 consumed a total of 62.1 TWh of final energy.

1 Table. Lithuania's FEC in 2020, GWh

Sector	DH system	Gas	Electricity	RES fuel	Ambient energy	Fossil fuels	Total
Households	4.889	2.028	3.045	5.357	323	1.033	**16.675**
Services	1.836	807	3.301	414	16	324	**6.699**
Industry	1.793	3.178	3.594	1.443	10	1.393	**11.413**
Transport	-	333	72	1.197	-	23.872	**25.473**
Agriculture	40	236	195	200	1	650	**1.322**
Construction	16	198	147	26	-	117	**504**
Fisheries	-	-	2	-	-	8	**10**
Total	**8.575**	**6.780**	**10.355**	**8.636**	**351**	**27.398**	**62.096**

Source: Statistics Lithuania

Based on our assessment[10], in 2020 Lithuania's UEC came up to 58.5 TWh.

2 Table. Lithuania's UEC in 2020, GWh

Sector	DH system	Gas	Electricity	RES fuel	Ambient energy	Fossil fuels	Total
Households	4.889	1.844	3.045	4.464	339	908	**15.489**
Services	1.836	734	3.301	376	388	273	**6.908**
Industry	1.793	2.890	3.594	1.312	317	1.267	**11.172**
Transport	-	302	72	1.088	6	21.702	**23.170**
Agriculture	40	215	195	182	17	591	**1.239**
Construction	16	180	147	23	12	107	**485**
Fisheries	-	-	2	-	0	7	**10**
Total	**8.575**	**6.164**	**10.355**	**7.445**	**1.079**	**24.854**	**58.473**

Source: authors of the Study

When comparing FEC with UEC, it is important to pay attention to the following:

- In the case of DH, FEC is equal to UEC as all thermal energy supplied to the consumer at the inlet of the house is considered to be used for space heating (losses in the internal networks of the house are negligible);
- In the case of ambient energy, additional UEC is calculated on the basis of the electricity consumption for space heating and cooling, considering the use of heat pumps with COP 2.7 efficiency.

9 Excluding fuel consumption for inputs and energy transformation.

10 The energy balance provides information on final energy consumption (FEC). More detailed information on useful energy consumption (UEC) calculations is provided in Annex 2.1.

Based on our assessment[11], in 2020 UEC for heating and cooling came up to 25.6 TWh.

3 Table. Lithuania's UEC for heating and cooling in 2020, GWh

Sector	Total UEC	UEC for other than heating and cooling			UEC for heating and cooling	
		Electricity	Transport fuels	Other		
Households	**15.489**	-2.966	-	-184	12.339	48%
Services	**6.908**	-3.072	-	-	3.836	15%
Industry	**11.172**	-3.407	-	-	7.765	30%
Transport	**23.170**	-69	-22.790	-	312	1%
Agriculture	**1.239**	-186	-	-	1.053	4%
Construction	**485**	-139	-	-	346	1%
Fisheries	**10**	-2	-	-	8	0%
Total	**58.473**	**-9.841**	**-22.790**	**-424**	**25.659**	**100%**

Source: Statistics Lithuania, authors of the Study

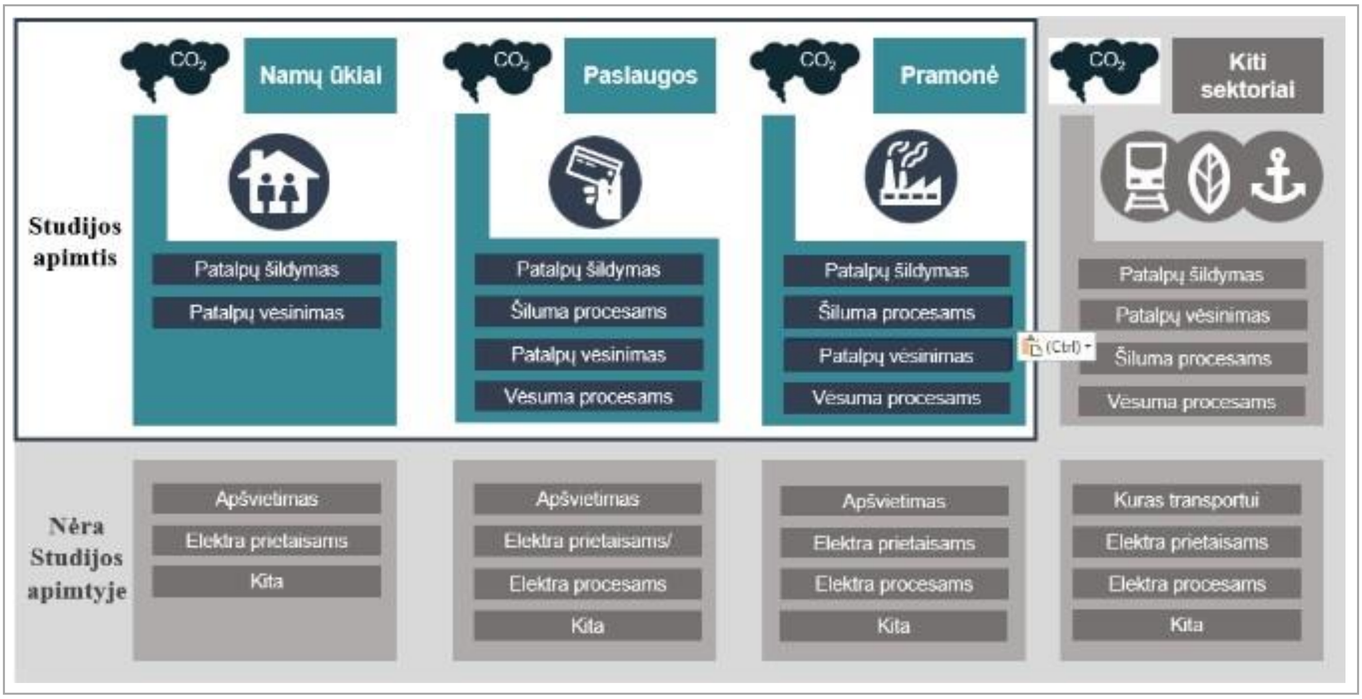
Looking at the level of some sectors' UEC for heating and cooling, it can be observed that in 2020:

- Households consumed 48.1% of the total UEC for heating and cooling;
- The service sector consumed 15.0% of the total UEC for heating and cooling;
- The industry sector consumed 30.3% of the total UEC for heating and cooling;
- All other sectors consumed less than 5% of the total UEC to heating and cooling.

Accordingly, the scope of the Study covers an assessment of the following sectors consuming >5% of the total UEC for heating and cooling:

1. Households: space heating and cooling;
2. The service sector: space heating and cooling as well as heat and cooling for processes;
3. The industry sector: space heating and cooling as well as heat and cooling for processes.

2 Figure. Limits of the Study



Source: authors of the Study

11 More detailed information is provided in Annex 2.1.

Essential parameters of the Study

The essential parameters of the Study are important for proper interpretation of the Study results and further decision making:

a) Definitions of heating and cooling;

b) Types of energy by metering point;

c) Assessment periods.

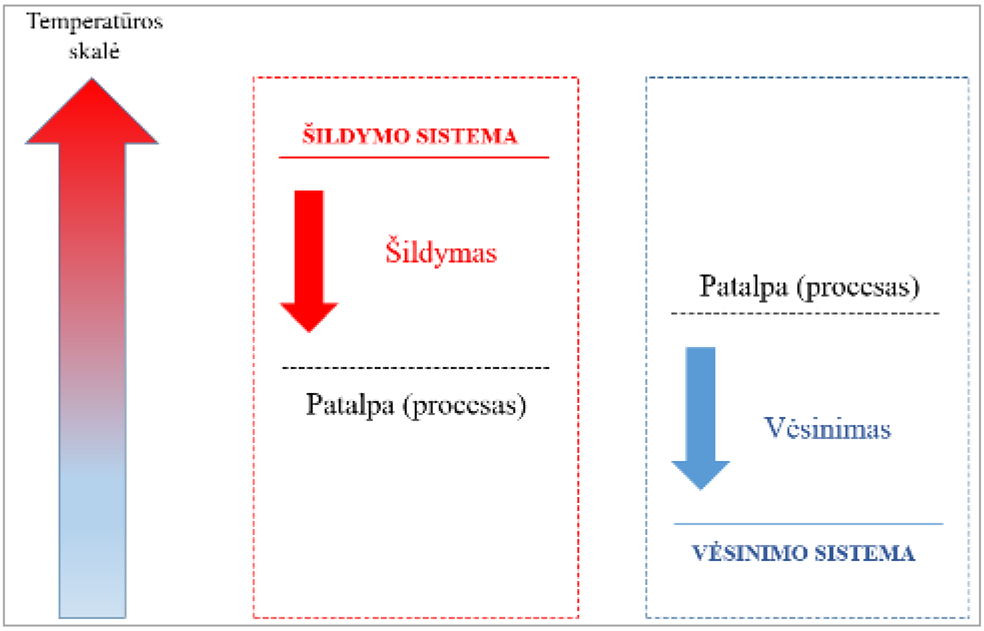
a) Definition of heating and cooling

The scope of the Study assesses energy required for heating and cooling.

- Heating is supplying heat to an enclosed space (or a process) in order to increase or maintain the temperature of a room or a process. The difference between the temperature provided by the heating system and the temperature of the room (or the process) ensures heat transfer. The amount of heat transferred to the room (or the process) is considered to be the heat supplied.
- Cooling is extracting heat from an enclosed space (or a process) in order to reduce or maintain the temperature of a room or a process at a certain level. The difference between the temperature provided by the cooling system and the temperature of the room (or the process) ensures heat extraction. The amount of heat extracted from the room (or the process) is considered to be the cooling supplied.

An illustration of the principles of heating and cooling is given in the figure below (the arrows represent the supply of heat to the room and its extraction from the room).

3 Figure. Heating and cooling principles



Source: the study commissioned by the EC[12]

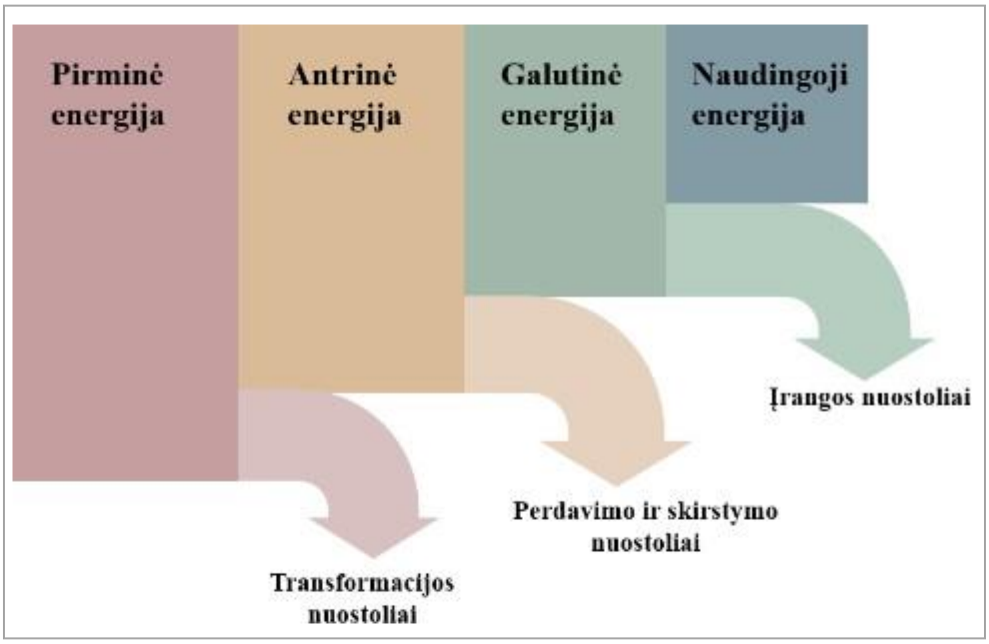
12 Study "Renewable Cooling under the Revised Renewable Energy Directive ENER/C1/2018-493"

b) Types of energy by metering point

Energy required for supplying heating and cooling is divided into four main types by metering point:

- Primary energy means energy from natural resources, i.e. energy accumulated in organic fuels (oil, peat, biomass, etc.), nuclear energy, water power energy and energy of wind, solar, geothermal and chemical processes.
- Secondary energy means primary energy transformed in generating installations and prepared for transmission to consumers (electricity, liquid fuels, district heating, etc.).
- Final energy means energy supplied to final customers: industry, construction, agricultural and businesses in other areas of economic activity as well as households.
- Useful energy means all heating and cooling energy required by final consumers after all stages of energy transformation in heating and cooling systems/equipment.

4 Figure. Types of energy by metering point



Source: Our World In Data[13]

The main findings of the Study are presented in terms of final energy consumption (FEC) and useful energy consumption (UEC).

In order to properly interpret the findings of the Study, it is important to understand practical differences between FEC and UEC. In the example shown in the table below, the final energy consumption of two identical multi-apartment buildings consuming the same amount of primary energy (fuel) and having the same demand for useful energy will differ depending on the type of source:

- In the case of a DH-run boiler, final energy consumption will correspond to the amount of energy supplied to the building;
- In the case of an individual boiler, final energy consumption will correspond to the amount of fuel consumed.

4 Table. Sample calculation of FEC and UEC

Source of production	Primary energy	Final energy	Useful energy
DH-run biofuel boiler	107,5	100,0	100,0
Individual biofuel boiler	107,5	107,5	100,0

Source: authors of the Study

13 Project "Our World In Data": https://ourworldindata.org/.

It is also important to note that energy required to supply heating and cooling analysed within the scope of the Study does not include fuel consumption as inputs (e.g. use of gas for fertiliser production) and energy transformation (heat and power generation).

c) Assessment periods

In accordance with the EED provisions, the assessment must include:

1. Data on the current heating and cooling supply to final consumption sectors (current demand);
2. Data on the previous share of energy from waste heat or cooling in the last five years (demand in earlier periods);
3. Forecast trends in demand for heating and cooling for the next 30 years (forecast demand for future periods).

At the same time, final energy consumption for heating and cooling should be based on real, measured and verified information, as provided for in European energy statistics and in national energy and fuel balances.

When the Study was being drawn up, Lithuania's energy and fuel balance data were only available for 2020. As the energy balance data is one of the main control points for the calculations, the following assessment periods have been established:

1. Current demand: 2020.
2. Demand in earlier periods: 2015-2019.
3. Forecast demand for future periods: 2021-2050.

4. HEATING AND COOLING DEMAND

Recommendation 2.1.1. In accordance with point 1 of Annex VIII to the EED, Member States are required to provide the latest quantitatively assessed final energy consumption (FEC) data for heating and cooling in household, service and industry sectors and in all other sectors, each of which accounts for more than 5% of total national useful heating and cooling demand. Member States must also assess and notify the demand for useful heating energy consumption (UEC) in those sectors. Each sector's FEC and UEC must be given in GWh.

Based on our assessment, in the sectors included in the scope of the Study[14] in 2020 UEC for heating and cooling came up to 23.9 TWh.

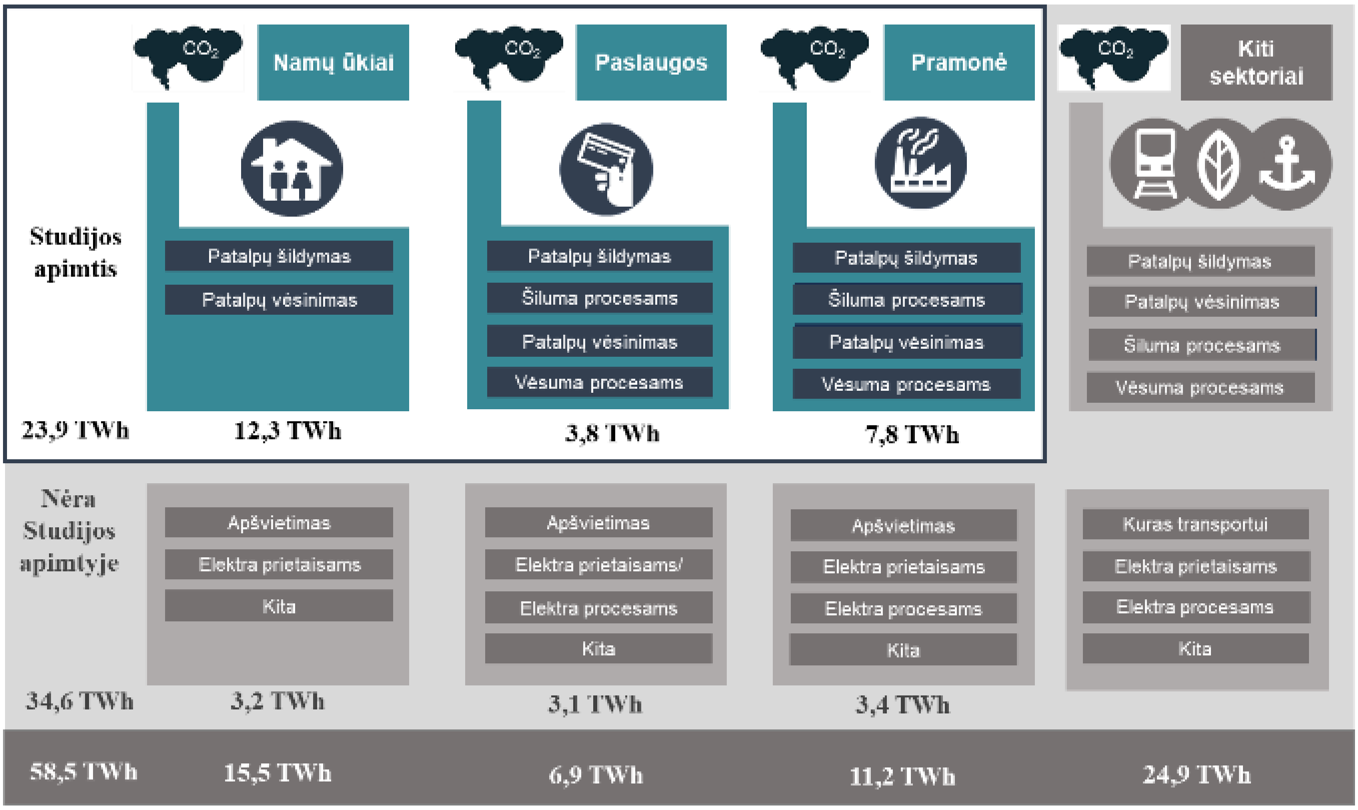
5 Table. Lithuania's UEC and FEC for heating and cooling in 2020, GWh

Sector	Total energy balance		Heating and cooling
	FEC	UEC	UEC
Households	16.675	15.487	12.339
Services	6.699	6.895	3.836
Industry	11.413	11.172	7.765
Total	**34.787**	**33.554**	**23.940**

Source: Statistics Lithuania, authors of the Study

This figure was about 41% of the country's total UEC in 2020[15].

5 Figure. Limits of the Study in terms of UEC



Source: Statistics Lithuania, authors of the Study

14 Consuming more than 5% of total UEC for heating and cooling (see Table 3).

15 A major part of UEC not included in the scope of the Study was transport fuel consumption: 22.8 TWh or 38% UEC (see Table 3).

Taking into account the limits of the Study, the specifics of the sectors concerned and the origin of (reasons for) the emergence of heating and cooling demand in the respective sector, the following six basic segments of heating and cooling demand listed in the table below have been established.

6 Table. Heating and cooling demand segments

Sector	**Demand segment**		**UEC 2020, GWh**	
	Heating demand	**Cooling demand**	**Heating demand**	**Cooling demand**
Households	A1	A2	12.314	25
Services	B1	B2	3.619	217
Industry	C1	C2	7.359	406
Total			**23.292**	**648**
			23.940	

Source: authors of the Study

The following demand segments are described in terms of the results of the comprehensive assessment of current demand for heating and cooling (Objective 1):

- Segment A1: Household demand for heating (Chapter 4.3.1);
- Segment A2: Household demand for cooling (Chapter 4.3.2);
- Segment B1: Heating demand in the service sector (Chapter 4.4.1);
- Segment B2: Cooling demand in the service sector (Chapter 4.4.2);
- Segment C1: Heating demand in the industry sector (Chapter 4.5.1);
- Segment C2: Cooling demand in the industry sector (Chapter 4.5.2);
- Summary results (Chapter 4.6).

To take stock of the data accumulated on the national level and necessary for both the assessment of heating and cooling demand (Objective 1) and the drawing up of an interactive heating and cooling map (Objective 2), the following has been performed:

- Analysis of heating consumers (Chapter 4.1) and
- Analysis of cooling consumers (Chapter 4.2).

4.1. HEATING DEMAND ANALYSIS

The analysis of heating demand is the first stage in the assessment of heating demand aimed at taking stock of, structuring and characterising data on heat consumers collected at the national level.

Since one of the aims of the Study is to collect data on heating demand necessary for the drawing up of the heating and cooling map, the analysis of demand was carried out at the level of a specific consumer (building), assigning to them not only the attributes necessary for assessing demand but also geographical coordinates. The national building stock based on the data from the RPR[16] is the Lithuanian Building Database as of 31 December 2020.

4.1.1. Analysis of heating consumers

Having compiled the heating consumer base, we proceeded to carry out an analysis of heating consumers (buildings) in order to:

a) Identify consumers for whom the actual heating consumption demand can be established;

b) Assign attributes to consumers who do not have actual demand data to group consumers into benchmark categories so that a specific benchmark reflects their specific heating demand for a building;

c) Identify consumer groups that consume heat for processes (both manufacturing and services).

To achieve these objectives, we performed the analysis of heating consumers from the following viewpoints:

- By type of heating supply;
- By energy performance class;
- By year of construction;
- By property type.

Heating consumers by type of heating supply

The first step of the analysis is to identify consumers connected to DH systems ('DH systems') as actual data on heating consumption are collected for this segment of consumers at the level of each DH system.

The heating consumer base by connection to the DH system (RPR data) as a number and in thousand m^2 is presented in the tables below.

7 Table. Heating consumers by type of heating supply (number)

Group, subgroup	DH system		Total	Connected, %
	Connected	Not connected		
1. Residential	26.872	436.421	463.293	**6%**
1.1. Single-family	6.241	418.313	424.554	1%
1.2. MAB (S)	1.161	10.317	11.478	10%
1.3. MAB (M)	18.622	7.758	26.380	71%
1.4. MAB (L)	848	33	881	96%
2. Service sector	11.466	29.249	40.715	**28%**
2.1. Services	2.030	10.494	12.524	16%
2.2. Administrative	1.751	6.440	8.191	21%
2.3. Trade	4.083	5.725	9.808	42%
2.4. Other	3.602	6.590	10.192	35%
3. Industry	3.911	39.432	43.343	**9%**
Total	**42.249**	**505.102**	**547.351**	**8%**
Total, %	8%	92%	100%	

Source: RPR data (31 12 2020)

16 Detailed information is provided in Annex 3.1.

8 Table. Heating consumers by type of heating (thou m²)

Group, subgroup	DH system		Total	Connected, %
	Connected	Not connected		
1. Residential	40.935	51.657	**92.592**	**44%**
1.1. Single-family	876	44.660	**45.536**	2%
1.2. MAB (S)	242	1.856	**2.098**	12%
1.3. MAB (M)	34.427	4.889	**39.316**	88%
1.4. MAB (L)	5.390	253	**5.643**	96%
2. Service sector	22.853	13.996	**36.848**	**62%**
2.1. Services	3.830	3.456	**7.285**	53%
2.2. Administrative	3.752	3.057	**6.809**	55%
2.3. Trade	6.759	3.271	**10.031**	67%
2.4. Other	8.512	4.212	**12.724**	67%
3. Industry	7.606	25.868	**33.473**	**23%**
Total	71.394	91.520	**162.914**	**44%**
Total, %	**44%**	**56%**	**100%**	

Source: RPR data (31 12 2020)

In order to assess the reliability of the RPR data, the data were compared with the information provided by the Lithuanian District Heating Association ('the LDHA').

9 Table. Buildings connected to DH systems (number and thou m²)

Group	LDHA data		RPR data		Difference	
	Number	Heated area	Number	Heated area	Number	Heated area
Single-family	2.102	281	6.241	876	197%	212%
Multi-apartment	18.508	37.672	20.631	40.059	15%	6%
Non-residential	7.878	16.078	15.377	30.459	95%	89%
Total	**28.488**	**54.031**	**42.249**	**71.394**	**48%**	**32%**

Source: LDHA (31 12 2020), authors of the Study

Note that , with the exception of multi-apartment buildings, the data of the LDHA and the RPR differ significantly. Within the scope of this Study, the LDHA data are considered more reliable, so they are used to assess the demand for district heating.

To sum up the above data provided by the LDHA, it can be said that:

- Various indicators on the connection of groups of buildings to DH systems are fundamentally different: about 80% of the surface area in the segment of multi-apartment buildings is connected to DH systems, while in the individual consumer segment it is only about 1% of the surface area.
- About 33% of the total surface area of the heating consumer base is connected to DH systems. Actual consumption data for this segment can be used as a basis for estimating heating demand for buildings for which no actual demand data are available.

Heating customers by energy performance class

The energy performance class is one of the indicators based on which the need for heating in buildings can be calculated in cases where no actual demand data are available.

Information on energy performance certificates issued is collected in a register[17] managed by the State Enterprise Centre for the Certification of Construction Products ('the SPSC Register'). The RPR also collects information (an attribute) on the energy performance class (EPC) of buildings. The tables below show the view of the heating consumer base by data on building-specific ENC certificates (if any) as a number and in thousand m².

17 https://www.spsc.lt/cms/index.php?option=com_wrapper&view=wrapper&Itemid=288&lang=lt.

10 Table. Heating consumers by EPC (number)

Group, subgroup	Buildings, total	EPC							Certified, %
		<D	C	B	A	A+	A++	Total	
1. Residential	463.293	78.537	19.665	29.851	3.222	3.189	56	134.520	**29%**
1.1. Single-family	424.554	53.426	16.632	27.580	3.045	3.056	41	103.780	24%
1.2. MAB (S)	11.478	6.096	160	159	15	6	0	6.436	56%
1.3. MAB (M)	26.380	18.420	2.774	2.007	149	118	13	23.481	89%
1.4. MAB (L)	881	595	99	105	13	9	2	823	93%
2. Service sector	40.715	6.128	2.354	2.666	230	239	6	11.623	**29%**
2.1. Services	12.524	1.294	616	915	66	87	3	2.981	24%
2.2. Administrative	8.191	1.123	327	659	66	90	2	2.267	28%
2.3. Trade	9.808	2.318	506	474	63	37	0	3.398	35%
2.4. Other	10.192	1.393	905	618	35	25	1	2.977	29%
3. Industry	43.343	1.121	327	787	54	66	17	2.372	**5%**
Total	**547.351**	**85.786**	**22.346**	**33.304**	**3.506**	**3.494**	**79**	**148.515**	**27%**
Total, %		58%	15%	22%	2%	2%	0%		

Source: SPSC register, RPR data

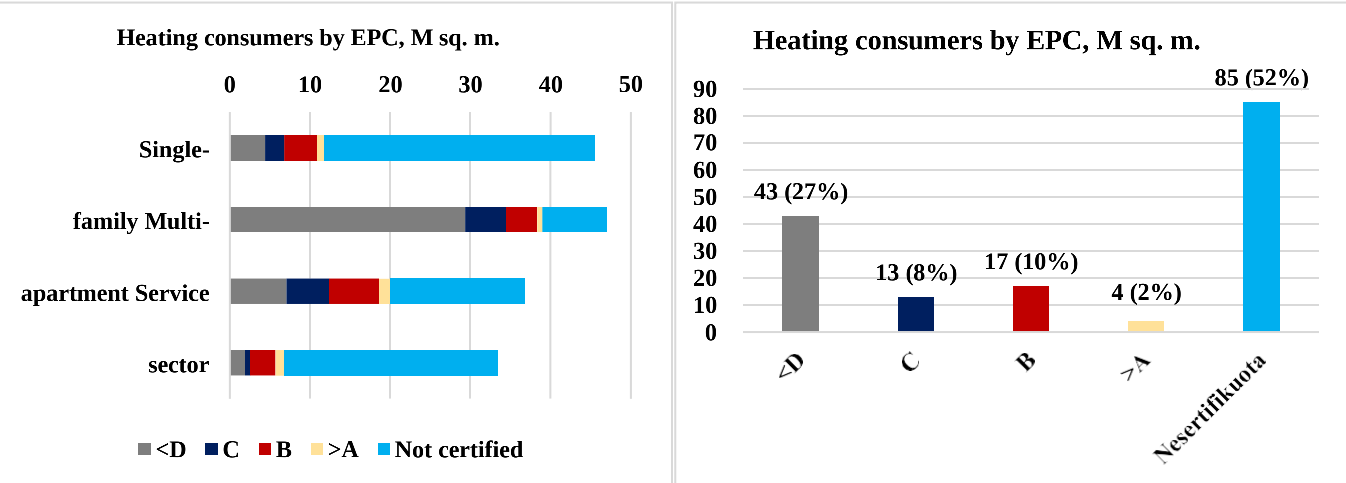
11 Table. Heating consumers by EPC (thou m²)

Group, subgroup	Buildings, total	Certified							Certified, %
		<D	C	B	A	A+	A++	Total	
1. Residential	92.592	33.854	7.453	8.019	761	618	51	50.755	**55%**
1.1. Single-family	45.536	4.462	2.391	4.110	421	366	7	11.758	26%
1.2. MAB (S)	2.098	477	30	32	4	1	0	543	26%
1.3. MAB (M)	39.316	25.372	4.364	3.098	227	175	26	33.262	85%
1.4. MAB (L)	5.643	3.544	668	779	109	75	18	5.192	92%
2. Service sector	36.848	7.087	5.351	6.165	748	678	5	20.033	**54%**
2.1. Services	7.285	1.278	991	1.431	110	105	2	3.918	54%
2.2. Administrative	6.809	800	888	2.049	121	171	2	4.031	59%
2.3. Trade	10.031	2.558	937	971	467	314	0	5.247	52%
2.4. Other	12.724	2.451	2.534	1.714	49	88	1	6.837	54%
3. Industry	33.473	1.913	642	3.164	324	466	230	6.739	**20%**
Total	**162.914**	**42.854**	**13.446**	**17.347**	**1.832**	**1.762**	**286**	**77.527**	**48%**
Total, %		55%	17%	22%	2%	2%	0%		

Source: SPSC register, RPR

Aggregated data according to the ENC of heating consumers are presented in the figure below.

Figure 6. Heating consumers by EPC (aggregate)



Source: SPSC register, RPR

To sum up the data, it can be observed that:

- Based on the combined data of the RPR and the SPSC register, only 27% of buildings have the attribute of EPC (48% by surface area).
- Most of the buildings certified are of sizes M and L (over 300 m^2 in size) in the multi-apartment segment (85-92%).
- The fewest certified buildings are in the single-family house (26%) and the industry (20%) segments.

Heating consumers by year of construction

Since only about a quarter of heating consumers (by number) have the attribute of EPC assigned to them, we proceeded to carry out an analysis based on the year of construction of buildings. The use of appropriate assumptions allows the year of construction of a building to be linked to the corresponding EPC and the need for heating demand in buildings to be calculated in cases where neither actual demand nor EPC data are available.

The tables below show the view of the heating consumer base by year of completion of construction of the building as a number and in thousand m^2.

12 Table. Heating consumers by construction completion year (number)

Group, subgroup	Year of construction							Total	Total, %
	before 1900	1901-1960	1961-1992	1993-2005	2006-2013	2014-2019	2020		
1. Residential	7.287	123.588	216.743	29.058	37.041	42.261	7.315	463.293	85%
1.1. Single-family	5.984	111.927	195.519	27.361	36.001	40.661	7.101	424.554	78%
1.2. MAB (S)	907	7.506	2.835	58	53	113	6	11.478	2%
1.3. MAB (M)	396	4.147	17.798	1.545	876	1.426	192	26.380	5%
1.4. MAB (L)	0	8	591	94	111	61	16	881	0%
2. Service sector	1.645	7.333	21.129	4.527	2.799	2.887	395	40.715	7%
2.1. Services	158	1551	6355	1263	1421	1563	213	12.524	2%
2.2. Administrative	91	1183	3724	1852	619	628	94	8.191	1%
2.3. Trade	215	2004	5946	893	381	319	50	9.808	2%
2.4. Other	1181	2595	5104	519	378	377	38	10.192	2%
3. Industry	411	5.127	30.049	3.750	2.048	1.717	241	43.343	8%
Total	**9.343**	**136.048**	**267.921**	**37.335**	**41.888**	**46.865**	**7.951**	**547.351**	
Total, %	2%	25%	49%	7%	8%	9%	1%		

Source: RPR data (31 12 2020)

13 Table. Heating consumers by construction completion year (thou m^2)

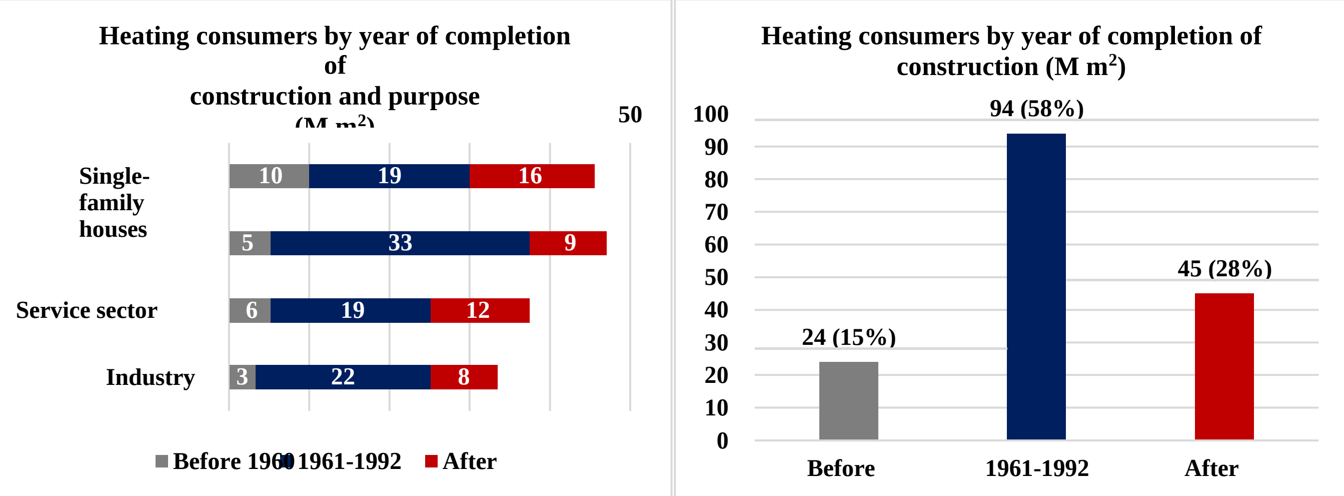
Group, subgroup	Year of construction							Total	Total, %
	before 1900	1901-1960	1961-1992	1993-2005	2006-2013	2014-2019	2020		
1. Residential	967	14.123	52.514	7.374	7.733	8.468	1.413	92.592	**57%**
1.1. Single-family	591	9.831	19.095	3.994	5.287	5.805	933	45.536	28%
1.2. MAB (S)	166	1.360	519	13	12	26	1	2.098	1%
1.3. MAB (M)	211	2.877	29.365	2.744	1.606	2.166	347	39.316	24%
1.4. MAB (L)	0	54	3.535	623	828	471	132	5.643	3%
2. Service sector	823	4.876	19.414	3.891	4.074	3.208	562	36.848	**23%**
2.1. Services	96	879	3.912	702	818	807	71	7.285	4%
2.2. Administrative	45	466	2.170	1.526	1.636	885	80	6.809	4%
2.3. Trade	165	1.495	5.508	897	848	789	329	10.031	6%
2.4. Other	517	2.037	7.824	765	772	727	82	12.724	8%
3. Industry	203	3.106	21.801	3.143	2.555	2.151	514	33.473	**21%**
Total	**1.994**	**22.105**	**93.729**	**14.408**	**14.362**	**13.827**	**2.488**	**162.914**	

Total, %	1%	14%	58%	9%	9%	8%	2%		

Source: RPR data (31 12 2020)

Aggregated data according to the year of completion of construction of the building are presented in the figure below.

Figure 7. Heating consumers by construction completion year (aggregate)



Source: RPR data (31 12 2020)

To sum up the above data of the analysis of the year of construction, it can be noted that:

- The absolute majority of buildings by surface area (73%) in Lithuania were built before 1993.
- In general, this means that insulation materials were not used for better thermal insulation of these buildings and the thermal resistance of the building depended solely on the specific thermal resistance of the building materials.
- As a significant part of these buildings has not been essentially renovated, a large part of the buildings (especially in the multi-apartment segment) have low energy efficiency.

Heating consumers by type of ownership

The property type attribute is not directly linked to the need for heating demand but is important in shaping targeted policy implementation measures (e.g. renovation of buildings) as it may directly cause obstacles to the implementation of measures[18]. The tables below show the view of the heating consumer base by type of ownership as a number and in thousand m^2.

14 Table. Heating consumers by type of ownership (number)

Group	Type of ownership					Total	Total, %
	Private			Public			
	Natural persons	Legal entities	Mixed, other	State	Municipal		
1. Residential	340.936	2.622	118.378	470	887	463.293	**85%**
1.1. Single-family	340.130	2.425	81.181	207	611	424.554	78%
1.2. MAB (S)	671	65	10.644	28	70	11.478	2%
1.3. MAB (M)	133	125	25.691	226	205	26.380	5%
1.4. MAB (L)	2	7	862	9	1	881	0%
2. Service sector	10.127	13.296	7.648	3.575	6.069	40.715	**7%**
2.1. Services	5.165	3.602	2.025	732	1.000	12.524	2%
2.2. Administrative	2.536	3.443	2.094	27	91	8.191	1%
2.3. Trade	1.495	3.904	2.434	1.203	772	9.808	2%
2.4. Other	931	2.347	1.095	1.613	4.206	10.192	2%
3. Industry	10.780	22.703	7.011	1.840	1.009	43.343	**8%**
Total	**361.843**	**38.621**	**133.037**	**5.885**	**7.965**	**547.351**	
Total, %	66%	7%	24%	1%	1%		

Source: RPR data (31 12 2020)

18 Generally speaking, because of the split incentives dilemma.

15 Table. Heating consumers by type of ownership (thou m²)

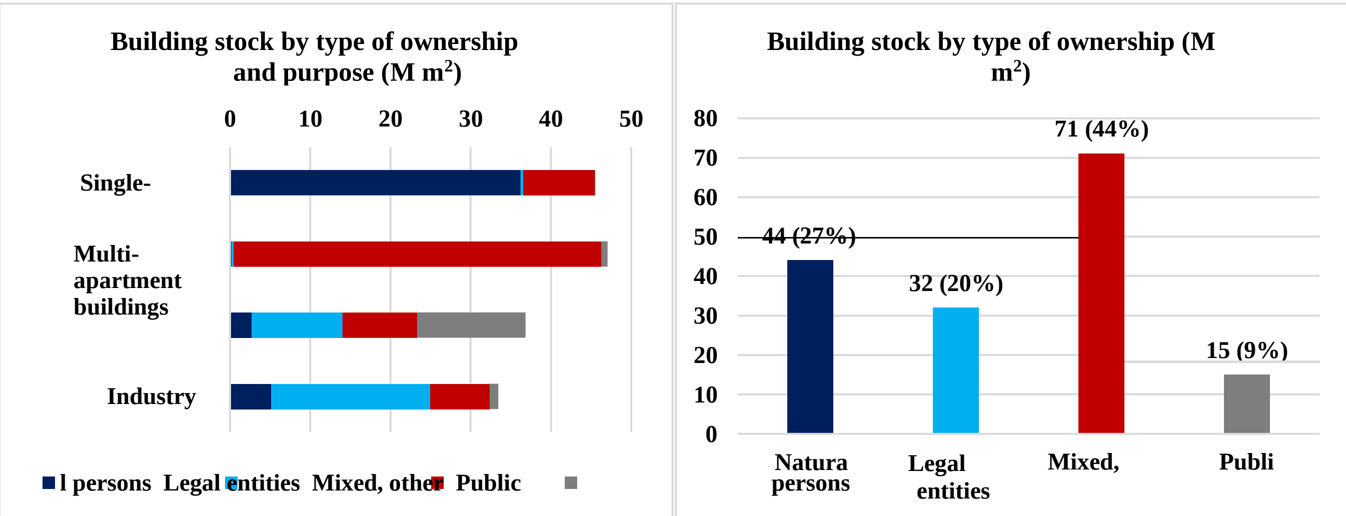
Group	Type of ownership					Total	Total, %
	Private			Public			
	Natural persons	Legal entities	Mixed, other	State	Municipal		
1. Residential	36.434	544	54.771	527	315	92.592	**57%**
1.1. Single-family	36.219	316	8.921	25	55	45.536	28%
1.2. MAB (S)	112	11	1.958	5	11	2.098	1%
1.3. MAB (M)	91	171	38.373	438	243	39.316	24%
1.4. MAB (L)	13	46	5.518	59	5	5.643	3%
2. Service sector	2.697	11.336	9.278	5.199	8.339	36.848	**23%**
2.1. Services	1.032	2.136	1.730	1.144	1.243	7.285	4%
2.2. Administrative	610	3.527	2.630	6	36	6.809	4%
2.3. Trade	611	3.907	3.714	1.341	457	10.031	6%
2.4. Other	444	1.766	1.203	2.707	6.603	12.724	8%
3. Industry	5.173	19.836	7.383	837	244	33.473	**21%**
Total	**44.304**	**31.716**	**71.432**	**6.564**	**8.898**	**162.914**	
Total, %	27%	19%	44%	4%	5%	100%	

Source: NTRdata (31 12 2020)

The NTR attribute ‘Mixed ownership’ is defined as joint ownership of natural and legal persons, the State and municipalities, the State and natural and legal persons, municipalities and natural and legal persons. This attribute is also given to buildings for which no ownership rights are registered.

Aggregate building stock data by type of ownership are presented in the figure below.

Figure 8. Heating consumers by type of ownership (aggregate)



Source: RPR data (31 12 2020)

To sum up the data presented in the tables above, it can be said that:

- Nearly half (44%) of buildings by surface area are of mixed ownership, i.e. a situation where the owner of the building is more than one person (e.g. 97% of multi-apartment buildings by surface area are mixed ownership). This situation in general implies a more complex decision-making process than with a single building owner. Decision making is further complicated when a building is owned by different persons by type of ownership, e.g. a part of the building is owned by natural persons while another part is owned by public persons or legal entities.
- 27% of the heating surface area of the building stock are owned by natural persons, which are mostly single-family houses. The implementation of policy measures for this consumer segment is likely to be accelerated due to faster and simpler decision-making and a stronger interest of owners in personal

property.

- 19% of the heating surface area of the building stock are owned by legal entities. Decisions of legal entities to a large extent depend on the return period of investments, which directly depends on the prices of raw materials and energy price levels affecting investment costs.
- 9% of the heating surface area of the building stock are public (municipal and State) ownership. This segment can be controlled from the State perspective.

Summary and conclusions of the analysis

The results of the analysis performed allow the following generalisations and conclusions to be drawn:

1. About one third of the surface area of the heating consumer base is connected to DH systems. The assessment of demand for the district heating segment will be carried out based on actual data provided by heat suppliers (Chapter 4.1.3).
2. The remaining two thirds of the heating consumer base area are heated in a decentralised manner. The assessment of demand for the decentralised heating segment will be carried out in the following order:
   - The assessment of demand of heating customers connected to the gas distribution system (DSO) will be carried out based on actual data provided by the DSO (Chapter 4.1.4).
   - Heating demand of the remaining decentralised heating customers will be assessed based on actual heat consumption data collected from heat suppliers and the DSO, adjusted and normalised as necessary (Chapter 4.1.5).

4.1.2. Heating consumer base

The determination of the heating consumer base is the first step in the assessment of the current heating demand, and taking into account the number of heating consumers, one can further assess how much heating energy each of them might consume.

Data of the Real Estate Register of the Republic of Lithuania ('NTR')[19] on buildings registered in the Republic of Lithuania were used to establish the heating consumer base. In accordance with the NTRdata of 31 December 2020, Lithuania had
about 2.4 million buildings registered, with the total surface area reaching about 264 million m^2 ('the national building stock').

Table 16. National building stock by group

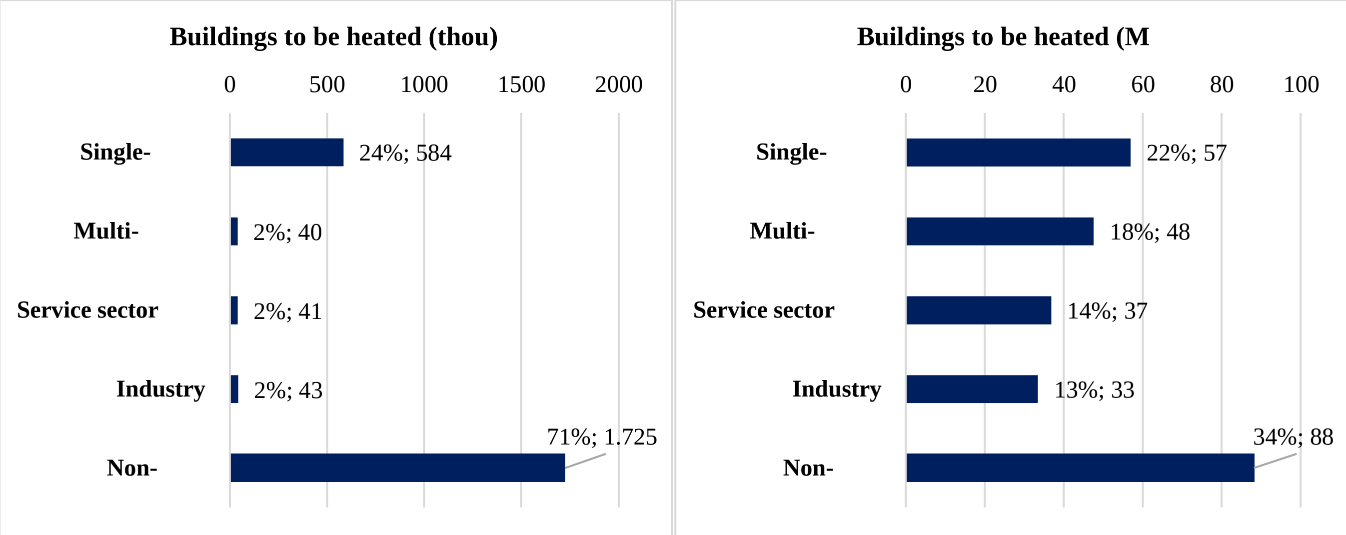
Group of buildings	Subgroup of buildings	Number	Number, %	Total surface area, m^2	Total surface area, %
Heated residential	**Residential**	**624.435**	**26%**	**104.524**	**40%**
	Single-family	584.077	24%	56.941	22%
	Multi-apartment	40.358	2%	47.583	18%
Heated non-residential	**Service sector**	**40.715**	**2%**	**36.849**	**14%**
	Services	12.524	1%	7.285	3%
	Trade	8.191	0%	6.809	3%
	Administrative	9.808	0%	10.031	4%
	Other, services	10.192	0%	12.724	5%
	Industry	**43.343**	**2%**	**33.473**	**13%**
	Total to be heated:	**708.493**	**29%**	**174.846**	**66%**
Non-heated	Non-heated (auxiliary)	1.677.348	69%	65.811	25%
	Non-heated (other)	47.491	2%	22.387	9%
	Total non-heated:	**1.724.839**	**71%**	**88.198**	**34%**
	TOTAL	**2.433.332**		**263.044**	

Source: RPR data (31 12 2020)

Aggregate data of the national building stock by group of buildings are presented in the figure below.

19 Detailed information is provided in Annex 3.1.

Figure 9. National building stock by group of buildings (aggregate)



Source: RPR data (31 12 2020)

The correlation between groups of buildings established for the purposes of this Study and the RPR attributes is presented in the table below.

17 Table. Correlation between building groups and RPR attributes

Group of buildings (the Study)	RPR attribute
Single-family	Residential (one- and two-apartment buildings)
Multi-apartment	Residential (three and more apartments – multi-apartment buildings) Residential (for various social groups)
Industry	Manufacturing and industrial, storage
Services	Hotels Recreatio n Treatment Catering Services
Trade	Trade
Administrative	Administrative
Other heated	Science Culture Transport Sports Special Religious
Non-heated (auxiliary)	Auxiliary, farm (farm structures, barns, nurseries, wood sheds, etc.)
Non-heated (other)	Agricultura l Gardens Greenhous e Farms Garages

Source: authors of the Study

As can be seen from the analysis of the national stock data, the group of buildings 'Unheated' accounts for 71% of the national building stock by number and 34% by surface area.

This group covers buildings which are not subject to the requirements of the Technical Construction Regulation[20] relating to energy performance and for which data on their actual heat consumption were not available in the course of the Study[21].

20 STR 2.01.02:2016 'Energy-efficient building design and certification'.

21 If the data obtained in the course of the Study indicate that a building consumes heat (from the DSO or DH), the building is assigned to the subgroup 'Other heated'.

The part of the national building stock, minus the group of buildings 'Unheated' , is assessed in the scope of the Study as “Buildings to be heated”, i.e. buildings that are heated for their intended purpose if they are properly operated (potential heat consumers).

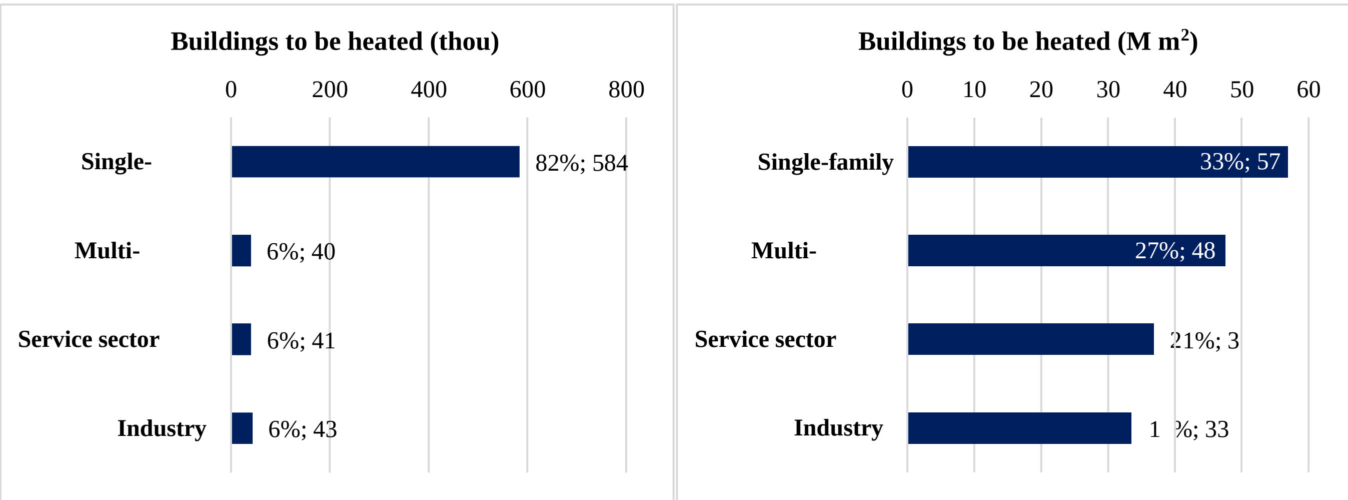
18 Table. Buildings to be heated by group

Subgroup of buildings	**Number**	**Number, %**	**Total surface area, m^2**	**Total surface area, %**
Residential	**624.435**	**88%**	**104.524**	**60%**
Single-family	584.077	82%	56.941	33%
Multi-apartment	40.358	6%	47.583	27%
Service sector	**40.715**	**6%**	**36.848**	**21%**
Services	12.524	2%	7.285	4%
Trade	8.191	1%	6.809	4%
Administrative	9.808	1%	10.031	6%
Other	10.192	1%	12.724	7%
Industry	**43.343**	**6%**	**33.473**	**19%**
TOTAL	**708.493**		**174.846**	

Source: authors of the Study

Aggregate data of buildings to be heated by group of buildings are presented in the figure below.

Figure 10. Buildings to be heated by group (aggregate)



Source: authors of the Study

Moreover, in order to assess the current (2020) heating demand at the building level, an array of heated buildings data (database) has been created.

For this purpose, residential buildings eliminated from the buildings to be heated, for which no actual data on their operation were available, i.e. during the period concerned the building did not consume centrally supplied energy – neither heat (heat supplier data[22]) nor electricity[23] or gas[24] (DSO data[25]) and the energy performance class of the building was not certified. For the purposes of this Study such buildings are considered ‘to be heated’ but were not heated during the period concerned.

Data on buildings that are considered heated during the period concerned (the 2020 heating consumer base), with further breakdown of the subgroup of multi-apartment buildings by size of the building, are presented in the table below.

22 Detailed information is provided in Annex 3.2.

23 Did not consume or consumed less than 240 kWh per year per building.

24 Did not consume or consumed less than 14 m^3 of gas per month per building.

25 DSO data are available only for residential buildings. Detailed information is provided in Annexes 3.3 and 3.4.

19 Table. Heating consumer base, 2020

Subgroup of buildings	Number	Number, %	Total surface area, m^2	Total surface area, %
Residential	**463.293**	**85%**	**92.592**	**57%**
Single-family	424.554	78%	45.536	28%
Multi-apartment S (<0.3 thou m^2)	11.478	2%	2.098	1%
Multi-apartment M (0.3-5 thou m^2)	26.380	5%	39.316	24%
Multi-apartment L (>5 thou m^2)	881	0%	5.643	3%
Service sector	**40.715**	**7%**	**36.848**	**23%**
Services	12.524	2%	7.285	4%
Trade	8.191	1%	6.809	4%
Administrative	9.808	2%	10.031	6%
Other	10.192	2%	12.724	8%
Industry	**43.343**	**8%**	**33.473**	**21%**
TOTAL	**547.351**		**162.914**	

Source: authors of the Study

The heating consumer base comprises 93% of buildings to be heated[26] and 62% of the total surface area of the national building stock.

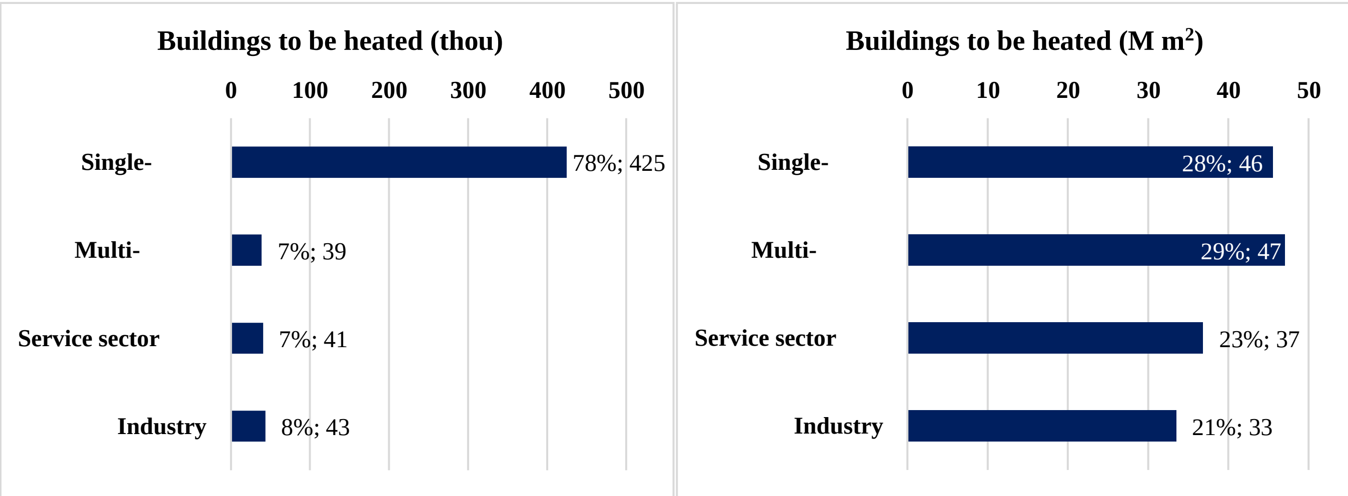
20 Table. Summary calculation of the heating consumer base

Indicato r	Surface area, m^2	Number		
		Total	Residential	Non-residential
National building stock	**263.044**	**2.433.332**	**624.435**	**1.808.897**
Eliminated not to be heated	(88.198)	(1.724.839)	-	(1.724.839)
Buildings to be heated	**174.846**	**708.493**	**624.435**	**84.058**
Eliminated non-heated in 2020	(11.932)	(161.142)	(161.142)	-
Heating consumer base in 2020	**162.914**	**547.351**	**463.293**	**84.058**

Source: authors of the Study

Aggregate data of the heating consumer base by group of buildings are presented in the figure below.

Figure 11. Heating consumer base (aggregate)



Source: authors of the Study

26 Based on the DSO data on residential buildings, 28% of residential buildings by number and 13% of residential buildings by surface area were eliminated as non-heated during the reporting period.

To sum up the above data, it can be noted that in the heating consumer base:

- The individual consumer (household) segment accounts for the largest share by number of buildings (78%).
- The multi-apartment segment is significantly smaller by number of buildings (7%) but is the largest by surface area of buildings (29%).
- Non-residential buildings (in industry and services) account for the remaining 44% of the total surface area of the heating consumer base.
- The average building area varies significantly: single-family houses – about 130 m^2, multi-apartment buildings – about 1 450 m^2, industrial buildings – about 700 m^2, services – about 900 m^2.

4.1.3. Demand for district heating

In accordance with the energy balance data, in 2020 in Lithuania 8.6 TWh of thermal energy was supplied by DH systems.

21 Table. Thermal energy by sector, 2020, GWh

Group	FEC	UEC
Households	4.889	4.889
Services	1.836	1.836
Industry	1.793	1.793
Other sectors	56	56
Total energy balance	**8.575**	**8.575**
Scope of the Study, total	8.519	8.519

Source: Statistics Lithuania

This quantity of thermal energy consists of the following:

- Thermal energy supplied by heat suppliers for heating as heat transfer agent (regulated activity);
- Thermal energy supplied by heat suppliers and producers for processes as steam (non-regulated activity).

Nationally regulated activities are carried out by licensed heat suppliers, who, based on volumes of heat supplied, are divided into:

- Heat suppliers regulated by the National Energy Regulatory Council ('the NERC') (supplying >10 GWh of thermal energy per year);
- Municipality-regulated heat suppliers (supplying <10 GWh of thermal energy per year).

22 Table. Thermal energy (UEC) by type of service, 2020, GWh

Type of service	Thermal energy
Space heating (regulated by the NERC)	6.860
Space heating (regulated by municipalities)	200*
Steam (non-regulated)	1.515
Total energy balance	**8.575**
Scope of the Study, total	8.519

Source: NERC, Statistics Lithuania, authors of the Study

In accordance with the data of the NERC[27], regulated heat suppliers supplied the total of about 6.8 TWh of thermal energy for heating in 2020. The data of heat suppliers regulated by municipalities are not centrally collected and have not been received, however, in our opinion[28], they account for no more than 200 GWh of thermal energy for heating per year. The remainder of thermal energy consists of thermal energy for processes as steam (non-regulated activity)[29].

27 More detailed information is provided in Annex 3.5.

28 Based on available data from individual municipality-regulated suppliers and the maximum threshold of 10 GWh/year.

29 Actual data were not available and the amount was calculated as the difference between the energy balance and the NERC data.

Thermal energy for processes as steam is further analysed in the context of the assessment of heat demand in the industry sector (Chapter 4.5).

In order to detail the demand for district heating at the consumer level (for map creation purposes), an analysis of actual consumption data was carried out.

Data obtained from heat suppliers

In 2020, thermal energy supplied by NERC-regulated heat suppliers for space heating accounted for 97% of all energy supplied in DH systems for space heating.

In order to collect data on actual consumption in buildings connected to NERC-regulated DH systems, we conducted a survey of heat suppliers[30]. The survey results are shown in the table below.

23 Table. Data provided by NERC-regulated heat suppliers, GWh

Municipality serviced by heat suppliers	NERC data	Data provided by heat suppliers	Linked to address	%	Linked to building	%
Group I	**5.237**	**4.605**	**4.496**	**86%**	**3.757**	**72%**
Alytus City Municipality	173	173	163	94%	145	84%
Vilnius City Municipality	2.318	2.303	2.250	97%	1.852	80%
Kaunas City Municipality	1.092	1.091	1.083	99%	908	83%
Klaipėda City Municipality	614	**no data**	-		-	
Šiauliai City Municipality	349	350	343	98%	310	89%
Panevėžys City Municipality	508	507	487	96%	438	86%
Visaginas Municipality	182	180	170	94%	103	57%
Group II	**614**	**498**	**490**	**80%**	**394**	**64%**
Jonava District Municipality	103	102	101	98%	84	**82%**
Litesko	282	281	275	97%	226	**80%**
Mažeikiai District Municipality	113	**no data**	-		-	
Utena District Municipality	116	115	114	98%	83	72%
Group III	**278**	**166**	**137**	**49%**	**128**	**46%**
Elektrėnai Municipality	61	61	58	96%	55	91%
Ukmergė District Municipality	55	55	38	69%	34	**62%**
Palanga City Municipality	51	**no data**	-		-	
Šilutė District Municipality	61	**no data**	-		-	
Tauragė District Municipality	51	51	41	80%	38	75%
Group IV	**369**	**98**	**88**	**24%**	**73**	**20%**
Group V	**363**	**145**	**131**	**36%**	**132**	**36%**
Total	6.860	**5.512**	**5.343**	**78%**	**4.484**	65%

Source: authors of the Study

In analysing the data presented above, it can be noted that:

- The data was provided by the majority of regulated heat suppliers supplying about 80% (5,512 GWh) of all district heating supplied by regulated heat suppliers in 2020.
- Due to inadequate data quality, part of the data from heat suppliers could not be linked with the data of the heating consumer base (the RPR). The share of regulated heat suppliers associated with a specific address accounts for about 79% (5,343 GWh) while that linked with a specific building covers about 66% (4,484 GWh) of all heating supplied by regulated heat suppliers in 2020.

30 More detailed information is provided in Annex 3.2.

Heating demand (consumer groups)

The tables below show consumption data of buildings (GWh) associated with addresses and numbers of buildings.

24 Table. Data from heat suppliers: thermal energy consumption, GWh

Group, subgroup	EPC						Total	Total, %
	<D	**C**	**B**	**A**	**A+**	**A++**		
1. Residential	3.481	375	245	17	9	1	4.128	**77%**
1.1. Single-family	28	2	1	-	-	-	31	1%
1.2. MAB (S)	21	1	1	-	-	-	23	0%
1.3. MAB (M)	3.021	315	193	10	6	1	3.546	66%
1.4. MAB (L)	411	57	49	7	3	-	527	10%
2. Service sector	626	189	218	19	10	-	1.062	**20%**
2.1. Services	110	42	63	4	2	-	221	4%
2.2. Administrative	191	45	33	11	6	-	286	5%
2.3. Trade	48	19	49	1	1	-	118	2%
2.4. Other	277	83	73	3	1	-	437	8%
3. Industry	127	13	12	-	1	-	153	**3%**
Total	**4.234**	**577**	**475**	**36**	**20**	**1**	**5.343**	
Total, %	79%	11%	9%	1%	0%	0%		

Source: heat suppliers, authors of the Study

25 Table. Data from heat suppliers: number of buildings connected to DH systems, number

Group, subgroup	EPC						Total	Total, %
	<D	**C**	**B**	**A**	**A+**	**A++**		
1. Residential	**12.079**	**1.905**	**1.217**	**92**	**59**	**15**	**15.367**	**66%**
1.1. Single-family	1.347	87	56	2	0	0	1.492	**6%**
1.2. MAB (S)	486	37	38	1	1	0	563	**2%**
1.3. MAB (M)	9.755	1.691	1.037	75	50	13	12.621	**54%**
1.4. MAB (L)	491	90	86	14	8	2	691	**3%**
2. Service sector	**4.081**	**762**	**766**	**76**	**48**	**1**	**5.734**	**25%**
2.1. Services	605	113	172	11	15	1	917	**4%**
2.2. Administrative	495	86	210	15	13	0	819	**4%**
2.3. Trade	1421	175	138	33	16	0	1783	**8%**
2.4. Other	1560	388	246	17	4	0	2215	**10%**
3. Industry	**1.972**	**99**	**112**	**4**	**3**	**1**	**2.191**	**9%**
Total	18.132	2.766	2.095	172	110	17	23.292	**100%**

Source: heat suppliers, authors of the Study

From the above data, it can be noted that heating demand in multi-apartment buildings accounts for as much as 76% while that in single-family houses accounts for only 1% of total DH system heat consumption (data obtained).

Heating demand (kWh/m^2)

In order to determine the average actual heating demand[31], the DH system data used are linked to a specific building[32]. The tables below show consumption data of these buildings (GWh) and numbers of buildings.

31 To use these data to assess heating demand of buildings without any actual consumption data available.

32 Consumption at an address is seen as an unreliable indicator since there may be several buildings with different EPCs and uses at the same

address.

26 Table. Data from heat suppliers: actual thermal energy consumption, GWh

Group, subgroup	EPC						Total	Total, %
	<D	**C**	**B**	**A**	**A+**	**A++**		
1. Residential	3.232	359	234	16	10	2	**3.852**	**86%**
1.1. Single-family	26	2	1	0	-	-	29	1%
1.2. MAB (S)	19	1	1	0	0	-	21	0%
1.3. MAB (M)	2.800	302	186	10	6	1	3.305	74%
1.4. MAB (L)	387	54	47	6	3	0	497	11%
2. Service sector	347	116	126	18	10	0	**618**	**14%**
2.1. Services	40	15	20	3	2	0	81	2%
2.2. Administrative	116	35	27	11	6	-	195	4%
2.3. Trade	38	17	28	1	1	-	86	2%
2.4. Other	153	49	51	3	0	-	256	6%
3. Industry	10	2	3	-	1	0	**14**	**0%**
Total	3.588	477	363	34	20	2	**4.484**	100%
Total, %	**80%**	**11%**	**8%**	**1%**	**0%**	**0%**	**100%**	

Source: heat suppliers, authors of the Study

27 Table. Data from heat suppliers: buildings linked with RPR data, number

Group, subgroup	EPC						Total	Total, %
	<D	**C**	**B**	**A**	**A+**	**A++**		
1. Residential	11.179	1.845	1.166	93	69	16	14.368	**82%**
1.1. Single-family	1.343	93	63	2	-	-	1.501	9%
1.2. MAB (S)	442	37	29	1	1	-	510	3%
1.3. MAB (M)	8.938	1.631	994	77	59	14	11.713	67%
1.4. MAB (L)	456	84	80	13	9	2	644	4%
2. Service sector	2.003	426	449	62	48	1	2.989	**17%**
2.1. Services	228	43	73	6	14	1	365	2%
2.2. Administrative	772	111	86	32	16	-	1.017	6%
2.3. Trade	304	62	150	11	15	-	542	3%
2.4. Other	699	210	140	13	3	-	1.065	6%
3. Industry	85	7	19	0	1	1	113	**1%**
Total	**13.267**	**2.278**	**1.634**	**155**	**118**	**18**	**17.470**	

Source: heat suppliers, authors of the Study

Estimated average heating demand data for these buildings are presented below.

28 Table. Data from heat suppliers: average thermal energy consumption (kWh/m^2/year)

Group, subgroup	EPC					
	<D	**C**	**B**	**A**	**A+**	**A++**
1. Residential	147	101	91	58	46	33
1.1. Single-family	126	105	68	90	-	-
1.2. MAB (S)	206	121	165	660	19	-
1.3. MAB (M)	148	101	95	57	46	38
1.4. MAB (L)	142	95	80	59	45	24
2. Service sector	77	57	57	36	19	58
2.1. Services	96	81	63	55	35	58
2.2. Administrative	78	67	56	28	18	-
2.3. Trade	49	36	43	30	11	-
2.4. Other	84	57	68	108	26	-
3. Industry	36	65	39	-	40	28
Total	**134**	**85**	**75**	**44**	**27**	**32**

Source: heat suppliers, authors of the Study

When analysing these data, it is important to note that:

- Actual average heat consumption of some benchmark buildings could not be calculated due to the absence of any benchmarks representing a building (e.g. the benchmark 'Single-family, A++');
- Actual average heat consumption of some benchmark buildings was calculated using data from a relatively small sample of buildings, which may result in an non-representative average (e.g. the benchmark 'MAB (S), A').

Accordingly, in order to make proper use of these data for the assessment of the heating demand of buildings with no actual consumption data available, the data should be appropriately normalised (excluding non-representative samples and atypical consumption deviations).

4.1.4. Demand for gas heating

In accordance with the energy balance sheet, for energy needs[33] in 2020 5.6 TWh of gas (FEC) was supplied in Lithuania, of which 5.0 TWh of useful energy[34] (UEC) was produced.

29 Table. Gas consumption in Lithuania, 2020

Group	FEC, GWh	UEC, GWh
Households	1.562	1.420
Services	807	734
Industry	3.178	2.890
Total	**5.547**	**5.043**

Source: Statistics Lithuania

The above quantities of gas were supplied by:

- AB Energijos skirstymo operatorius ('the DSO') – for households and businesses in the service and industry sectors – for customers of the distribution network.
- AB Amber Grid – an industry sector for businesses whose gas supply infrastructure is directly connected to the transmission network[35].
- Other distribution operators (UAB Gren Lietuva, UAB Intergas, AB Agrofirma Josvainiai, UAB SG dujos) – for households and businesses in the service and industry sectors in separate geographical areas.

In order to detail the demand for gas heating at the consumer level (for map creation purposes), an analysis of actual data was carried out. At consumer level, only DSO household consumption data were obtained. Accordingly, an analysis of the service and industry sectors could not be carried out.

Gas heating demand of households

The table below shows a comparison of DSO-associated gas consumption with the Real Property Register.

30 Table. Gas consumer data received from the DSO (FEC), GWh

Group	Energy balance	Actual data received		
		Total DSO	Linked to address	Linked share, %
Households	2.028[36]	1.970	1.787	98%

Source: authors of the Study

33 Excluding consumption of gas for raw materials and energy transformation (heat and power generation) but including gas for cooking in households.

34 The factor 1/1.1 based on STR 2.01.02:2016 is used.

35 https://www.ambergrid.lt/lt/paslaugos/perdavimosistemosnaudotojai.

36 Includes gas used for cooking in households.

Details of the DSO data received (gas consumption) by municipality are presented in the table below.

31 Table. Linking of DSO gas consumer data by municipality (FEC), GWh

Data by municipality	Demand, GWh	Share, %
Vilnius City Municipality	400	22%
Kaunas City Municipality	375	21%
Klaipėda City Municipality	92	5%
Šiauliai City Municipality	86	5%
Panevėžys City Municipality	69	4%
Palanga City Municipality	33	2%
Alytus City Municipality	28	2%
Ukmergė District Municipality	22	1%
Remaining municipalities	682	38%
Total	**1.787**	**100%**

Source: authors of the Study

It can be noted that the 5 largest municipalities consume more than half (57%) of total[37] gas consumption of households. None of the remaining 55 municipalities has households consuming more than 50 GWh per year. The tables below show FEC data of buildings (GWh) associated with addresses and numbers of buildings.

32 Table. Natural gas FEC (DSO data), GWh

Group, subgroup	EPC						Total	Total, %
	<D	C	B	A	A+	A++		
1. Residential	1.148	297	283	28	10	-	1.766	99%
1.1. Single-family	786	247	248	26	10	-	1.317	74%
1.2. MAB (S)	48	1	2	-	-	-	52	3%
1.3. MAB (M)	293	46	34	1	-	-	375	21%
1.4. MAB (L)	21	2	0	-	-	-	23	1%
2. Service sector	13	3	5	-	-	-	20	1%
2.1. Services	4	-	-	-	-	-	4	0%
2.2. Administrative	2	-	-	-	-	-	3	0%
2.3. Trade	3	2	3	-	-	-	9	0%
2.4. Other	2	1	1	-	-	-	3	0%
3. Industry	1	0	0	-	-	-	1	0%
Total	**1.161**	**300**	**288**	**28**	**10**	**-**	**1.787**	**100%**
Total, %	65%	17%	16%	2%	1%	0%	100%	

Source: DSO, authors of the Study

33 Table. Number of natural gas consumers (DSO data), number

Group, subgroup	EPC						Total	Total, %
	<D	C	B	A	A+	A++		
1. Residential	72.132	15.027	17.890	2.604	1.384	1	109.038	98%
1.1. Single-family	58.595	13.274	16.892	2.552	1.366	1	92.680	84%
1.2. MAB (S)	2.533	66	69	12	2	-	2.682	2%
1.3. MAB (M)	10.648	1.645	922	39	16	-	13.270	12%
1.4. MAB (L)	356	42	7	1	-	-	406	0%
2. Service sector	673	119	290	18	10	-	1.110	1%
2.1. Services	217	76	246	17	10	-	566	1%
2.2. Administrative	186	17	21	1	-	-	225	0%
2.3. Trade	197	22	19	-	-	-	238	0%
2.4. Other	73	4	4	-	-	-	81	0%
3. Industry	701	16	24	-	-	-	741	1%
Total	**73.506**	**15.162**	**18.204**	**2.622**	**1.394**	**1**	**110.889**	**100%**
Total, %	66%	14%	16%	2%	1%	0%	100%	

Source: DSO, authors of the Study

37 Provided by the DSO and linked to a specific address.

In order to assess gas demand for heating with greater accuracy, we eliminated buildings with less than 14 m^3 of gas per month per consumer from the above data. Within the scope of this Study these consumers are considered to use gas not for heating but for cooking. As a result, the number of consumers decreases by 25% (from 111 000 to 83 000) and total consumption – 9% (from 1.787 GWh to 1.639 GWh).

For natural gas heating, FEC data (GWh) and building numbers are presented in the tables below.

34 Table. FEC of natural gas intended for heating (DSO data), GWh

Group, subgroup	EPC						Total	Total, %
	<D	C	B	A	A+	A++		
1. Residential	1.017	282	282	28	10	-	1.618	99%
1.1. Single-family	796	253	253	27	10	-	1.339	82%
1.2. MAB (S)	48	1	2	-	-	-	51	3%
1.3. MAB (M)	166	28	27	1	-	-	222	14%
1.4. MAB (L)	7	-	-	-	-	-	7	0%
2. Service sector	9	2	4	-	-	-	16	1%
2.1. Services	3	2	3	-	-	-	9	1%
2.2. Administrative	2	1	-	-	-	-	3	0%
2.3. Trade	2	-	-	-	-	-	3	0%
2.4. Other	1	-	-	-	-	-	1	0%
3. Industry	4	-	-	-	-	-	4	0%
Total	**1.029**	**284**	**286**	**28**	**10**	**-**	**1.639**	**100%**
Total, %	63%	17%	17%	2%	1%	0%	100%	

Source: DSO, authors of the Study

35 Table. Number of consumers of natural gas intended for heating (DSO data), number

Group, subgroup	EPC						Total	Total, %
	<D	C	B	A	A+	A++		
1. Residential	49.538	12.579	16.523	2.374	1.090	1	82.105	99%
1.1. Single-family	44.756	12.148	16.060	2.330	1.086	1	76.381	92%
1.2. MAB (S)	1.919	48	55	12	1	-	2.035	2%
1.3. MAB (M)	2.819	381	407	32	3	-	3.642	4%
1.4. MAB (L)	44	2	1	-	-	-	47	0%
2. Service sector	423	88	254	13	8	-	786	1%
2.1. Services	142	65	221	12	8	-	448	1%
2.2. Administrative	105	10	14	1	-	-	130	0%
2.3. Trade	138	11	16	-	-	-	165	0%
2.4. Other	38	2	3	-	-	-	43	0%
3. Industry	235	7	8	0	0	-	250	0%
Total	**50.196**	**12.674**	**16.785**	**2.387**	**1.098**	**1**	**83.141**	**100%**
Total, %	60%	15%	20%	3%	1%	0%	100%	

Source: authors of the Study

The table below shows UEC-recalculated data of household gas consumption for heating purposes.

36 Table. UEC of natural gas intended for heating (DSO data), GWh

Group, subgroup	EPC						Total	Total, %
	<D	C	B	A	A+	A++		
1. Residential	925	256	256	26	9	-	1.473	99%
1.1. Single-family	725	230	230	24	9	-	1.218	82%
1.2. MAB (S)	44	1	1	0	-	-	47	3%
1.3. MAB (M)	151	25	24	1	-	-	202	14%
1.4. MAB (L)	6	-	-	-	-	-	6	0%
2. Service sector	8	2	4	0	-	-	14	1%
2.1. Services	3	1	3	0	-	-	8	1%
2.2. Administrative	2	1	-	-	-	-	3	0%
2.3. Trade	2	-	-	-	-	-	3	0%
2.4. Other	1	-	-	-	-	-	1	0%
3. Industry	3	0	0	0	-	-	4	0%
Total	**937**	**259**	**260**	**26**	**9**	**-**	**1.491**	**100%**
Total, %	63%	17%	17%	2%	1%	0%	100%	

Source: authors of the Study

Estimated average heating demand data for these buildings are presented below.

37 Table. Average UEC of natural gas intended for heating (DSO data), kWh/m²/year

Group, subgroup	EPC					
	<D	C	B	A	A+	A++
1. Residential	97	98	89	76	62	32
1.1. Single-family	116	105	93	77	62	32
1.2. MAB (S)	113	103	102	69	37	-
1.3. MAB (M)	56	63	67	64	49	-
1.4. MAB (L)	22	8	7	-	-	-
2. Service sector	16	32	31	64	33	-
2.1. Services	12	393	105	-	-	-
2.2. Administrative	40	95	72	-	-	-
2.3. Trade	35	5	3	-	-	-
2.4. Other	10	2	6	-	-	-
3. Industry	73	219	75	-	-	-
Total	**93**	**97**	**87**	**76**	**61**	**32**

Source: heat suppliers, authors of the Study

When analysing these data, it is important to note that:

- Actual average heat consumption of some benchmark buildings could not be calculated as no data were available for any particular benchmark building (e.g., service and industry sectors, Class A++ buildings).
- Actual average heat consumption of some benchmark buildings was calculated using data from a relatively small sample of buildings (e.g. the data obtained concerned only one Class C building within the subgroup 2.1. Services).
- Actual DSO data at consumer level are seen as less reliable than heat suppliers' data because:
  - Gas is also used for non-thermal energy generation purposes (e.g. cooking in households) and therefore assumptions are used to make a distinction between gas for heating and gas used for cooking.
  - Gas is not used as the sole source of thermal energy (e.g. additionally heating is obtained from district heating or electricity).
  - Gas consumption metering at consumer level is based on declared data which may be inaccurate and/or untimely. The margin of error is considered to be significantly higher than in the sector of DH systems.

Accordingly, it is assessed that actual gas consumption data are not sufficient and representative to serve as a basis for calculating heating demand of the remaining consumers.

4.1.5. Demand for decentralised heating

Based on the energy balance data[38], in 2020 in Lithuania 10.8 TWh of final or 9.7 TWh of useful energy was consumed for heating buildings in individual (decentralised) sources.

38 Table. Energy generated for heating from individual sources, GWh

Group	FEC, GWh	UEC, GWh
Households	7.023	6.005
Services	903	1.049
Industry	2.883	2.676
Total	**10.809**	**9.730**

Source: Statistics Lithuania

Actual consumption data at consumer level for decentralised heating are not systematically collected – there is no effective practical solution for this. A representative instant poll is also seen as an ineffective solution given the number of decentralised consumers (over 500,000 consumers) and the resources needed to conduct the poll.

Accordingly, heating demand in the decentralised heating segment will be calculated as follows:

- households and the service sector (in these segments the heating demand structure is dominated by space heating)
  – at consumer level, taking into account actual demand data collected during the demand analysis and other attributes reflecting heating demand specific to the benchmark consumer.
- Industry (the heating demand structure of this segment is dominated by heat intended for processes) – aggregated sector level, based on the energy balance data and taking into account other sources of information (e.g. energy audits, emission allowance data).

4.1.6. Analysis results

To sum up the results of the analysis carried out, it can be said that:

- Data on actual thermal energy consumption obtained from heat suppliers using DH systems account for about 23% of total thermal energy consumption in the period concerned (2020).
- Data on actual consumption of gas for heating from the DSO accounts for about 6% of total thermal energy consumption in the period concerned (2020).
- For the remaining 71% of heat demand, there are no actual data available.

39 Table. Thermal energy (UEC), GWh

Group	Energy balance, GWh	Actual consumption data received		No actual consumption data available
		DH system	DSO (gas)	
Households	12.314	4.128	1.473	7.990
Service sector	3.619	1.062	14	4.393
Industry	7.359	153	4	7.156
Total	**23.292**	**5.343**	**1.491**	**16.458**
Total, %	100%	23%	6%	71%

Source: authors of the Study, Statistics Lithuania, heat suppliers, DSO

38 The data in the energy and fuel balances also include energy consumed for non-energy purposes. Detailed data analysis and calculations are given in Annex 2.1.

In our view:

- Actual data on DH system demand at consumer level provide a sufficiently reliable picture of actual heat consumption for heating buildings. Accordingly, the data can be used as a basis for assessing heat demand of consumers for whom no actual demand data are available (after proper data processing[39] and ensuring that the sample used is sufficiently representative).
- Actual gas consumption data in the DSO household segment at consumer level are seen as less reliable because assumptions are used to make a distinction between gas used for heating and gas used for cooking. In addition, the margin of error due to inaccurate or untimely declaration is considered to be significantly higher than in the DH system sector. Accordingly, the data will not be used as a basis for calculating heat demand for consumers for whom no actual demand data are available.
- As the industrial heating demand structure is dominated by heat intended for processes but there are no actual data on heat consumed for processes available at consumer level, and consumption for processes cannot be standardised or linked to attributes assigned to the consumer (building) (e.g. surface area, purpose, EPC, etc.), we do not believe it is possible to reliably assess demand at consumer level based on actual consumption data obtained from the DH system or the DSO. Thus, heating demand will be calculated at aggregated sector level, based on the energy balance data and taking into account other sources of information (e.g. energy audits, emission allowance data).

39 For example, excluding atypical values resulting from untimely or inaccurate declaration in buildings where remote metering is not installed.

4.2. COOLING DEMAND ANALYSIS

The analysis of cooling demand is the first stage in the assessment of cooling demand aimed at taking stock of, structuring and typifying data on cooling consumers collected at the national level.

Since one of the aims of the Study is to collect data on cooling demand necessary for the drawing up of the heating and cooling map, the analysis of demand was carried out at the level of a specific consumer (building) assigning to them not only the attributes necessary for assessing demand but also geographical coordinates.

4.2.1. Cooling consumer base

The determination of the cooling consumer base is the first step in the assessment of the current cooling demand, and taking into account the number of cooling consumers, one can further assess how much cooling energy each of them could consume.

In our opinion, the cooling consumer base is the same as the heating consumer base. Accordingly, the cooling customer base has been established through the same 2 stages as the heating customer base[40]:

- Stage 1: unheated and uncooled buildings are eliminated from the national building stock, i.e. buildings that are not subject to the requirements of the Technical Construction Regulation relating to energy performance and no data on their actual heating and cooling consumption were obtained during the course of the Study.
- Stage 2: buildings then eliminated from the remaining heated and cooled buildings (potential cooling consumers) are those for which no actual data on their operation were available, i.e. the buildings that did not consume centrally supplied energy during the period concerned – neither heat (heat supplier data[41]) nor electricity[42] or gas[43] (DSO data[44]). For the purposes of this Study it is considered that such buildings are in principle cooled but were not operated during the period concerned.

40 Table. Cooling consumer base

Indicator	Surface area, m²	Number		
		Total	Residential	Non-residential
National building stock	**263.044**	**2.433.332**	**624.435**	**1.808.897**
1. Eliminated unheated and uncooled	(88.198)	(1.724.839)	-	(1.724.839)
Heated and cooled	**174.846**	**708.493**	**624.435**	**84.058**
2. Eliminated non-heated in 2020	(11.932)	(161.142)	(161.142)	-
Cooling consumer base	**162.914**	**547.351**	**463.293**	**84.058**

Source: authors of the Study

4.2.2. Analysis results

In order to assess how much cooling energy could be consumed by potential cooling consumers, we carried out an analysis of the data on cooling demand in buildings and cooling demand for processes.

Cooling of buildings

Summarised results of the analysis of cooling demand data for buildings:

- We have not identified any data on district cooling supply in 2020. Accordingly, we estimate that district cooling supply in 2020 was not available or the volumes were negligible for assessment purposes, i.e. insufficient to serve as a basis for a comprehensive assessment of the need for cooling.

40 For more information see Chapter 4.1.2.

41 Detailed information is provided in Annex 3.2.

42 Did not consume or consumed less than 240 kWh per year per building.

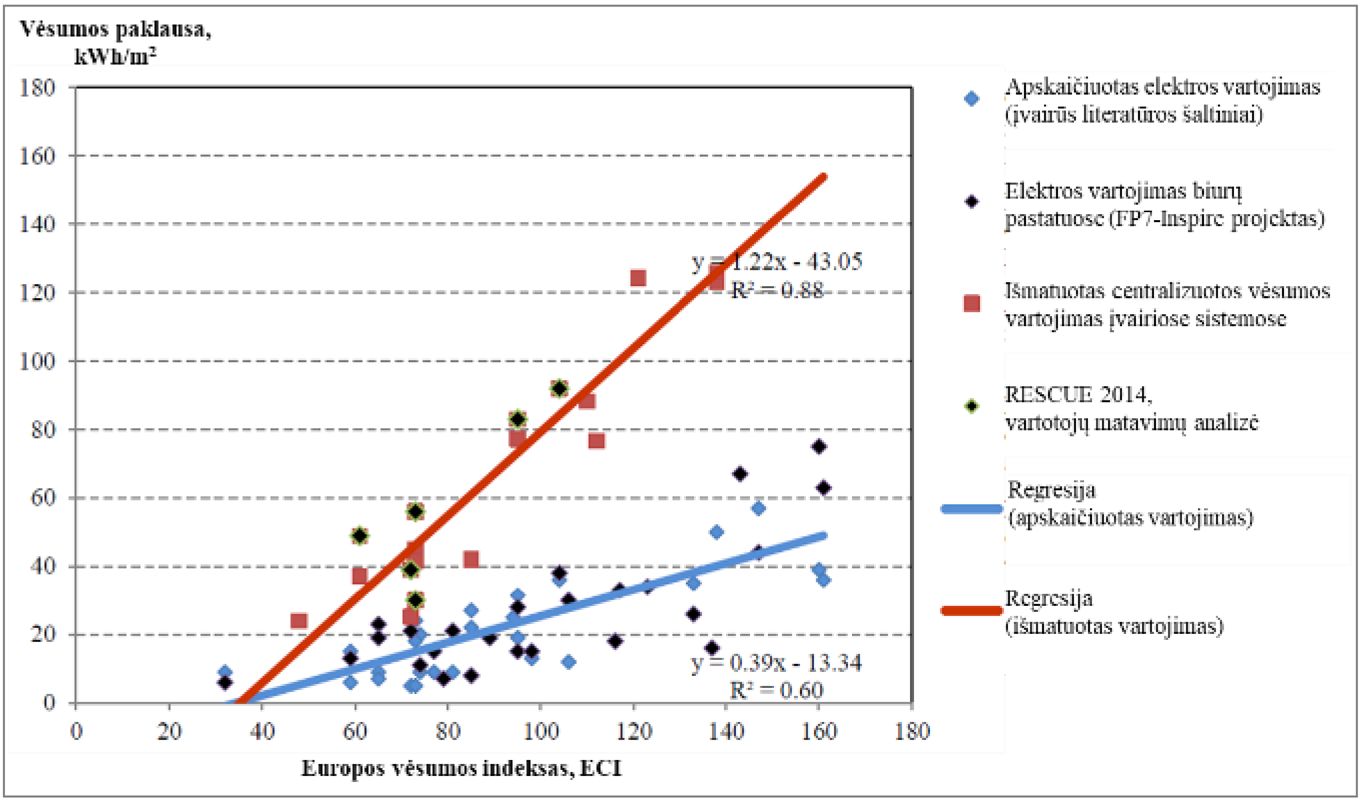
43 Did not consume or consumed less than 14 m^3 of gas per month per building.

44 DSO data are available only for residential buildings. Detailed information is provided in Annexes 3.3 and 3.4.

- We have not identified any public data sources systematically collecting data on actual cooling demand in buildings in 2020. Accordingly, we estimate that cooling demand cannot be reliably assessed based on actual data and therefore statistical and quantifiable cooling data will be used for the assessment.
- We have not identified any public data sources systematically collecting sufficient and reliable statistics on cooling demand in buildings (e.g. energy audits, survey results).
- Estimated (design) data at building level are documented in ENC certificates but are not systematically stored in the SPSC database. There is therefore no practical way of processing them within the scope of this Study.
- We identified a Halmstad University study[45] carried out within the framework of a project by Stratego[46] ('the Stratego Study') as the main EU-wide source for analysing estimated (design) cooling demand of buildings.

The Stratego Study examining the need for cooling in the EU countries states that, taking into account the value of the Lithuanian European Cooling Index[47] (85 ECI), the need for cooling in buildings in Lithuania should be within the range of 20-61 kWh/m^2 per year.

Figure 12. Summary of results of the analysis of cooling demand data for buildings



Source: Quantifying the Heating and Cooling Demand in Europe, Stratego

Taking into account the specifics of buildings, the Stratego Study on the need for cooling in the EU countries estimates that the need for cooling energy in Lithuania amounts to:

- For residential buildings: about 27 kWh/m^2 per year.
- Service sector buildings: about 59 kWh/m^2 per year.
- Average: about 35 kWh/m^2 per year.

45 Quantifying the Heating and Cooling Demand in Europe, Stratego.
46 http://www.stratego-project.eu/.
47 European cooling index (ECI).

It is also stated that a significant part of the need for cooling is not met – it is estimated that the level of 'saturation' is about 1% for the residential sector and about 10% for the non-residential sector.

Cooling for processes

Summarised results of the analysis of cooling demand data for processes:

- We have not identified any data on district cooling supply in 2020. Accordingly, we estimate that district cooling supply in 2020 was not available or the volumes were negligible for assessment purposes, i.e. insufficient to serve as a basis for a comprehensive assessment of the need for cooling.
- We have not identified any public data sources systematically collecting data on actual cooling demand for processes in 2020. Accordingly, we estimate that cooling demand cannot be reliably assessed based on actual data and therefore statistical and quantifiable cooling data will be used for the assessment.
- After the analysis of foreign sources, we identified a study[48] carried out by Riga Technical University as commissioned by the Ministry of the Economy of the Republic of Latvia calculating the factors of the industry's need for cooling and electricity consumption in the industry sector. During the preparation of the Study there was no information about a similar study in Lithuania, therefore, taking into account the geographical, cultural and economic level of development, it is assumed that the share of electricity for cooling is similar to that established in Latvia.

41 Table. Share of electricity for generating cooling in the industry sector

Segment	Share of electricity for cooling, %
Manufacture of rubber and plastic products	9.5%
Manufacture of furniture	9.5%
Manufacture of food products, beverages and tobacco	8.0%
Manufacture of basic metals	5.4%
Manufacture of paper and paper products	4.1%
Printing and reproduction of recorded media	4.1%
Other mining and quarrying	1.8%
Manufacture of chemicals and chemical products	1.7%
Manufacture of basic pharmaceutical products and pharmaceutical preparations	1.7%
Manufacture of other transport equipment	1.2%
Manufacture of motor vehicles and trailers	1.2%
Manufacture of textiles	0.7%
Manufacture of wearing apparel	0.7%
Manufacture of leather and related products	0.7%
Manufacture of other non-metallic mineral products	0.4%
Manufacture of fabricated metal products, except machinery and equipment	0.2%
Manufacture of wood and products of wood, except furniture	0.04%
Other industry sectors	-
Average	**4%**

Source: Riga Technical University

48 Data collected under Contract No. 03000-3.3.2-e/13 of 20 May 2019 signed between the Ministry of the Economy of the Republic of Latvia

4.3. HOUSEHOLD DEMAND

After the analysis of heating and cooling demand, during which the heating and cooling consumption data (Chapters 4.1 and 4.2) were sorted, structured and typified, the next step is the assessment of the demand in the sectors within the scope of the Study. This Chapter presents assessment results on households:

- Household demand for heating (Chapter 4.3.1).
- Household demand for cooling (Chapter 4.3.2).

4.3.1. Household demand for heating

This Chapter presents assessment results of heating demand in the household segment (Demand Segment A1).

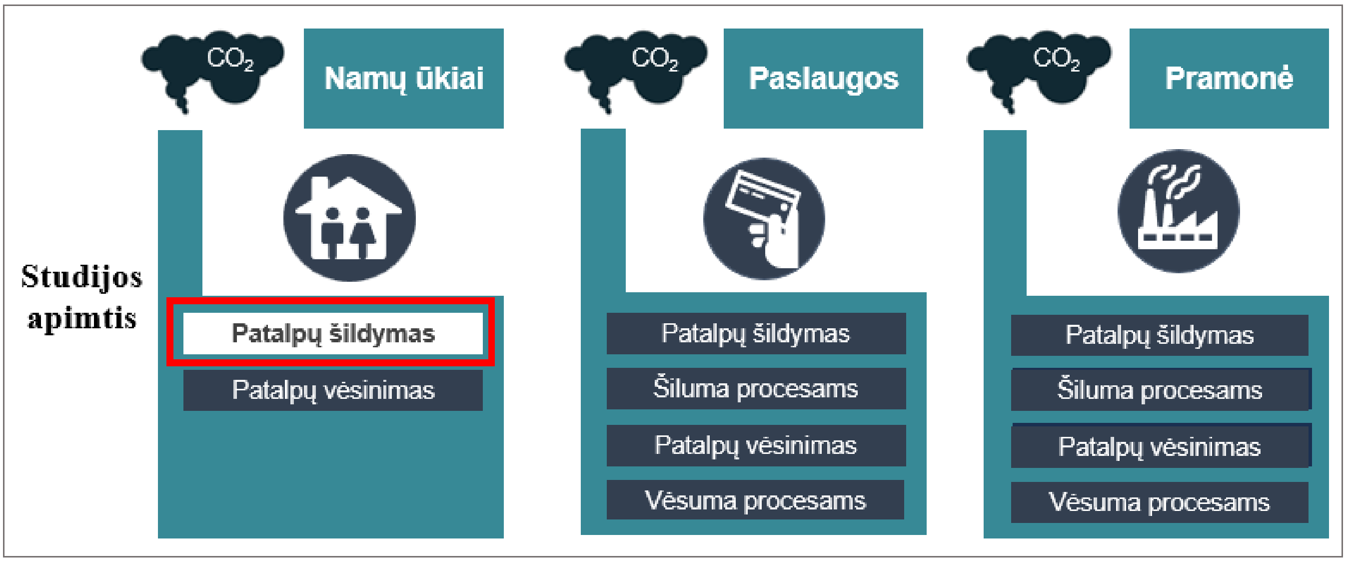
42 Table. Heating and cooling demand segments

Sector	Demand segment		UEC 2020, GWh	
	Heating demand	Cooling demand	Heating demand	Cooling demand
Households	A1	A2	12.314	25
Services	B1	B2	3.619	217
Industry	C1	C2	7.359	406

Source: authors of the Study

Heating demand in the household segment includes space heating (including hot water preparation).

Figure 13. Household demand for heating



Source: authors of the Study

Actual demand data collected during the analysis of heating demand account for about 45% of total heating demand of households.

43 Table. Thermal energy (UEC), GWh

Group	Energy balance	Actual data collected			Estimated demand
		DH system	DSO gas	Total	
Households	12.314	4.128	1.473	5.601	6.713
	100%	33%	12%	45%	55%

Source: authors of the Study

Actual heating demand

Actual consumption data are collected from DH and DSO data on gas consumers. Consumer data of a total of 97,441 households were obtained. In 2020, those consumers consumed 5,601 GWh of energy.

44 Table. Actual household consumption (UEC) in 2020, GWh

Group, subgroup	EPC						Total
	<D	C	B	A	A+	A++	
1. Residential							
1.1. Single-family	753	232	231	24	9	0	1.250
1.2. MAB (S)	64	2	3	0	0	0	70
1.3. MAB (M)	3.172	341	218	11	6	1	3.747
1.4. MAB (L)	417	57	49	7	3	0	534
Total	4.406	632	501	43	19	1	**5.601**

Source: DSO, heat suppliers, authors of the Study

45 Table. Number of household consumers (buildings), number

Group, subgroup	EPC						Total
	<D	C	B	A	A+	A++	
1. Residential							
1.1. Single-family	46.083	12.234	16.116	2.332	1.086	1	77.852
1.2. MAB (S)	2.400	85	93	13	2	0	2.593
1.3. MAB (M)	12.572	2.071	1.442	107	53	13	16.258
1.4. MAB (L)	535	92	87	14	8	2	738
Total	61.590	14.482	17.738	2.466	1.149	16	**97.441**

Source: DSO, heat suppliers, authors of the Study

These actual demand data will be attributed to relevant consumers and displayed on the heating and cooling map.

Estimated heating demand

Actual demand data at consumer level account for about 45% of total household heating demand indicated in the energy balance. In order to show heating demand of all consumers on the map, it is necessary to calculate heating demand of the remaining consumers.

Based on the results of the analysis of heating demand (Chapter 4.1.6), the following assessments are made:

- Actual data on DH system demand at consumer level provide a sufficiently reliable picture of actual heat consumption for heating buildings. Accordingly, the data can be used as a basis for assessing heat demand of consumers for whom no actual demand data are available (after proper data processing39 and ensuring that the sample used is sufficiently representative).
- Actual data in the DSO household segment at consumer level are seen as less reliable because there is no accurate practical method to make a distinction between gas used for heating and gas used for cooking. In addition, the margin of error due to inaccurate or untimely declaration is considered to be significantly higher than in the DH system sector. Accordingly, the data will not be used as a basis for calculating heat demand for consumers for whom no actual demand data are available.

Data were obtained from heat suppliers on energy consumption of 15,300 household buildings.

46 Table. Data from heat suppliers: number of household buildings connected to DH systems, number

Group, subgroup	**EPC**						**Total**
	<D	**C**	**B**	**A**	**A+**	**A++**	
1. Residential	12.052	1.903	1.215	92	59	15	**15.336**
1.1. Single-family	1.327	86	56	2	-	-	1.471
1.2. MAB (S)	481	37	38	1	1	-	558
1.3. MAB (M)	9.753	1.690	1.035	75	50	13	12.616
1.4. MAB (L)	491	90	86	14	8	2	691

Source: heat suppliers, authors of the Study

Average (arithmetic mean) heating demand data for these buildings are presented below.

47 Table. Data from heat suppliers: average thermal energy consumption by households (kWh/m²/year)

Group, subgroup	**EPC**					
	<D	**C**	**B**	**A**	**A+**	**A++**
1. Residential	147	101	91	59	49	32
1.1. Single-family	140	112	78	89	-	-
1.2. MAB (S)	204	120	155	658	19	-
1.3. MAB (M)	148	102	95	58	50	38
1.4. MAB (L)	141	95	79	60	48	24

Source: heat suppliers, authors of the Study

In order to ensure that average actual consumption data are representative and suitable for extrapolation, from the above data we eliminated the following[49]:

- Insufficiently accurate data, i.e. consumption data that cannot be assigned to a specific building (addresses where more than 1 building is registered);
- Atypical deviations, i.e. atypical minimum and maximum consumption values;
- Data samples that are insufficient to reflect heat demand of a specific benchmark building.

Data on average actual consumption after identifying and eliminating outliers are presented in the table below.

48 Table. Data from heat suppliers: normalised average thermal energy consumption by households (kWh/m²/year)

Group, subgroup	**EPC**					
	<D	**C**	**B**	**A**	**A+**	**A++**
1. Residential	147	101	95	58	47	35
1.1. Single-family	104	97	81	-	-	-
1.2. MAB (S)	194	124	-	-	-	-
1.3. MAB (M)	150	101	96	58	47	35
1.4. MAB (L)	144	95	79	-	-	

Source: heat suppliers, authors of the Study

When analysing the above data, it can be observed that some benchmarks have no actual average heat consumption attributed to them due to the inadequate data sample. Consumption in such benchmark buildings is calculated taking into account consumption of the entire household sector (Group '1. Residential') by EPC[50].

Estimated average consumption data for all benchmark buildings are presented in the table below.

49 More detailed information is provided in Annex 2.2.

50 More detailed information is provided in Annex 2.2.

49 Table. Estimated average consumption (UEC) (kWh/m²/year)

Group, subgroup	EPC					
	<D	C	B	A	A+	A++
1. Residential	147	101	95	59	46	34
1.1. Single-family	104	97	81	50	39	29
1.2. MAB (S)	194	124	117	73	57	42
1.3. MAB (M)	150	101	96	58	47	35
1.4. MAB (L)	144	95	79	49	39	29

Source: authors of the Study

These estimated demand data are attributed to consumers for whom no actual consumption data (by benchmark) are available and are displayed on the heating and cooling map. Total UEC calculated for these users is disclosed in the table below.

50 Table. Estimated UEC for heating household buildings, GWh

Group, subgroup	EPC						Total
	<D	C	B	A	A+	A++	
1. Residential							
1.1. Single-family	3.133	410	293	15	10	0	**3.862**
1.2. MAB (S)	338	2	2	0	0	0	**342**
1.3. MAB (M)	1.736	45	70	3	3	0	**1.858**
1.4. MAB (L)	165	4	13	1	0	0	**183**
Total	**5.372**	**461**	**378**	**19**	**14**	**1**	**6.246**

Source: authors of the Study

Results of the assessment of heating demand

According to the calculations described above, with actual and estimated consumption combined, we obtain the following data on heating demand of household buildings.

51 Table. Annual useful energy consumption for heating buildings, GWh

Group, subgroup	EPC						Total
	<D	C	B	A	A+	A++	
1. Residential							
1.1. Single-family	3.886	642	524	40	20	0	**5.112**
1.2. MAB (S)	402	5	5	0	0	0	**412**
1.3. MAB (M)	4.908	386	288	14	9	1	**5.606**
1.4. MAB (L)	582	61	62	7	4	1	**717**
Total	**9.778**	**1.093**	**879**	**62**	**33**	**2**	**11.847**

Source: authors of the Study

When analysing the results, it is important to note that total heat consumption of households (11.8 TWh) is estimated to be 4% lower than the one indicated in the energy balance (12.3 TWh). In order to maintain consistency with the statistics, estimated consumption is increased by 4% for each benchmark.

The final results of the assessment of household heating demand are presented in the tables below.

52 Table. Household FEC for heating buildings, GWh

Group, subgroup	EPC						Total
	<D	C	B	A	A+	A++	
1. Residential							
1.1. Single-family	3.546	590	479	37	18	0	4.670
1.2. MAB (S)	989	8	8	1	0	-	1.006
1.3. MAB (M)	6.160	470	355	18	14	2	7.019
1.4. MAB (L)	619	78	69	8	4	1	780
Total	**11.314**	**1.145**	**912**	**63**	**36**	**4**	**13.474**

Source: authors of the Study

53 Table. Household UEC for heating buildings, GWh

Group, subgroup	EPC						Total
	<D	C	B	A	A+	A++	
1. Residential							
1.1. Single-family	3.092	519	424	33	16	0	4.083
1.2. MAB (S)	850	7	7	1	0	-	866
1.3. MAB (M)	5.801	444	334	17	13	2	6.610
1.4. MAB (L)	602	73	67	8	4	1	755
Total	**10.345**	**1.043**	**832**	**58**	**33**	**3**	**12.314**

Source: authors of the Study

4.3.2. Household demand for cooling

This Chapter presents assessment results of current cooling demand in the household segment (Demand Segment A2).

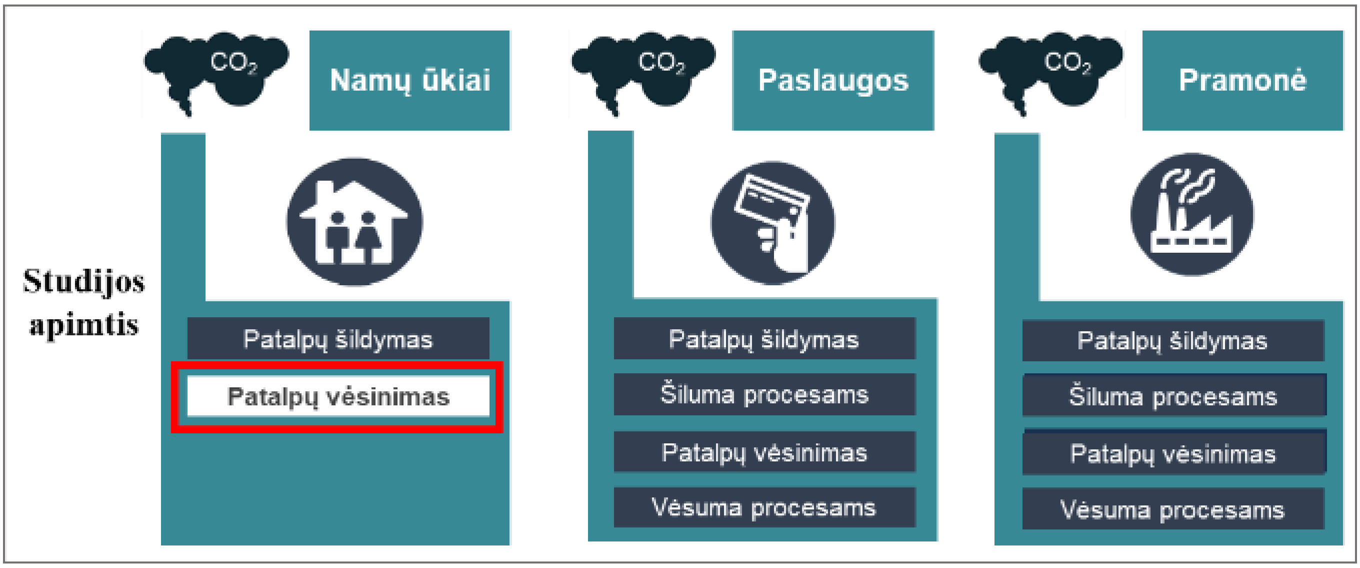
54 Table. Heating and cooling demand segments

Sector	Demand segment		UEC 2020, GWh	
	Heating demand	Cooling demand	Heating demand	Cooling demand
Households	A1	A2	12.314	25
Services	B1	B2	3.619	217
Industry	C1	C2	7.359	406

Source: authors of the Study

Cooling demand in the household segment includes space cooling.

Figure 14. Household demand for cooling



Source: authors of the Study

Based on our estimates[51], cooling demand in households amounts to about 25 GWh per year (UEC).

55 Table. Thermal energy (UEC), GWh

Group	Energy balance, GWh	Actual consumption	Estimated consumption
Households	25	-	25

Source: authors of the Study

51 More detailed information is provided in Annex 2.1.

Actual cooling demand

During the preparation of the Study, no sources of actual household energy consumption for cooling were identified.

Estimated cooling demand

In absence of actual data on household energy consumption for cooling, we performed a calculation of cooling energy consumption based on standardised consumption for the purposes of this Study. The calculation was performed taking the following steps:

- Estimating the need for cooling in buildings (maximum energy quantity).
- Estimating the level of meeting the need for cooling in buildings (the share of the maximum energy quantity consumed).

Need for cooling

The first step is to calculate the need for cooling, i.e. the amount of cooling required to ensure a comfortable temperature inside the building, which is not necessarily met in full.

As described in Chapter 4.2.2, taking into account the availability and limitations of data, the assessment uses the need for cooling energy in residential buildings in Lithuania estimated in the Stratego Study on the need for cooling in the EU countries – 27 kWh/m^2 per year.

The table below shows the surface area of cooled buildings by sector and actual or attributed energy performance class.

56 Table. Surface area of cooled buildings, thou m^2

Group, subgroup	**EPC**						
	<D	**C**	**B**	**A**	**A+**	**A++**	**Total**
1. Residential	71.316	10.171	9.424	974	656	51	**92.592**
1.1. Single-family	32.987	5.816	5.707	618	401	7	45.536
1.2. MAB (S)	2.019	36	37	4	1	0	2.098
1.3. MAB (M)	32.291	3.678	2.907	236	178	26	39.316
1.4. MAB (L)	4.019	641	774	116	75	18	5.643
Total	**71.316**	**10.171**	**9.424**	**974**	**656**	**51**	**92.592**

Source: authors of the Study

The average need for cooling energy (27 kWh/m^2/year) allows to obtain the estimated need for cooling.

57 Table. UEC need for cooling in 2020, GWh per year in 2020

Group, subgroup	**EPC**						
	<D	**C**	**B**	**A**	**A+**	**A++**	**Total**
1. Residential							
1.1. Single-family	891	157	154	17	11	0	1.229
1.2. MAB (S)	55	1	1	0	0	0	57
1.3. MAB (M)	872	99	78	6	5	1	1.062
1.4. MAB (L)	109	17	21	3	2	0	152
Total	1.926	**275**	**254**	**26**	**18**	**1**	**2.500**

Source: authors of the Study

Based on the above data, the need for cooling in households in Lithuania is 2,500 GWh per year.

Level of meeting the need for cooling

In accordance with the Stratego Study, the 'saturation' level of the need for cooling is about 1% for the residential sector and about 10% for the non-residential sector. In absence of data on the level of meeting the need for cooling by energy performance class, we assume that it is the same for all buildings of the respective purpose.

58 Table. Assumption used in the study for meeting the need for cooling

	<D	**C**	**B**	**A**	**A+**	**A++**
Residential	1%	1%	1%	1%	1%	1%

Source: authors of the Study

Results of the assessment of cooling demand

Based on the assumptions described above, estimated cooling consumption data are presented in the table below.

59 Table. Estimated consumption (UEC) for cooling, GWh per year in 2020

Group, subgroup	**EPC**						
	<D	**C**	**B**	**A**	**A+**	**A++**	**Total**
1. Residential							
1.1. Single-family	8,91	1,57	1,54	0,17	0,11	0,00	12,29
1.2. MAB (S)	0,55	0,01	0,01	0,00	0,00	0,00	0,57
1.3. MAB (M)	8,72	0,99	0,78	0,06	0,05	0,01	10,62
1.4. MAB (L)	1,09	0,17	0,21	0,03	0,02	0,00	1,52
Total	19,26	2,75	2,54	0,26	0,18	0,01	25,00

Source: authors of the Study

To sum up, current cooling demand of households (UEC) amounts to 25 GWh or 0.2% of total useful energy consumed by households.

It is assumed that all cooling energy is produced using heat pumps. We estimate that cooling is produced with an average cooling coefficient of performance of COP 2.7 (an average of 2.7 kWh of cooling is produced from 1 kWh of electricity). Accordingly, current cooling demand of households (FEC) is estimated at 9 GWh.

60 Table. Estimated electricity consumption for cooling purposes (FEC), GWh per year in 2020

Group, subgroup	**EPC**						
	<D	**C**	**B**	**A**	**A+**	**A++**	**Total**
1. Residential							
1.1. Single-family	3,30	0,58	0,57	0,06	0,04	0,00	4,55
1.2. MAB (S)	0,20	0,00	0,00	0,00	0,00	0,00	0,21
1.3. MAB (M)	3,23	0,37	0,29	0,02	0,02	0,00	3,93
1.4. MAB (L)	0,40	0,06	0,08	0,01	0,01	0,00	0,56
Total	**7,13**	**1,02**	**0,94**	**0,10**	**0,07**	**0,01**	**9,26**

Source: authors of the Study

4.4. DEMAND IN THE SERVICE SECTOR

After the analysis of heating and cooling demand, during which the heating and cooling consumption data (Chapters 4.1 and 4.2) were sorted, structured and typified, the next step is the assessment of the demand in the sectors within the scope of the Study. This Chapter presents assessment results on the service sector:

- Heating demand in the service sector (Chapter 4.4.1).
- Cooling demand in the service sector (Chapter 4.4.2).

4.4.1. Heating demand in the service sector

This Chapter presents assessment results of heating demand in the service sector (Demand Segment B1).

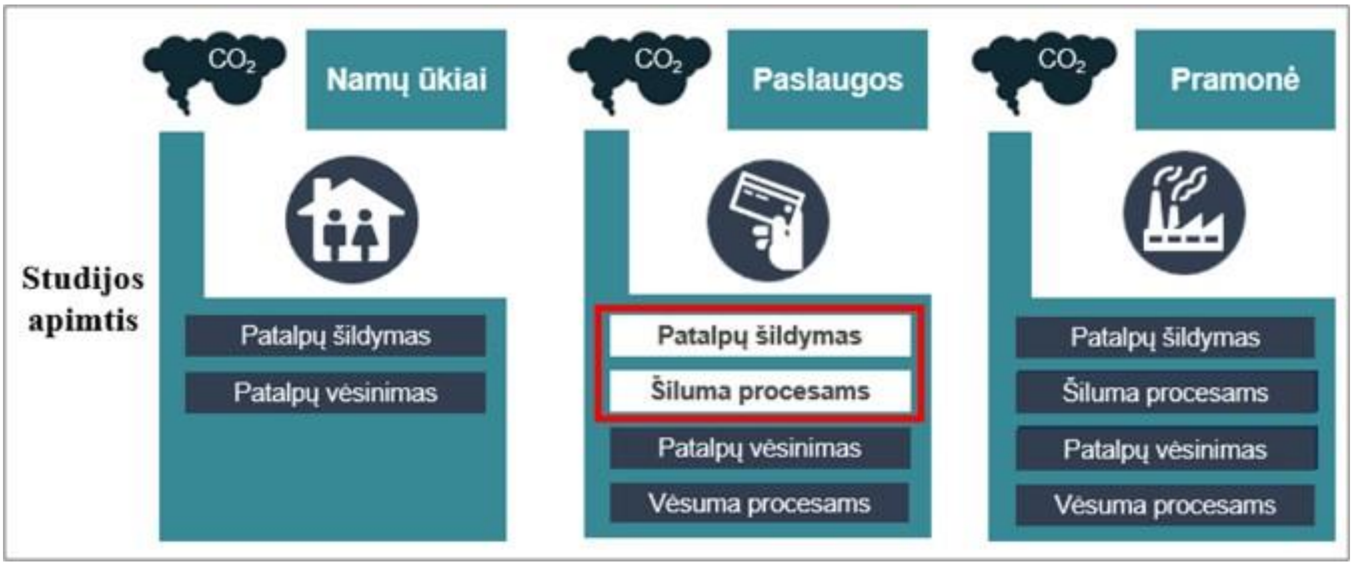
61 Table. Heating and cooling demand segments

Sector	Demand segment		UEC 2020, GWh	
	Heating demand	Cooling demand	Heating demand	Cooling demand
Households	A1	A2	12.314	25
Services	B1	B2	3.619	217
Industry	C1	C2	7.359	406

Source: authors of the Study

Heating demand in the service sector segment includes space heating (including hot water preparation) and heat for processes (e.g. pool water heating).

Figure 15. Heating demand in the service sector



Source: authors of the Study

Actual demand data collected during the analysis of heating demand account for about 30% of total heating demand of the service sector.

62 Table. Thermal energy (UEC), GWh

Group	Energy balance	Actual demand			Estimated demand
		DH system	DSO gas	Total	
Service sector	3.619	1.062	15	1.077	2.542
	100%	29%	0.4%	30%	70%

Source: authors of the Study

Actual heating demand

Actual data on gas consumption in the service sector were not provided[52]. Accordingly, 99% of actual consumption data reflect consumption data of DH consumers. Consumer data of a total of 6,400 consumers from the service sector were obtained. In 2020, those consumers consumed 1,107 GWh of useful energy.

63 Table. Actual consumption in the service sector (UEC) in 2020, GWh

Group, subgroup	EPC						
	<D	C	B	A	A+	A++	Total
2. Service sector							
2.1. Services	113	43	66	4	2	0	229
2.2. Administrative	193	45	33	11	6	0	289
2.3. Trade	50	19	49	1	1	0	120
2.4. Other	277	83	73	3	1	0	438
Total	**635**	**191**	**222**	**19**	**10**	**0**	**1.077**

Source: authors of the Study

64 Table. Number of consumers (buildings) in the service sector, number

Group, subgroup	EPC						
	<D	C	B	A	A+	A++	Total
2. Service sector							
2.1. Services	741	176	393	23	23	1	1.357
2.2. Administrative	1.511	184	150	34	16	0	1.895
2.3. Trade	624	94	224	15	13	0	970
2.4. Other	1.576	380	248	17	4	0	2.225
Total	**4.452**	**834**	**1.015**	**89**	**56**	**1**	**6.447**

Source: heat suppliers, authors of the Study

Actual demand data will be attributed to relevant consumers and displayed on the heating and cooling map.

Estimated heating demand

Actual demand data at consumer level account for about 30% of total heating demand in the service sector indicated in the energy balance. In order to show heating demand of all consumers in the service sector on the map, it is necessary to calculate heating demand of the remaining consumers.

Actual consumption data obtained do not allow to make a distinction between heat used for processes and heat used for heating the building. Moreover, within the scope of the Study we have not identified any reliable data sources that provide estimates of how much heating demand in the service sector is attributable to processes. However, taking into account the structure of the heating consumer base in the service sector (see table below), we estimate that heat is used intensively for processes only by a specific part of consumers in the service sector, such as swimming pools, health resorts, spas, saunas, etc.

65 Table. Heating consumer base in the service sector in 2020

Group, subgroup	Number	Number, %	Total surface area, m^2	Total surface area, %
Service sector	**40.715**	**100%**	**36.848**	**23%**
Services	12.524	31%	7.285	5%
Administrative	9.808	24%	10.031	6%
Trade	8.191	20%	6.809	4%
Other	10.192	25%	12.724	8%

Source: authors of the Study

Accordingly, in the scope of this Study, we estimate that the largest share of heating demand in the service sector is thermal energy for heating buildings.

52 15 GWh (Table 52) covers consumer household consumption contracts in the service sector.

Based on the results of the analysis of heating demand (Chapter 4.1.6), the following assessments are made:

- Actual data on DH system demand at consumer level provide a sufficiently reliable picture of actual heat consumption for heating buildings. Accordingly, the data can be used as a basis for assessing heat demand of consumers for whom no actual demand data are available (after proper data processing and ensuring that the sample used is sufficiently representative).
- Actual DSO data for the service sector segment were obtained only for a small part of the buildings (0.3%), i.e. only for those whose owners concluded household supply contracts. The data are therefore seen as unrepresentative and are not used for further analysis.

Data were obtained from heat suppliers on energy consumption of about 5,600 buildings in the service sector.

66 Table. Data from heat suppliers: number of service sector buildings connected to DH systems, number

Group, subgroup	EPC						
	<D	**C**	**B**	**A**	**A+**	**A++**	**Total**
2. Service sector							
2.1. Services	599	111	172	11	15	1	909
2.2. Administrative	1.406	174	136	33	16	-	1.765
2.3. Trade	486	83	208	15	13	-	805
2.4. Other	1.538	378	245	17	4	-	2.182
Total	**4.029**	**746**	**761**	**76**	**48**	**1**	**5.661**

Source: heat suppliers, authors of the Study

Average (arithmetic mean) heating demand data for these buildings are presented below.

67 Table. Data from heat suppliers: average thermal energy consumption in the service sector (kWh/m[2]/year)

Group, subgroup	EPC					
	<D	**C**	**B**	**A**	**A+**	**A++**
2. Service sector	**80**	**61**	**60**	**37**	**24**	**58**
2.1. Services	98	90	81	59	35	58
2.2. Administrative	77	66	54	28	20	-
2.3. Trade	50	36	44	30	28	-
2.4. Other	83	60	65	105	49	-

Source: heat suppliers, authors of the Study

In order to ensure that average actual consumption data are representative and suitable for extrapolation, from the above data we eliminate the following[53]:

- Insufficiently accurate data, i.e. consumption data that cannot be assigned to a specific building (addresses where more than 1 building is registered).
- Atypical deviations, i.e. minimum and maximum consumption values.
- Data samples that are insufficient to reflect heat demand of a specific benchmark building.

Consumption data after identifying and eliminating outliers are presented in the table below.

68 Table. Data from heat suppliers: normalised average thermal energy consumption by households (kWh/m[2]/year)

Group, subgroup	EPC					
	<D	**C**	**B**	**A**	**A+**	**A++**
2. Service sector	**87**	**69**	**61**	**47**	**26**	**58**
2.1. Services	79	74	58	35	26	58
2.2. Administrative	79	74	58	35	26	58
2.3. Trade	79	74	58	35	26	58
2.4. Other	101	65	68	108	26	

Source: heat suppliers, authors of the Study

53 Detailed information is provided in Annex 2.2.

When analysing the above data, it can be observed that some benchmarks have no actual average heat consumption attributed to them due to the inadequate data sample. In such cases consumption in a benchmark building is calculated taking into account consumption of the entire service sector (Group '1. Service sector') by EPC[54].

Estimated average consumption data for all benchmark buildings are presented in the table below.

69 Table. Estimated average standardised consumption in benchmark buildings (kWh/m²/year)

Group, subgroup	EPC					
	<D	C	B	A	A+	A++
2. Service sector	**87**	**69**	**61**	**47**	**26**	**19**
2.1. Services	79	74	58	35	26	19
2.2. Administrative	79	74	58	35	26	19
2.3. Trade	79	74	58	35	26	19
2.4. Other	101	65	68	52	29	22

Source: heat suppliers, authors of the Study

These estimated heating demand data for heating buildings are attributed to consumers for whom no actual consumption data (by benchmark) are available and are displayed on the heating and cooling map.

Total UEC calculated for these users is disclosed in the table below.

70 Table. Estimated UEC for heating buildings, GWh

Group, subgroup	EPC						
	<D	C	B	A	A+	A++	Total
2. Service sector							
2.1. Services	404	72	98	2	1	0	577
2.2. Administrative	1.276	76	86	28	4	-	1.469
2.3. Trade	212	65	74	4	4	0	358
2.4. Other	575	109	50	1	2	0	738
Total	**2.468**	**322**	**307**	**34**	**11**	**0**	**3.142**

Source: authors of the Study

NB: estimated demand for consumers in the service sector for whom no actual consumption data are available covers only demand for heating buildings. In our opinion, heating demand for processes cannot be reliably calculated by extrapolating actual consumption data representing 19% of total heat consumption in the service sector.

Results of the assessment of heating demand

According to the calculations described above, with actual and estimated consumption combined, we obtain the following data on energy consumption for heating buildings.

71 Table. Annual UEC for heating buildings in the service sector, GWh

Group, subgroup	EPC						
	<D	C	B	A	A+	A++	Total
2. Service sector							
2.1. Services	518	115	164	6	3	0	806
2.2. Administrative	1.469	121	119	39	10	-	1.757
2.3. Trade	263	84	123	4	5	0	479
2.4. Other	853	193	124	4	3	0	1.176
Total	3.102	513	529	54	21	0	**4.219**

Source: authors of the Study

54 Detailed information is provided in Annex 2.2.

When analysing the results obtained, it is important to note that total heat consumption of the service sector (4.2 TWh) is estimated to be 17% higher than the one indicated in the energy balance (3.6 TWh). In our opinion, the main reasons for this are as follows:

- In absence of DSO data on actual electricity consumption, no identification and elimination of buildings that are not actually heated was carried out.
- A non-homogeneous heating consumer base in the service sector, i.e. to a significantly greater extent than the differentiated need for heat of individual consumer groups in the household segment (e.g. Subgroup '2.1. Services' includes both catering and medical treatment buildings), which is likely to lead to lower reliability of extrapolation.

In order to maintain consistency with the statistics, estimated consumption is proportionately reduced for each benchmark. The final results of the assessment of demand in the service sector are presented in the tables below.

72 Table. FEC for heating buildings in the service sector, GWh

Group, subgroup	EPC						
	<D	**C**	**B**	**A**	**A+**	**A++**	**Total**
2. Service sector							
2.1. Services	432	114	159	7	4	0	716
2.2. Administrative	209	114	119	3	3	0	448
2.3. Trade	917	107	92	29	10	-	1.155
2.4. Other	806	245	165	5	5	0	1.227
Total	**2.365**	**580**	**536**	**44**	**22**	**0**	**3.546**

Source: authors of the Study

73 Table. UEC for heating buildings in the service sector, GWh

Group, subgroup	EPC						
	<D	**C**	**B**	**A**	**A+**	**A++**	**Total**
2. Service sector							
2.1. Services	440	115	162	7	4	0	729
2.2. Administrative	214	111	121	3	3	0	453
2.3. Trade	944	110	97	29	10	-	1.191
2.4. Other	818	253	165	5	5	0	1.247
Total	**2.417**	**589**	**546**	**44**	**23**	**0**	**3.619**

Source: authors of the Study

4.4.2. Cooling demand in the service sector

This Chapter presents assessment results of current cooling demand in the service sector (Demand Segment B2).

74 Table. Heating and cooling demand segments

Sector	Demand segment		UEC 2020, GWh	
	Heating demand	Cooling demand	Heating demand	Cooling demand
Households	A1	A2	12.314	25
Services	B1	B2	3.619	217
Industry	C1	C2	7.359	406

Source: authors of the Study

Demand for cooling in the service sector segment includes space cooling and cooling used for processes (for providing services).

Figure 16. Cooling demand in the service sector

Source: authors of the Study

Based on our estimates[55], cooling demand in the service sector amounts to about 217 GWh per year (UEC).

75 Table. Thermal energy (UEC), GWh

Group	Energy balance, GWh	Actual consumption	Estimated consumption
Service sector	217	-	217

Source: authors of the Study

Actual cooling demand

During the preparation of the Study, no sources of actual energy consumption for cooling in the service sector were identified.

55 More detailed information is provided in Annex 2.1.

Estimated cooling demand

In absence of actual data on household energy consumption for cooling, we performed a calculation of cooling energy consumption based on standardised consumption for the purposes of this Study.

The calculation was performed taking the following steps:

- Estimating the need for cooling in buildings (maximum energy quantity).
- Estimating the level of meeting the need for cooling in buildings (the share of the maximum energy quantity consumed).

Need for cooling

The first step is to calculate the need for cooling, i.e. the amount of cooling required to ensure a comfortable temperature inside the building, which is not necessarily met in full.

As described in Chapter 4.2.2, taking into account the availability and limitations of data, the assessment uses the need for cooling energy in non-residential buildings in Lithuania estimated in the Stratego Study on the need for cooling in the EU countries – 59 kWh/m^2 per year.

The need for cooling is determined as the same for all residential buildings in all energy performance classes respectively.

The table below shows the surface area of cooled buildings by sector and actual or attributed energy performance class.

76 Table. Surface area of cooled buildings, thou m^2

Group, subgroup	EPC							Total, %
	<D	C	B	A	A+	A++	Total	
2. Service sector								
2.2. Services	4.239	1.252	1.565	123	105	2	7.285	20%
2.3. Administrative	7.098	1.145	985	487	314	0	10.031	27%
2.4. Trade	3.307	1.079	2.124	127	171	2	6.809	18%
2.5. Other	8.141	2.645	1.792	56	88	1	12.724	35%
Total	**22.785**	**6.122**	**6.466**	**793**	**678**	**5**	**36.848**	**100%**
Total, %	62%	17%	18%	2%	2%	0%		

Source: authors of the Study

The average need for cooling energy (59 kWh/m^2/year) allows to obtain the estimated need for cooling.

77 Table. Need for cooling in 2020, GWh per year in 2020

Group, subgroup	EPC						
	<D	C	B	A	A+	A++	Total
2. Service sector							
2.2. Services	250	74	92	7	6	0	430
2.3. Administrative	419	68	58	29	19	0	592
2.4. Trade	195	64	125	7	10	0	402
2.5. Other	480	156	106	3	5	0	751
Total	**1.344**	**361**	**381**	**47**	**40**	**0**	**2.174**

Source: authors of the Study

Based on the above data, the need for cooling in the service sector in Lithuania is 2,174 GWh per year.

Level of meeting the need for cooling

In accordance with the Stratego Study, the ‘saturation’ level of the need for cooling is about 1% for the residential sector and about 10% for the non-residential sector. In absence of reliable data on the level of meeting the need for cooling by energy performance class, it is believed to be the same.

78 Table. Level of meeting the need for cooling in the service sector

	<D	**C**	**B**	**A**	**A+**	**A++**
Service sector	10%	10%	10%	10%	10%	10%

Source: authors of the Study

Results of the assessment of cooling demand

Based on the assumptions described above, estimated cooling consumption data are presented in the table below.

79 Table. Estimated UEC for cooling in the service sector, GWh per year (2020)

Group, subgroup	**EPC**						
	<D	**C**	**B**	**A**	**A+**	**A++**	**Total**
2. Service sector							
2.2. Services	25,01	7,39	9,23	0,73	0,62	0,01	42,98
2.3. Administrative	41,88	6,76	5,81	2,87	1,85	0,00	59,18
2.4. Trade	19,51	6,37	12,53	0,75	1,01	0,01	40,17
2.5. Other	48,03	15,61	10,57	0,33	0,52	0,01	75,07
Total	**134,43**	**36,12**	**38,15**	**4,68**	**4,00**	**0,03**	**217,40**

Source: authors of the Study

Based on the calculations, current cooling demand of the service sector (UEC) amounts to 217.4 GWh or 5.7% of total useful energy consumed by the service sector.

It is assumed that all cooling energy is produced using heat pumps. We estimate that cooling is produced with an average cooling coefficient of performance of COP 2.7 (an average of 2.7 kWh of cooling is produced from 1 kWh of electricity). Accordingly, current cooling demand of households (FEC) is estimated at 80.5 GWh.

80 Table. Estimated FEC for cooling in the service sector, GWh per year (2020)

Group, subgroup	**EPC**						
	<D	**C**	**B**	**A**	**A+**	**A++**	**Total**
2. Service sector							
2.2. Services	9,26	2,74	3,42	0,27	0,23	0,00	15,92
2.3. Administrative	15,51	2,50	2,15	1,06	0,69	0,00	21,92
2.4. Trade	7,23	2,36	4,64	0,28	0,37	0,00	14,88
2.5. Other	17,79	5,78	3,92	0,12	0,19	0,00	27,80
Total	**49,79**	**13,38**	**14,13**	**1,73**	**1,48**	**0,01**	**80,52**

Source: authors of the Study

4.5. DEMAND IN THE INDUSTRY SECTOR

After the analysis of heating and cooling demand, during which the heating and cooling consumption data (Chapters 4.1 and 4.2) were sorted, structured and typified, the next step is the assessment of the demand in the sectors within the scope of the Study. This Chapter presents assessment results on the industry sector:

- Heating demand in the industry sector (Chapter 4.5.1).
- Cooling demand in the industry sector (Chapter 4.5.2).

4.5.1. Heating demand in the industry sector

This Chapter presents assessment results of heating demand in the industry sector (Demand Segment C1).

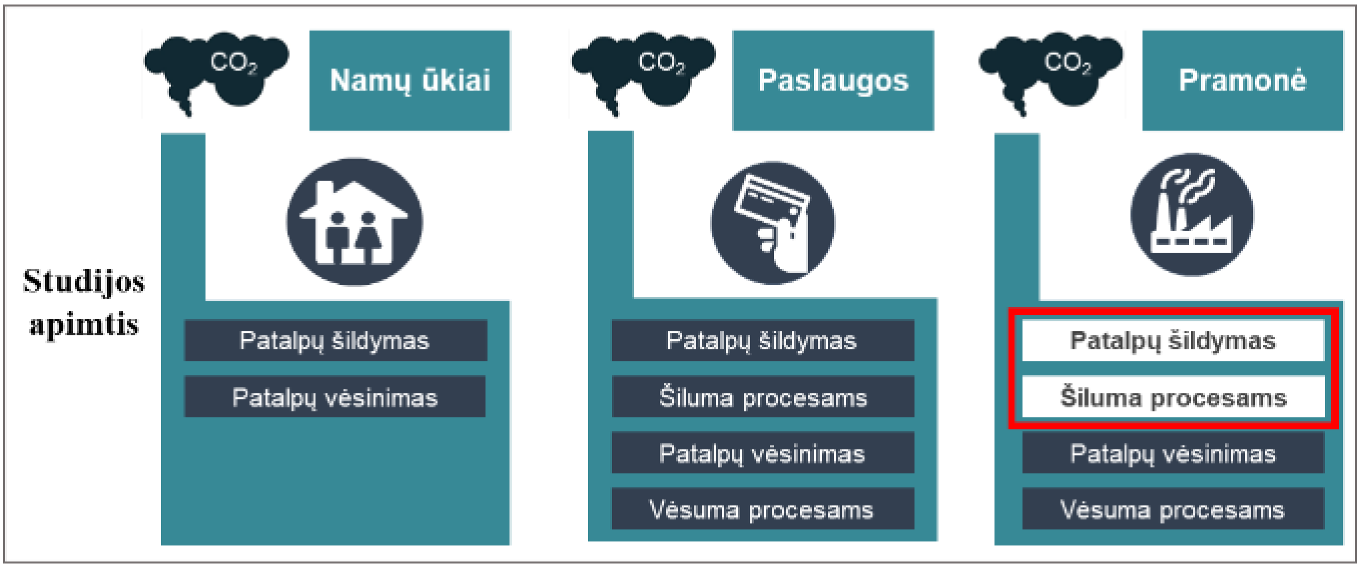
81 Table. Heating and cooling demand segments

Sector	Demand segment		UEC 2020, GWh	
	Heating demand	Cooling demand	Heating demand	Cooling demand
Households	A1	A2	12.314	25
Services	B1	B2	3.619	217
Industry	C1	C2	7.359	406

Source: authors of the Study

Heating demand in the industry sector includes heating of buildings and heat for manufacturing processes.

Figure 17. Heating demand in the industry sector



Source: authors of the Study

Actual demand data collected during the analysis of heating demand account for about 2% of total heating demand of the industry sector.

82 Table. Thermal energy (UEC), GWh

Group	Energy balance	Actual consumption data received	No actual consumption data available
Industry sector	7.359	156	7.203
	100%	2%	98%

Source: authors of the Study

Actual heating demand

Actual data on gas consumption in the industry sector were not provided[56]. Accordingly, 98% of actual consumption data reflect consumption data of DH consumers. Data of a total of 2,928 industrial consumers were obtained. In 2020, these consumers consumed 156 GWh of thermal energy (UEC).

83 Table. Thermal energy in the industry sector, UEC, GWh

Indicator	Total, GWh	Thermal energy		Gas	Other sources
		Heat transfer agent	Steam		
Energy balance[57]	**7.359**	224	1.569	2.890	2.676
Data from heat suppliers	**153**	153	-	-	-
DSO data	**3**	-	-	3	-

Source: authors of the Study

In analysing the actual consumption data presented above, it can be noted that:

- The absolute majority of actual demand data (153 GWh) reflect the consumption of thermal energy for heating buildings as heat transfer agent. Actual data were obtained only from some heat suppliers (see Table 23), so only a part of the UEC included in the energy balance (224 GWh) could be attributed to specific customers.
- No actual demand data for thermal energy in the form of steam at consumer level were obtained from heat suppliers. This type of energy supply is not a regulated monopoly service and actual consumption data are treated as commercially sensitive information.
- Actual gas consumption data of industrial plants are also considered commercially sensitive information and were therefore not provided. Data from other individual production sources are not systematically collected.

To sum up, actual data on heating demand in the industry sector were obtained only for a negligible part of consumers and represent only thermal energy for heating buildings. At the same time, it is estimated that a major share of heating demand in the industry sector is thermal energy for manufacturing processes.

According to a 2015 study on enhancing energy efficiency of industrial plants[58], the amount of thermal energy for heating buildings is as follows:

- For the largest plants in the industry sector consuming the most thermal energy – about 1% of total thermal energy consumption;
- For other industrial plants – about 20% of total thermal energy consumption.

Accordingly, it is assessed that the sample of actual consumption data obtained is not sufficient and representative to serve as a basis for calculating heating demand of the remaining consumers.

Estimated heating demand

The analysis of data sources helped to identify two main sources of energy consumption data for consumers in the industry sector:

- Data from LAND and AIVIKS databases managed by the Environmental Protection Agency ('EPA data');
- Data collected by the Lithuanian Energy Agency from energy audits carried out at the most energy-intensive industrial plants ('ENA data').

56 3 GWh UEC reflects situations where consumption of an industrial building is paid for by a household consumer.
57 More detailed information is provided in Annex 2.1.
58 Study "Identification of the potential for enhancing energy efficiency of industrial plants and measures to promote efficient use of

various types of energy", 2015, commissioned by the Ministry of Foreign Affairs of the Republic of Lithuania.

EPA data

EPA data are collected for pollution control and prevention purposes:

- The LAND database stores data for reporting emissions from fuel and combustion plants into ambient air[59]. Such reports must be submitted by operators of combustion plants with a thermal input over 1 MW, except for those operating combustion plants respecting the terms of emission allowances (see below).
- The AIVIKS database stores data from the annual reports on air pollution[60]. Such reports must be submitted by operators who operate combustion plants respecting the terms of emission allowances or the integrated pollution prevention and control permit.

The table below offers a summary of EPA data on the amount of fuel consumed by plants (converted as FEC), revealing the top 10 largest plants by FEC.

84 Table. Largest energy consumers in the industry sector, FEC, GWh

No	Company name	Fuel consumption
1	AB ORLEN Lietuva	1.710
2	AB Achema	989
3	AB Akmenės cementas	911
4	UAB Technology projects	612
5	UAB NEO GROUP	448
6	UAB gamybinė-komercinė firma Fonas	389
7	AB Amilina	365
8	AB Grigeo	305
9	AB Grigeo Klaipėda	267
10	UAB Orion Global PET	222
	Other companies	3.115
	Total	**9.333**

Source: Environmental Protection Agency (AIVIKS and LAND databases)

In analysing the EPA data presented above, it is important to note that:

- Consumption by top 10 largest plants by FEC accounts for about two thirds of total 2020 energy consumption as registered in EPA-administered databases.
- Fuel consumption declared by businesses may be intended not only for generating thermal energy (e.g. some of that fuel may be used for generating electricity).
- Although the EPA data do not cover all businesses in the industry sector, the reports indicate that total FEC of those businesses in 2020 (9.3 TWh) is almost a fifth greater than total FEC for the relevant energy sources in the industry sector as a whole as reported in the energy balance (7.9 TWh).

The EPA data are therefore considered not relevant for the assessment of heating demand in the industry

sector. ENA data

Data collected by the ENA on the most energy-intensive industrial plants reveal the results of energy audits carried out. In general, such data represent average energy needs of an audited industrial plant for 2 to 3 years.

The table below provides a summary of the ENA data revealing top 20 largest plants by FEC.

59 In accordance with the requirements of the Emission standards for combustion plants LAND 43-2013 approved by Order No. D1-244 of the Minister for the Environment of the Republic of Lithuania of 10 April 2013.

60 In accordance with the requirements of the Procedure for the accounting and reporting of emissions into ambient air.

85 Table. ENA summary data, FEC, GWh

No	Company name	Fuel consumption	Electricity costs	Heating costs
1	AB Achema	5.062	410	0
2	UAB Marijampolės pieno konservai plant	4.786	12	0
3	UAB NEO GROUP	1.508	74	0
4	UAB Bauwerk Boen	1.421	41	0
5	AB Akmenės cementas	890	134	0
6	UAB NEO Group	339	93	0
7	AB Amilina	246	158	0
8	UAB HI-STEEL	227	1	0
9	UAB Nemuno banga	225	6	0
10	UAB IKEA Industry Lietuva	219	64	0
	Other companies	3.552	3.000	1.238
	Total	**18.474**	**3.991**	**1.238**

Source: Lithuanian Energy Agency

In analysing the ENA data presented above, it is important to note that:

- Consumption by top 10 largest plants by FEC accounts for about four fifths of total 2020 energy consumption as registered in the ENA database.
- Fuel consumption declared by businesses may be intended not only for generating thermal energy (e.g. some of that fuel may be used for producing raw materials or generating electricity).
- Although the ENA data do not cover all businesses in the industry sector, the reports indicate that total fuel FEC of those businesses in 2020 (18.5 TWh) is more than twice as great as total FEC for the relevant energy sources in the industry sector as reported in the energy balance (7.9 TWh).
- Compared to the EPA data, data from the same companies differ significantly.

The ENA data are therefore considered not relevant for the assessment of heating demand in the industry sector.

Results of the assessment of heating demand

To sum up, there are no actual or reliable statistics on the consumption of energy for heating by individual industrial consumers. The energy consumption forecast in the industry sector for the purposes of the Study is therefore based on the energy balance data by industry sector (subsector). Data on UEC and FEC for heating by industry sector are presented below.

86 Table. Thermal energy consumption in the industry sector, FEC and UEC

No	Segment	FEC, GWh	Total, %	UEC, GWh	Total, %
1	Manufacture of chemicals and chemical products	3102	39%	2972,2	40%
2	Manufacture of food products, beverages and tobacco	1430	18%	1319,9	18%
3	Manufacture of cement, lime and plaster	918	12%	836,8	11%
4	Manufacture of wood and products of wood	824	10%	762,6	10%
5	Manufacture of other non-metallic mineral products	386	5%	351,1	5%
6	Manufacture of paper and paper products	370	5%	338,7	5%
7	Manufacture of furniture	184	2%	173,1	2%
8	Manufacture of glass and glass products	134	2%	122,8	2%
9	Other manufacturing (up to 1%)	508	6%	481,4	7%
15	**Total**	**7.855**	**100%**	**7.359**	**100%**

Source: Statistics Lithuania, authors of the Study

4.5.2. Cooling demand in the industry sector 74

This Chapter presents assessment results of current cooling demand in the service sector (Demand Segment B2).

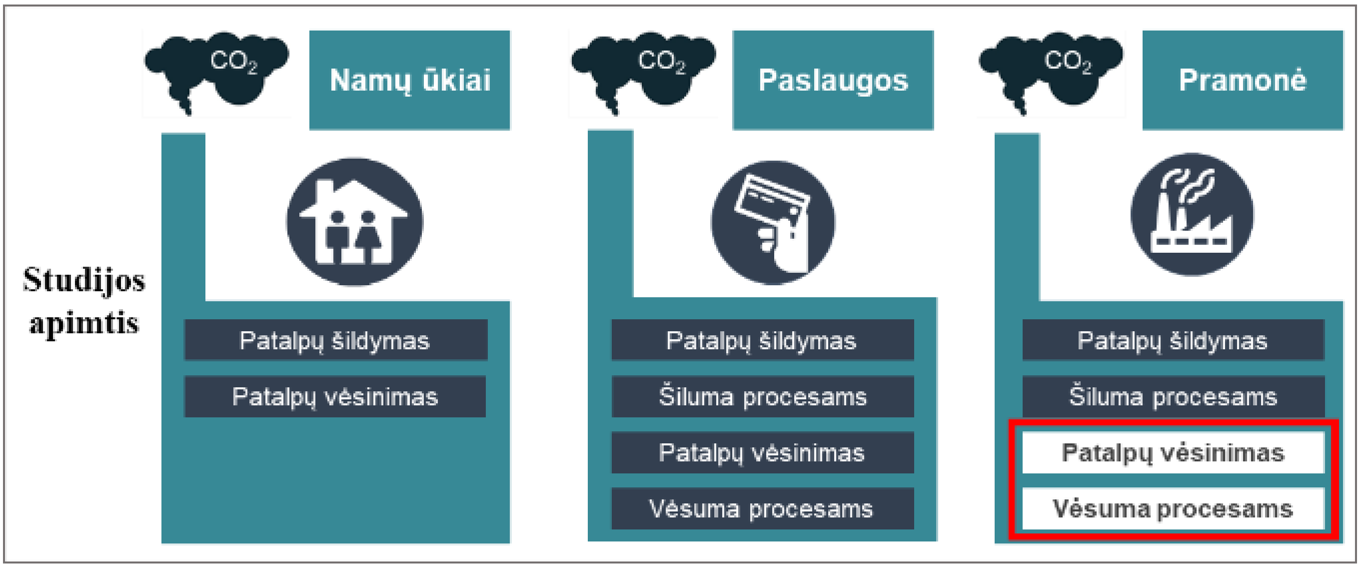
87 Table. Heating and cooling demand segments

Sector	Demand segment		UEC 2020, GWh	
	Heating demand	Cooling demand	Heating demand	Cooling demand
Households	A1	A2	12.314	25
Services	B1	B2	3.619	217
Industry	C1	C2	7.359	406

Source: authors of the Study

Demand for cooling in the industry sector segment includes space cooling and cooling used for processes and manufacturing.

Figure 18. Cooling demand in the industry sector



Source: authors of the Study

Based on our estimates[61], cooling demand in the industry sector amounts to about 406 GWh per year (UEC).

88 Table. Thermal energy (UEC), GWh

Group	Energy balance, GWh	Actual consumption	Estimated consumption
Industry sector	406	-	406

Source: authors of the Study

Actual demand

During the preparation of the Study, no sources of actual energy consumption for cooling in the industry sector were identified.

Estimated demand

In absence of actual data on energy consumption for cooling in the industry sector, we performed a calculation of cooling energy consumption based on standardised consumption by industry subsector for the purposes of this Study.

61 More detailed information is provided in Annex 2.1.

Cooling demand for industry

Within the scope of the Study, an assessment of the need for cooling was only carried out only by sector, assessing the need for cooling for building microclimate control and processes performed by industrial plants. For this purpose, we used the energy balance data of Statistics Lithuania by business sectors and the need for cooling in the industry sector and electricity consumption by coefficients assigned to industry sectors as calculated by Riga Technical University and commissioned by the Ministry of the Economy of the Republic of Latvia[62]. There is no information about a similar study drawn up in Lithuania as the one commissioned by the Ministry of the Economy of the Republic of Latvia, therefore, taking into account the geographical, cultural and economic level of development, it is assumed that the share of electricity for cooling is similar to that established in Latvia.

89 Table. Assessment of the need for cooling in the industry sector by sector

Industry sector	Electricity consumption, GWh	Share of electricity intended for cooling, %	Share of electricity intended for cooling, GWh	Generated cooling, GWh
Manufacture of chemicals and chemical products	818,8	2%	14,1	38,00
Manufacture of food products, beverages and tobacco	781,5	8%	62,5	168,81
Manufacture of wood and products of wood, except furniture	382,6	0%	0,2	0,41
Manufacture of rubber and plastic products	358,2	10%	34,0	91,88
Manufacture of furniture	290,8	10%	27,6	74,58
Manufacture of paper and paper products	152,4	4%	6,2	16,87
Manufacture of other non-metallic mineral products	260,5	0%	1,0	2,81
Manufacture of fabricated metal products, except machinery and equipment	122,1	0%	0,2	0,66
Manufacture of textiles	97,7	1%	0,7	1,85
Other mining and quarrying	44,2	2%	0,8	2,13
Manufacture of computer, electronic and optical products	40,7	-	-	-
Other manufacturing	40,7	-	-	-
Printing and reproduction of recorded media	34,9	4%	1,4	3,86
Manufacture of wearing apparel	33,7	1%	0,2	0,64
Manufacture of electrical equipment	32,6	-	-	-
Manufacture of machinery and equipment n.e.c.	32,6	-	-	-
Manufacture of other transport equipment	26,7	1%	0,3	0,87
Manufacture of motor vehicles and trailers	23,3	1%	0,3	0,75
Manufacture of basic metals	10,5	5%	0,6	1,53
Manufacture of basic pharmaceutical products and pharmaceutical preparations	8,1	2%	0,1	0,38
Manufacture of leather and related products	1,2	1%	0,0	0,02
Mining support service activities	-	0%	-	-
Total	**3.593,7**	**4%**	**150,4**	**406**

Source: authors of the Study

In order to calculate the need for cooling produced in the industry sector based on data of electricity consumed for cooling, we estimate that cooling is produced with an average coefficient of performance of COP 2.7 (an average of 2.7 kWh of cooling is produced from 1 kWh of electricity). Accordingly, the result is that the need for cooling in Lithuania's industry sector amounts to 406 GWh, as described in greater detail by industry sector in the table above.

90 Table. Useful energy need for cooling in the industry sector, GWh

Sector	Cooling
Industry	406

Source: authors of the Study

62 Data collected under Contract No. 03000-3.3.2-e/13 of 20 May 2019 signed between the Ministry of the Economy of the Republic of Latvia and Riga Technical University.

4.6. AGGREGATE DATA

After the assessment of demand in the sectors falling within the scope of the Study, the next step is to summarise the data at the national level:

- Assessment of current (2020) heating and cooling demand (Chapter 4.6.1).
- Assessment of heating and cooling demand in 2015-2019 (Chapter 4.6.2).

4.6.1. Heating and cooling demand (2020)

To sum up the above calculations, we estimate that current UEC demand for heating and cooling (in 2020) amounted to 23.9 TWh in the sectors falling within the scope of the Study.

The table below shows heating and cooling demand in 2020 by sector and source of production (UEC).

91 Table. Heating and cooling UEC, 2020, GWh

Sector		DH	Gas	Electricity	RES fuel	Ambience	Other FF	Total
Heat	Households	4.889	1.420	311	4.464	323	908	**12.314**
	Services	1.836	734	148	376	252	273	**3.619**
	Industry	1.793	2.890	36	1.312	61	1.267	**7.359**
	Total	**8.519**	**5.043**	**494**	**6.152**	**635**	**2.447**	**23.292**
Cooling	Households	-	-	9	-	16	-	**25**
	Services	-	-	80	-	137	-	**217**
	Industry	-	-	150	-	256	-	**406**
	Total	-	-	**239**	-	**409**	-	**648**
Total	Households	4.889	1.420	320	4.464	339	908	**12.339**
	Services	1.836	734	228	376	389	273	**3.836**
	Industry	1.793	2.890	186	1.312	317	1.267	**7.765**
	Total	**8.519**	**5.043**	**733**	**6.152**	**1.044**	**2.447**	**23.940**

Source: authors of the Study

The table below shows heating and cooling demand in 2020 by sector and source of production (FEC).

92 Table. Heating and cooling FEC, 2020, GWh

Sector		DH	Gas	Electricity	RES fuel	Ambience[63]	Other FF	Total
Heat	Households	4.889	1.562	311	5.357	323	1.033	**13.474**
	Services	1.836	807	148	414	16	324	**3.546**
	Industry	1.793	3.178	36	1.443	10	1.393	**7.855**
	Total	**8.519**	**5.547**	**494**	**7.214**	**350**	**2.750**	**24.875**
Cooling	Households	-	-	9	-	16	-	**25**
	Services	-	-	80	-	137	-	**217**
	Industry	-	-	150	-	256	-	**406**
	Total	-	-	**239**	-	**409**	-	**648**
Total	Households	4.889	1.562	320	5.357	339	1.033	**13.499**
	Services	1.836	807	228	414	153	324	**3.763**
	Industry	1.793	3.178	186	1.443	266	1.393	**8.261**
	Total	**8.519**	**5.547**	**733**	**7.214**	**759**	**2.750**	**25.523**

Source: authors of the Study

63 When converting UEC to FEC, 1,028 GWh of ambient energy was calculated but in order to maintain comparability, the table provides data

corresponding to the energy balance.

4.6.2. Heating and cooling demand (2015-2019)

Based on the calculations described in the chapter above, demand for the previous periods over the last five years has also been calculated. The tables below show heating and cooling demand in 2015-2019 by sector and source of production.

93 Table. Heating and cooling UEC, 2015-2020, GWh

Sector		**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Heat	Households	12.367	13.066	12.751	13.177	12.615	12.314
	Services	3.787	3.923	4.276	4.436	4.031	3.619
	Industry	7.398	7.368	8.035	8.363	8.332	7.359
	Total	**23.552**	**24.357**	**25.062**	**25.976**	**24.979**	**23.292**
Cooling	Households	23	23	24	24	25	25
	Services	201	205	208	212	215	217
	Industry	360	365	386	401	408	406
	Total	**584**	**593**	**618**	**637**	**648**	**648**
Total	Households	12.390	13.089	12.775	13.201	12.640	12.339
	Services	3.988	4.128	4.484	4.648	4.246	3.836
	Industry	7.758	7.733	8.421	8.764	8.741	7.765
	Total	**24.136**	**24.950**	**25.680**	**26.613**	**25.627**	**23.940**

Source: authors of the Study

94 Table. Heating and cooling FEC, 2015-2020, GWh

Sector		**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Heat	Households	13.090	13.791	13.971	14.408	13.793	13.474
	Services	3.755	3.897	4.247	4.403	3.959	3.546
	Industry	8.048	8.012	8.685	9.083	9.072	7.855
	Total	**24.892**	**25.699**	**26.904**	**27.894**	**26.824**	**24.875**
Cooling	Households	8	8	8	8	8	8
	Services	67	68	69	71	72	72
	Industry	133	135	143	149	151	150
	Total	**208**	**211**	**220**	**227**	**231**	**231**
Total	Households	13.098	13.798	13.979	14.416	13.801	13.483
	Services	3.822	3.965	4.317	4.473	4.030	3.619
	Industry	8.181	8.147	8.828	9.232	9.223	8.005
	Total	**25.101**	**25.910**	**27.124**	**28.121**	**27.054**	**25.106**

Source: authors of the Study

4.7. KEY OBSERVATIONS

4.7.1. Heating demand

95 Table. Heating UEC, 2020, GWh

Sector	DH	Gas	Electricit y	RES fuel	Ambience	Other FF	Total
Households	4.889	1.420	311	4.464	323	908	**12.314**
Services	1.836	734	148	376	252	273	**3.619**
Industry	1.793	2.890	36	1.312	61	1.267	**7.359**
Total	**8.519**	**5.043**	**494**	**6.152**	**635**	**2.447**	**23.292**
Total, %	37%	22%	2%	26%	3%	11%	100%

Source: authors of the Study

Household demand

Household demand accounts for more than half (53%) of estimated thermal energy demand. It is estimated that basically all demand is for heating buildings. Key observations:

- 84% of household demand is in energy inefficient buildings (energy performance classes D or lower).
- 28% of household heating demand (including district heating and electricity produced from fossil fuels) is met by using fossil fuels.

Demand in the service sector

16% of total estimated heating demand comes from the service sector. It is estimated that most of the demand is for heating buildings (heat is used intensively for processes only by a specific part of consumers in the service sector, e.g. swimming pools, health resorts, spas, saunas, etc.). Key observations:

- 65% of demand in the service sector is in energy inefficient buildings (energy performance classes D or lower).
- 40% of heating demand in the service sector (including district heating and electricity produced from fossil fuels) is met by using fossil fuels.

Demand in the industry sector

31% of total estimated heating demand comes from energy consumption in the industry sector. It is estimated that most of the demand is for industrial processes (the amount of thermal energy for heating buildings accounts for 1-20% of the sector's demand). Key observations:

- For heating in the industry sector, fossil fuels account for 61% of total heating demand in the sector (including district heating and electricity generated from fossil fuels).

Use of electricity for heating

Nearly 5% of estimated heating demand is met through electricity and ambient energy. This consumption was calculated using significant assumptions:

- No data are available on actual consumption of electricity and ambient energy for heating at consumer level;
- The data included in the energy balance also include electricity used for non-heating purposes (e.g. for lighting and appliances);
- Moreover, electricity consumption is calculated as part of total electricity consumption, also calculating ambient energy consumed at the same time.

4.7.2. Cooling demand

96 Table. Cooling UEC, 2020, GWh

Sector	DH	Gas	Electricity	RES fuel	Ambience	Other FF	Total
Households	-	-	9	-	16	-	**25**
Services	-	-	80	-	137	-	**217**
Industry	-	-	150	-	256	-	**406**
Total	-	-	**231**	-	**393**	-	**648**
Total, %	-	-	37%	-	63%	-	100%

Source: authors of the Study

Data inadequacy

As actual data are inadequate, the need for energy intended for cooling is calculated based on significant assumptions:

- Calculating the average need for energy and the level of meeting the need in households and the service sector, and assuming that all cooling is generated by using electricity;
- Calculating the need for cooling energy as part of total electricity consumption in the industry sector;
- In addition, calculating ambient energy used along with electricity.

Meeting the need for cooling

Final data on cooling energy consumption do not reflect the potential need for cooling energy as only a small part of the need is actually met. The following assumptions were used during the analysis:

- Only 1% of the need for cooling is met in households;
- Only 10% of the need for cooling is met in the service sector.

5. HEATING DEMAND FORECAST

Recommendation 2.4. In accordance with point 4 of Annex VIII to the EED, it is required to draw up a 30-year heating and cooling demand forecast, with more detailed information on the upcoming decade. The forecast must take into account the effect of the policy and strategy relating to energy efficiency and heating and cooling demand (e.g. long-term building renovation strategies under the Directive on the energy performance of buildings, integrated energy and climate action plans under the Management Regulation) and reflect the needs of various industry sectors.

The assessment of the potential of efficient heating within the scope of this Study covers the long-term perspective (2021-2050). Thus, with a view to identifying optimal heating technologies and formulating long-term efficiency enhancing tasks, there is a need for a long-term heating demand forecast.

As heating demand is directly affected by demand efficiency enhancing measures taken (e.g. building renovation) for which the implementation effect in 2050 may show significant differences, the heating demand forecast is drawn up based on three alternative scenarios. This Chapter goes on to describe:

- The forecasting model (Chapter 5.1);
- The baseline scenario (Chapter 5.2).
- Alternative scenarios (Chapter 5.3).

5.1. FORECASTING MODEL

Simulation parameters: baseline demand level

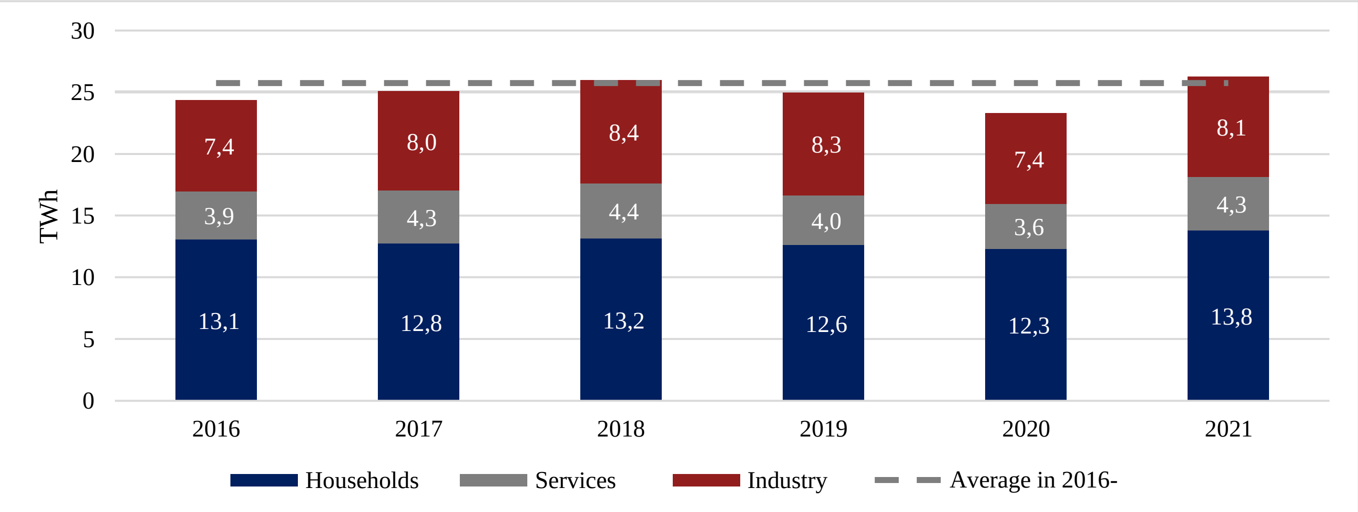
The initial stage of the heating demand forecast is establishing the level of baseline demand that will be used as a starting point for the forecast. The table and the diagram below show useful energy consumption for heat in 2016-2021 in Lithuania.

97 Table. Need for heat, UEC (GWh)

Sector	2016	2017	2018	2019	2020	2021	Average
Households	13.066	12.751	13.177	12.615	12.314	13.798	13.197
Services	3.923	4.276	4.436	4.031	3.619	4.340	4.269
Industry	7.368	8.035	8.363	8.332	7.359	8.123	8.273
Total	**24.357**	**25.062**	**25.976**	**24.979**	**23.292**	**26.261**	**25.739**

Source: authors of the Study

19 Figure. Useful energy consumption for heat in 2016-2021 (TWh)



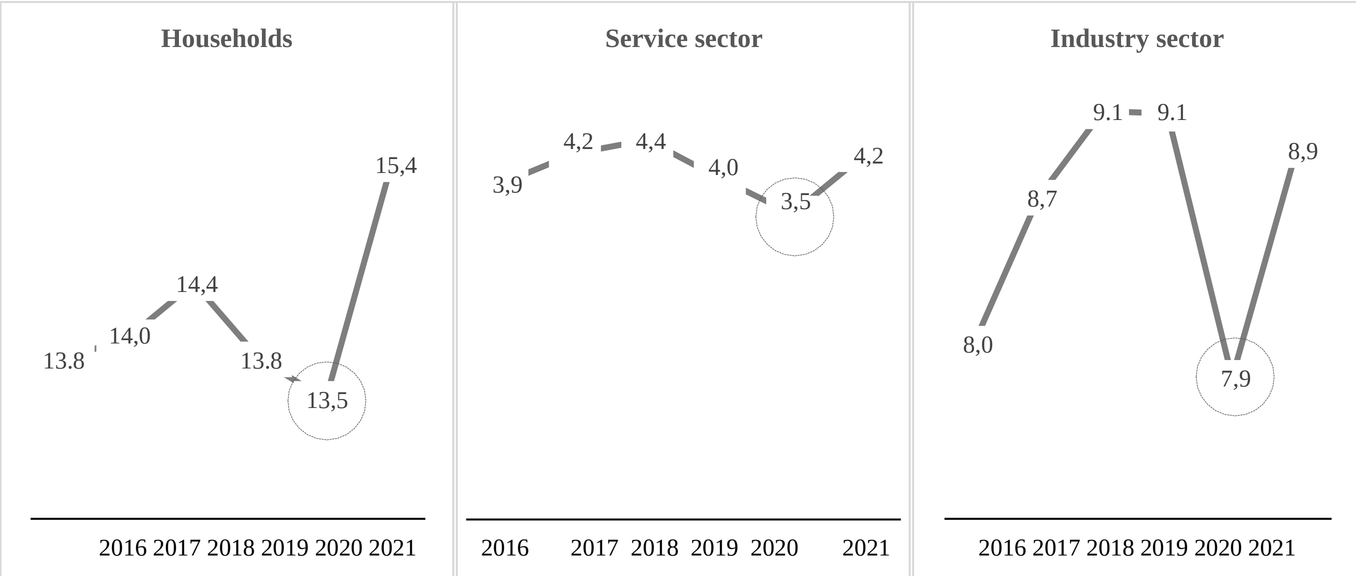
Source: authors of the Study

One may notice that in 2020 heating demand was about 9.5% lower than the last 6 years' average. This difference is mainly attributable to the following:

- Atypically high outdoor temperatures during the heating season (affecting households and the service sector).
- The slowing down of the economy due to COVID restrictions (affecting the activity in the industry and the service sectors).

The dynamics of changing heating demand in individual sectors is shown in the diagram below.

20 Figure. Need for heat, FEC, GWh



Source: authors of the Study

So the level of consumption in 2002 is seen as unrepresentative. For forecasting purposes, the baseline level of demand is calculated as an average for the years 2018, 2019 and 2021.

98 Table. Useful energy consumption for heating and cooling, GWh

Sector	2018	2019	2021	Baseline demand
Households	13.177	12.615	13.798	**13.197**
Services	4.436	4.031	4.340	**4.269**
Industry	8.363	8.332	8.123	**8.273**
Total	**25.976**	**24.979**	**26.261**	**25.739**

Source: authors of the Study

Simulation parameters: factors affecting demand

The main factors determining changes in heating demand have been identified by analysing heating demand (Chapter 4.1), strategic objectives (Chapter 8.2) and policy measures taken (Chapter 10.1):

v1. A shrinking heating consumer base – abandoned, unused, demolished buildings. v2.

A growing heating consumer base – construction of new buildings.

v3. Improving energy efficiency of the heating consumer base – renovation of energy inefficient buildings.

v4. The effect of climate change – an increase in air temperature, which reduces the need for heating.

v5. The development of the industry sector – an increasing need for heat for production processes due to the growth of the sector.

v6. Improving efficiency of the industry sector – a decreasing need for heat for production processes due to an increase in the efficiency of the sector.

Simulation parameters: forecast scenarios

The analysis of the factors determining heating demand shows that the most significant factor potentially influencing demand is the renovation of energy inefficient buildings (v3).

The long-term renovation strategy (the LTRS) sets an ambitious target of reducing primary heating energy consumption of the existing building stock by 60% by 2050. Achieving this target would have a significant impact not only on the overall volume of heating demand at national level but also on the heating supply infrastructure (e.g. the development of low-temperature DH system networks).

At the same time, this target requires a major breakthrough in many related areas such as renovation technologies (industrialisation), achieving economies of scale (quarterly renovation) and introducing new financing models. Dependence on external factors, some of which cannot be fully controlled, increases the risk that the objectives set in the LTRS may not be achieved to the full extent. Therefore, Factor 'v3. Enhancing energy efficiency of the heating consumer base' is seen as a critical factor based on which the baseline and the alternative scenarios of the heating demand forecast are created:

- Conservative (LTRS40): by 2050, 40% of the surface area of buildings envisaged in the LTRS will be renovated.
- Realistic (LTRS70): by 2050, 70% of the surface area of buildings to be renovated under the LTRS will be renovated.
- Optimistic (LTRS100): by 2050, 100% of the surface area of buildings to be renovated under the LTRS will be renovated.

5.2. BASELINE SCENARIO (LTRS40)

In accordance with the precautionary principle and in order to be prepared for a less optimistic pace of renovation of the building stock, for the purposes of this Study the conservative (LTRS40) scenario is used as the baseline scenario.

This solution allows for the development of the required policy measures to enhance supply efficiency, also in the event that the LTRS renovation targets are not fully met. In this way, even if the sectoral targets for reducing FEC and PEC intensity are not fully met, the GHG emission reduction targets would still be achievable.

Below is a description of the main parameters of this scenario (factors affecting demand).

v1. A shrinking heating consumer base

A shrinking heating consumer base due to abandoned (unused) and demolished buildings has a direct impact on other factors: it makes no sense to renovate or assess the impact of climate change on buildings that will be demolished or become inoperable.

In order to maintain the integrity of assumptions used in various strategic documents, the following LTRS indicator values are used in forecasting the shares of abandoned and demolished buildings.

99 Table. Forecast shares of abandoned and/or demolished buildings by 2050, %

Group, subgroup	EPC		
	≤D	C	≥B
1. Residential	6%	2%	
1.1. Single-family 1.2. Multi-apartment	7% 5%	3% 2%	- -
2. Service sector	5%		
2.1. Services 2.2. Administrative 2.3. Trade 2.4. Other	5% 5% 5% 5%	- - - -	- - - -
2. Industry	5%	-	-

Source: authors of the Study

Using these parameters, it can be predicted that by 2050 the existing surface area of the heating consumer base will decrease by 4.3% or 7.0 million m^2. According to our estimates, this change will lead to a 3.1% reduction in the annual need for useful heating energy (786 GWh).

100 Table. Impact of abandoned and demolished buildings on heat demand

Indicator	**Buildings**		**Heat consumption UEC, GWh**
	Number	**Surface area, thou m^2**	
Heating consumer base, 2020	**547.351**	**162.914**	**25.739**
1.1. Single-family	-24,800	-2,485	-246
1.2. Multi-apartment	-1,731	-2,003	-404
2. Service sector	-1,598	-1,135	-146
3. Industry	-1,940	-1,330	0
Heating consumer base, 2050	**517.282**	**155.960**	**24.953**
Demolished, abandoned, total	-30,069	-6,954	-786
Demolished, abandoned, %	-5.5%	-4.3%	-3.1%

Source: authors of the Study

The impact of this factor (v1) on heating energy demand in 2020-2050 is revealed in the table below.

101 Table. Impact of abandoned and demolished buildings on heat demand, UEC, GWh

Group, subgroup	**2020**	**2030**	**2040**	**2050**
1.1. Single-family	4.280	-81	-162	-246
1.2. Multi-apartment	8.917	-135	-269	-393
2. Services	4.269	-47	-95	-146
3. Industry	8.273	-	-	-
Change, total	**-**	**-263**	**-526**	**-786**
	-	-1.0%	-2.0%	-3.1%

Source: authors of the Study

The impact (v1) of the shrinking building stock in the industry sector on heating UEC is not assessed because thermal energy accounts for a negligible share of heating demand in industrial buildings.

v2. A growing heating consumer base

The second factor affecting the demand for thermal energy is a growing heating consumer base due to new-construction buildings. All newly constructed and heated buildings for which a building permit is issued after 2021 must meet the requirements of energy performance class A++. Although thermal energy costs of such buildings are low when considered individually, the overall impact on heating demand in the country is significant.

The simulation of this factor's effects was carried out by analysing the historical pace of building construction in 2002-2021. In accordance with the data of Statistics Lithuania, over the past 20 years the annual average of construction was
about 2 million m^2 surface area (about 0.9 million m^2 residential and about 1.1 million m^2 non-residential buildings).

Although the pace of new construction has increased over the past five years, the growth rate of the building stock until 2050 is projected to be in line with the 20-year statistical average. As a result, the surface area of buildings will increase by about 37%, and this change will lead to an increase in the annual need for heat of 1,481 GWh (5.8%).

102 Table. Impact of new construction buildings on heat demand

Indicator	Buildings		Heat consumption UEC, GWh
	of measurement	Surface area, thou m²	
Heating consumer base, 2020	**547.351**	**162.914**	**25.739**
1.1. Single-family	+130,080	+13,958	+509
1.2. Multi-apartment	+11,841	+14,399	+631
2. Service sector	+18,642	+16,876	+341
3. Industry	+19,857	+15,345	-
Heating consumer base, 2050	**727.771**	**223.491**	**27.219**
New buildings, total	+180,420	+60,578	+1,481
New buildings, %	+33%	+37%	+5.8%

Source: authors of the Study

The impact of this factor (v2) on heating energy demand in 2020-2050 is revealed in the table below.

103 Table. Impact of new construction buildings on heat demand, UEC, GWh

Group, subgroup	2020	2030	2040	2050
1.1. Single-family	4.280	+171	+343	+509
1.2. Multi-apartment	8.917	+208	+417	+631
2. Services	4.269	+113	+227	+341
3. Industry	8.273	-	-	
Change, total	**-**	**+493**	**+987**	**+1,481**
	-	+1.9%	+3.8%	+5.8%

Source: authors of the Study

The impact (v2) of the growing building stock in the industry sector on heating UEC is not assessed because thermal energy accounts for a negligible share of heating demand in industrial buildings.

v3. Enhancing energy efficiency of the heating consumer base

The third factor determining the demand for thermal energy is the renovation of the existing building stock by introducing energy efficiency measures. It is estimated that this factor has the greatest potential to reduce heat demand. The baseline scenario stipulates that by 2050 40% of the surface area of buildings to be renovated under the LTRS (proportionately by group of buildings and energy performance class) will be renovated.

104 Table. Share of the surface area of buildings under renovation by 2050

Group, subgroup	<D → C	<D → B	<D → A	C → B	C → A
1.1. Single-family	-	20%	12%	20%	12%
1.2. Multi-apartment	-	20%	12%	20%	12%
2. Service sector		20%	12%	20%	12%
3. Industry	-	-	-	-	-

Source: authors of the Study

Accordingly, the baseline scenario predicts that by 2050 renovation measures will be implemented for 135,000 (33.5 million m²) buildings. This change will lead to a decrease in the annual need for heat of 2,517 GWh (10%).

105 Table. Impact of the renovation of the building stock on heat demand by 2050, UEC, GWh

Group, subgroup	2020	2030	2040	2050
1.1. Single-family	4.316	-82	-214	-369
1.2. Multi-apartment	8.880	-494	-1,035	-1,501
2. Services	4.269	-134	-367	-647
3. Industry	8.273	-	-	-
Change, total	**-**	**-710**	**-1,616**	**-2,517**

	-	-2.8%	-6%	-10%

Source: authors of the Study

The impact (v3) of the building stock renovation in the industry sector on heating UEC is not assessed because thermal energy accounts for a negligible share of heating demand in industrial buildings.

v4. Effect of climate change

Based on the results of climate change studies[64] completed, the average air temperature in Lithuania may rise by 1.5-5.1°C by 2100, and in certain months, in the north-east of Lithuania – as much as up to 7°C. In 2035, the average air temperature in Lithuania may rise by 1.1-1.4°C. It is also predicted that cold periods (when the minimum air temperature drops down to -20°C) will occur only in January and February.

As the climate warms, a change in the average air temperature will lead to a decrease in the consumption of useful energy in buildings. In order to maintain the integrity of assumptions used in strategic documents, the LTRS assumes that the need for heat in households and the service sector will decrease by 10% over the next 30 years due to climate change.

106 Table. Impact of climate change on heat demand by 2050, UEC, GWh

Group, subgroup	2020	2030	2040	2050
1.1. Single-family	4.316	-144	-285	-421
1.2. Multi-apartment	8.880	-282	-534	-762
2. Services	4.269	-140	-269	-382
3. Industry	8.273	-	-	-
Change, total	**-**	**-566**	**-1,088**	**-1,564**
	-	-2.2%	-4.2%	-6%

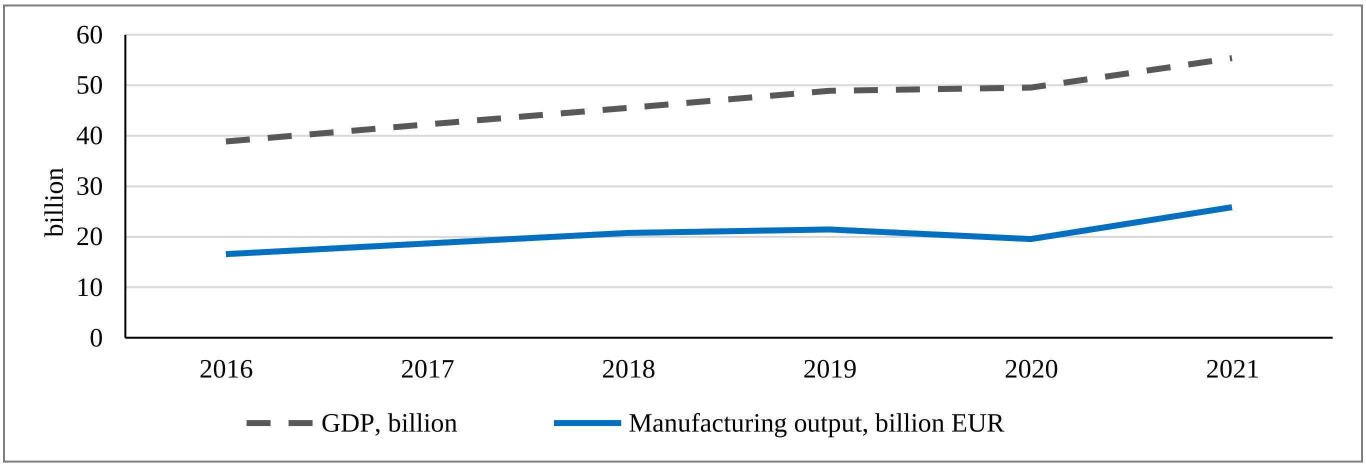
Source: authors of the Study

The effect of climate change (v4) in the industry sector is not assessed because thermal energy accounts for a negligible share of heating demand in industrial buildings.

v5. Development of the industry sector

The demand for heating energy used for industrial processes is dependent on both the overall growth of the industry sector and on the structure of the industry sector: with faster growth of energy-intensive industries, the need for heating energy is growing faster and vice versa. The analysis of statistics shows that the development of the industry sector is correlated with the GDP growth trajectory.

Figure 21. GDP and industry sector output in 2016-2021



Source: Statistics Lithuania

64 Commissioned by the Ministry of the Environment of the Republic of Lithuania and drawn up in 2015, the study identified the sensitivity of individual sectors to climate change impacts, risk assessment and adaptability to climate change, the most effective adaptation measures

and assessment criteria.

Thus, in forecasting the development of the industry sector in 2021-2050, the GDP growth forecast was used as a basis (assuming that the share of the industry sector in the country's GDP structure will remain stable).

Projections of the Ministry of Finance of the Republic of Lithuania and the Organisation for Economic Cooperation and Development (OECD) were used to forecast GDP growth rates:

- The forecast of the Ministry of Finance of the Republic of Lithuania was used for 2021-2025.
- The adjusted OECD forecast was used for 2025-2050.

107 Table. Projected GDP growth, %

Source	**2021**	**2022**	**2023**	**2024**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
MoF forecast	4.9%	1.6%	2.5%	3.0%	3.0%	-	-	-	-	-
OECD forecast	3.7%	4.0%	3.1%	2.4%	1.8%	1.0%	0.5%	0.3%	0.1%	-0.2%
Forecast used	**4.9%**	**1.6%**	**2.5%**	**3.0%**	**3.0%**	**2.5%**	**2.0%**	**1.5%**	**1.0%**	**0.5%**

Source: authors of the study, based on the data of the Ministry of Finance of the Republic of Lithuania and the OECD

The table below shows the heat UEC forecast for the industry sector estimating that the growth intensity of the industry sector is in line with the EU-19 average (108.23/199.32 =54%).

108 Table. Projected GDP growth, %

Indicator	**2021**	**2022**	**2023**	**2024**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Growth of the industry sector, %	4.9%	1.6%	2.5%	3.0%	3.0%	2.5%	2.0%	1.5%	1.0%	0.5%
UEC growth, %	2.7%	0.87%	1.4%	1.6%	1.6%	1.4%	1.1%	0.8%	0.5%	0.3%
UEC growth, TWh	220	74	116	141	144	128	109	85	59	30

Source: authors of the Study

The table below shows the projected effect of the industry sector's growth on heating energy demand in 2020-2050.

109 Table. Impact of industry growth on heat demand by 2050 (GWh)

Group, subgroup	**2020**	**2030**	**2040**	**2050**
1.1. Single-family	4.316	-	-	-
1.2. Multi-apartment	8.880	-	-	-
2. Services	4.269	-	-	-
3. Industry	8.273	+1,321	+2,272	+2,710
Change, total	**-**	**+1,321**	**+2,272**	**+2,710**
	-	5.1%	8.8%	10.5%

Source: authors of the Study

v6. Improving efficiency of the industry sector

Energy intensity is an indicator that links energy consumption to macroeconomic variables. The table below provides information on historical data for Lithuania and EU-19 countries based on Eurostat information.

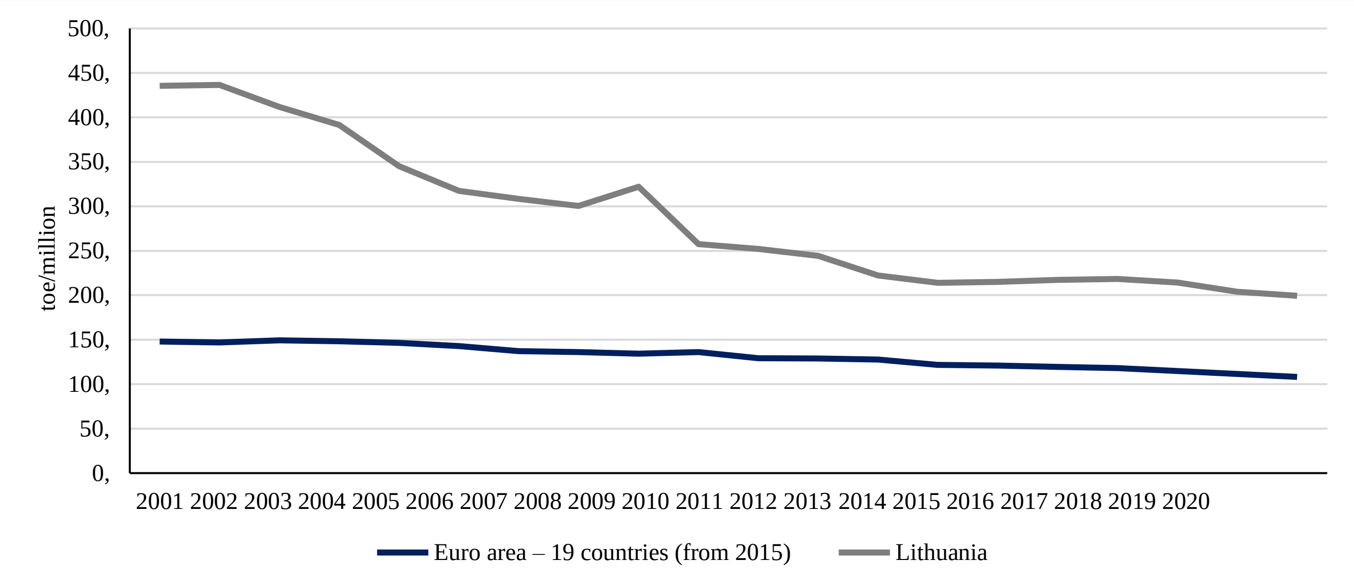
110 Table. Energy intensity in 2020 and its evolution in Lithuania and EU-19

Energy intensity	**2020**	**CAGR[65]**			
	kg_{ne}/1000€	**5 years**	**10 years**	**20 years**	**25 years**
EU-19	108,23	-2.2%	-2.3%	-1.5%	-1.5%
Lithuania	199,32	-1.5%	-2.5%	-3.5%	-4.4%

Source: Eurostat

65 CAGR – compound annual growth rate.

Figure 22. GDP and industry sector energy consumption in 2016-2021



Source: Eurostat

Based on Eurostat data, it can be observed that:

- Lithuania's energy intensity is 46% lower than the EU-19 average;
- Lithuania's energy intensity has been steadily declining over the past 25 years;
- Lithuania's energy intensity has been consistently slowing down in recent years.

Accordingly, it is assumed that energy intensity of the industry sector in Lithuania will continue to decrease and will maintain the pace of the last 5 years (1.5% per year). The table below shows the effect of the industry sector's energy efficiency improvement on heating energy demand in 2020-2050.

111 Table. Impact of energy efficiency growth in the industry sector on heat demand by 2050, GWh

Group, subgroup	**2020**	**2030**	**2040**	**2050**
1.1. Single-family	4.316	-	-	-
1.2. Multi-apartment	8.880	-	-	-
2. Services	4.269	-	-	-
3. Industry	8.273	-1,160	-2,158	-3,016
Change, total	-	**-1,160**	**-2,158**	**-3,016**
	-	-4.5%	-8.4%	-11.7%

Source: authors of the Study

Simulation results

In the baseline scenario, annual thermal energy demand for buildings is projected to decrease by 3,692 GWh (14%) by 2050.

112 Table. Forecast of changes in heat demand (UEC) by factors by 2050, GWh

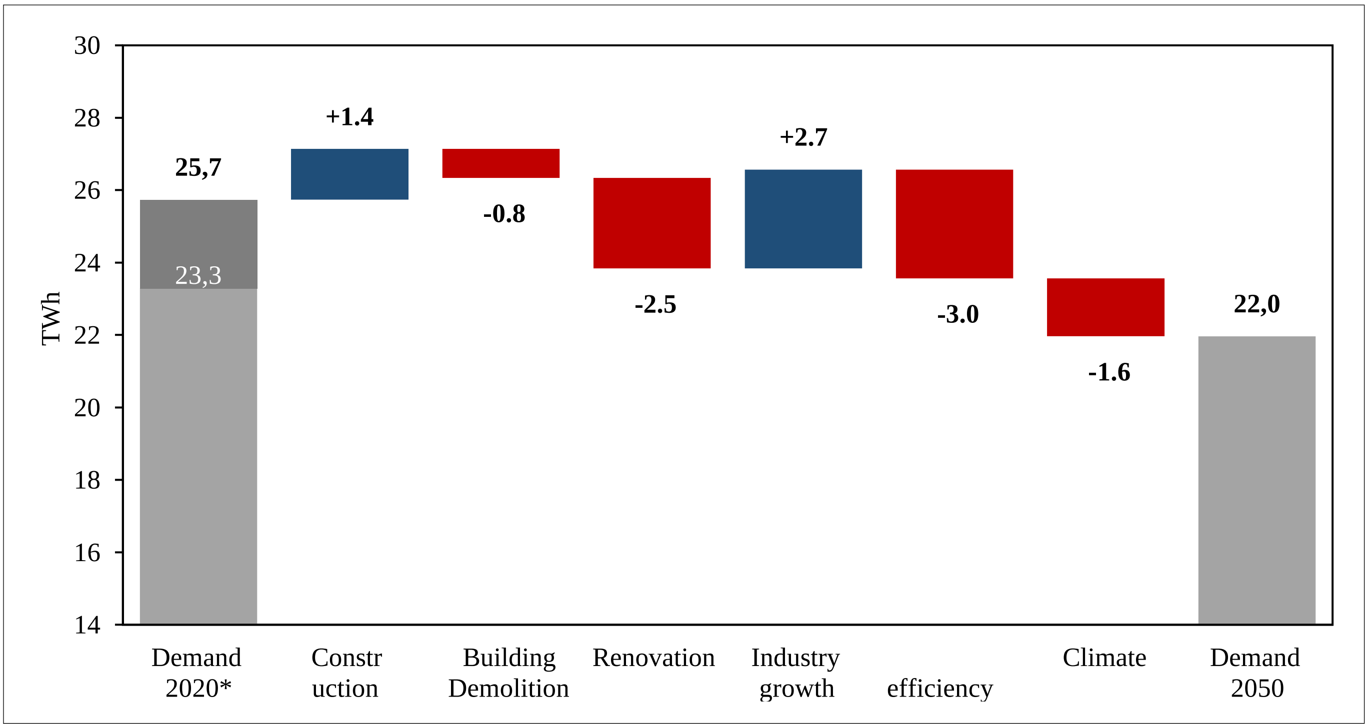
Factor	**2030**	**2040**	**2050**
UEC 2020	**25.739**	**25.739**	**25.739**
v1. Demolition of buildings	-262	-524	-786
v2. Construction of buildings	+494	+987	+1,481
v3. Renovation of buildings	-710	-1,616	-2,517
v4. Climate change	-566	-1,088	-1,564
v5. Industry growth	+1,321	+2,272	+2,710
v6. Industry’s efficiency	-1,160	-2,158	-3,016
Forecast UEC	**24.855**	**23.613**	**22.046**
Change, total	-884	-2,126	-3,692
Change, %	-3.4%	-8%	-14%

Source: authors of the Study

To sum up the results of the baseline scenario simulation, the following can be concluded:

- Although it is predicted that construction pace of new buildings will be about 9 times higher than the scale of demolition of buildings, however, due to the requirements of energy performance class A++ for new buildings, the impact of new construction on demand is relatively smaller than that of demolished buildings.
- Planned renovation of buildings (-2.5 TWh) will have the greatest impact on demand reduction. Under the baseline scenario, the expectation is \to renovate around 33.5 million m^2 of buildings, i.e. almost half the surface area expected to be newly built in 2020-2050.
- The increase in the efficiency of the industry sector will offset the increase in heat demand due to the growth of the sector.

Figure 23. Forecast of changes in heat demand (UEC) by factors by 2050, TWh



Source: authors of the Study

5.3. ALTERNATIVE SCENARIOS

The table below provides a summary of the factors (parameters) of the baseline and the alternative scenarios.

113 Table. Parameters of heat demand scenarios

Factor	Baseline scenario	Alternative scenarios	
	LTRS-40	LTRS-70	LTRS-100
v1. Demolition of buildings	Demolition of 183,000 m^2 buildings per year (EPC C and lower)		
v2. Construction of buildings	Construction of 1.5 million m^2 buildings per year (EPC A++)		
v3. Renovation of buildings	Renovation of 1.1 million m^2 per year (EPC C and lower)	Renovation of 2,0 million m^2 per year (EPC C and lower)	Renovation of 2,8 million m^2 per year (EPC C and lower)
v4. Climate change	Decrease in energy demand -10% by 2050 (0.33% annually)		
v5. Industry growth	Increase in energy consumption in proportion to GDP growth: 2030 +2,5%, 2040: +1.5%, 2050: +0,5% (per year)		
v6. Industry's efficiency	Decrease in energy consumption intensity: -1.5% per year		

Source: authors of the Study

As can be seen from the table above, the scenarios for the demand forecast differ only in values of Factor 'v3. Enhancing energy efficiency of the heating consumer base'.

The values of the remaining factors are identical but the impact of the climate change factor (v4) will depend on the results of the renovation (v3), i.e. heat demand in renovated buildings will decrease to a lesser extent than in non-renovated buildings due to the warming of the climate.

The following is an analysis of alternative scenarios for heating demand projections with effects different from the baseline scenario:

v3. Improving energy efficiency of the heating consumer base – renovation of energy inefficient buildings;

v4. The effect of climate change – an increase in air temperature, which reduces the need for heating.

5.3.1. Scenario LTRS70 89

This scenario envisages that by 2050 70% of the surface area of buildings to be renovated under the LTRS will be renovated. Below is a description of the parameters of this scenario that have different values and effects on consumption as compared to the baseline scenario.

v3. Enhancing energy efficiency of the heating consumer base

The pace of renovation is planned using indicators of the NECAP and the LTRS providing for the forecasted renovation scale by energy performance class and the purpose of buildings. The LTRS70 scenario stipulates that by 2050 70% of the surface area of buildings to be renovated under the LTRS will be renovated.

114 Table. Share of renovated buildings by 2050, GWh

Group, subgroup	<D → C	<D → B	<D → A	C → B	C → A
1.1. Single-family	-	35%	21%	35%	21%
1.2. Multi-apartment	-	35%	21%	35%	21%
2. Service sector	-	35%	21%	35%	21%
3. Industry	-	-	-	-	-

Source: authors of the Study

Accordingly, the prediction is that by 2050 renovation measures will be implemented for 236,000 (58 million m^2) buildings. This change will lead to a decrease in the annual need for heat of 4,404 GWh (25%). On average,

average heat consumption of each renovated building will decrease from 145 to 69 kWh/m^2.

The table below shows the effect of the renovation of the building stock on heating energy demand in 2020-2050.

115 Table. Impact of the renovation of the building stock on heat demand by 2050 (GWh)

Subgroup	2020	2030	2040	2050
1.1. Single-family	4.316	-143	-374	-645
1.2. Multi-apartment	8.880	-864	-1,811	-2,627
2. Services	4.269	-234	-643	-1,131
3. Industry	8.273	-	-	-
Change, total	**-**	**-1,242**	**-2,828**	**-4,404**
	-	-7.1%	-16%	-25%

Source: authors of the Study

v4. Effect of climate change

The impact of this factor depends on the number of renovated buildings – the need for thermal energy decreases for renovated buildings. The impact of climate change also decreases. The table below shows the effect of the climate change factor on heating energy demand in 2020-2050.

116 Table. Impact of climate change on heat demand by 2050, GWh

Subgroup	2020	2030	2040	2050
1.1. Single-family	4.316	-142	-274	-393
1.2. Multi-apartment	8.880	-269	-480	-646
2. Services	4.269	-137	-250	-333
3. Industry	8.273	-	-	-
Change, total	-	**-548**	**-1,005**	**-1,372**
	-	-3.1%	-5.8%	-8%

Source: authors of the Study

Scenario outcomes

In the scenario LTRS70, annual thermal energy demand is projected to decrease by 5,421375 GWh (21%) by 2050.

117 Table. Forecast of changes in heat demand (UEC) by factors by 2050, GWh

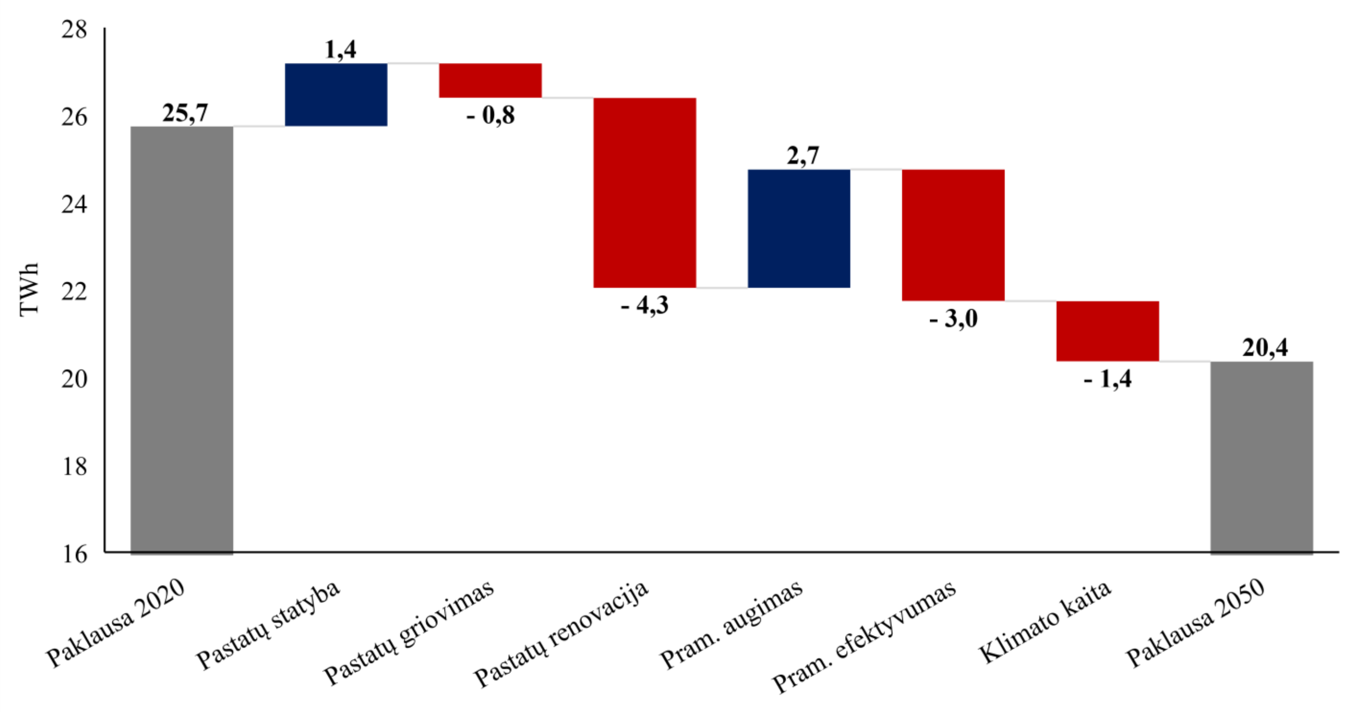
Factor	2030	2040	2050
UEC 2020	**25.739**	**25.739**	**25.739**
v1. Demolition of buildings	-262	-524	-786
v2. Construction of buildings	+482	+965	+1,447
v3. Renovation of buildings	-1,242	-2,828	-4,404
v4. Climate change	-548	-1,005	-1,372
v5. Industry growth	+1,321	+2,272	+2,710
v6. Industry’s efficiency	-1,160	-2,158	-3,016
Forecast UEC	**24.330**	**22.461**	**20.317**
Change, total	-1,409	-3,278	-5,421
Change, %	-5.5%	-13%	-21%

Source: authors of the Study

When comparing the results of the LTRS70 scenario with the baseline scenario, it can be observed that:

- The impact of building renovation (-4.4 TWh) is 76% higher as 79% more surface area of buildings is renovated (the baseline scenario: 33.5 million m^2, LTRS70: 58 million m^2 of buildings).
- The impact of climate change (-1.4 TWh) is 14% lower because the impact of climate change on renovated buildings is less significant than on non-renovated ones.

Figure 24. Forecast of changes in heat demand (UEC) by factors by 2050, GWh



Source: authors of the Study

5.3.2. Scenario LTRS100

This scenario envisages that by 2050 100% of the surface area of buildings to be renovated under the LTRS will be renovated. Below is a description of the parameters of this scenario that have different values and effects on consumption as compared to the baseline scenario.

v3. Impact of renovation and energy efficiency measures

The pace of renovation is planned using indicators of the NECAP and the LTRS providing for the forecasted renovation scale by energy performance class and the purpose of buildings. The LTRS100 scenario stipulates that by 2050 100% of the surface area of buildings to be renovated under the LTRS will be renovated.

118 Table. Share of renovated buildings by 2050, GWh

Group, subgroup	<D → C	<D → B	<D → A	C → B	C → A
1.1. Single-family	-	50%	30%	50%	30%
1.2. Multi-apartment	-	50%	30%	50%	30%
2. Service sector	-	50%	30%	50%	30%
3. Industry	-	-	-	-	-

Source: authors of the Study

Accordingly, the baseline scenario predicts that by 2050 renovation measures will be implemented for 337,000 (84 million m^2) buildings. This change will lead to a decrease in the annual need for heat of 6,292 GWh (24%). On average, average heat consumption of each renovated building will decrease from 145 to 69 kWh/m^2.

The table below shows the effect of the renovation of the building stock on heating energy demand in 2020-2050.

119 Table. Impact of the renovation of the building stock on heat demand by 2050 (GWh)

Subgroup	2020	2030	2040	2050
1.1. Single-family	4.316	-205	-534	-922
1.2. Multi-apartment	8.880	-1,234	-2,587	-3,754
2. Services	4.269	-335	-918	-1,616
3. Industry	8.273	-	-	-
Change, total	**-**	**-1,774**	**-4,039**	**-6,292**
	-	-6.9%	-16%	-24%

Source: authors of the Study

v4. Effect of climate change

The impact of this factor depends on the number of renovated buildings – the need for thermal energy decreases for renovated buildings. The impact of climate change also decreases. The table below shows the effect of the climate change factor on heating energy demand in 2020-2050.

120 Table. Impact of climate change on heat demand by 2050, GWh

Subgroup	2020	2030	2040	2050
1.1. Single-family	4.316	-140	-264	-366
1.2. Multi-apartment	8.880	-257	-429	-533
2. Services	4.269	-133	-232	-285
3. Industry	8.273	-	-	-
Change, total	**-**	**-530**	**-924**	**-1,184**
	-	-2.1%	-3.6%	-4.6%

Source: authors of the Study

Scenario outcomes

In the scenario LTRS100, annual thermal energy demand is projected to decrease by 7,120 GWh (28%) by 2050.

121 Table. Forecast of changes in heat demand (UEC) by factors by 2050, GWh

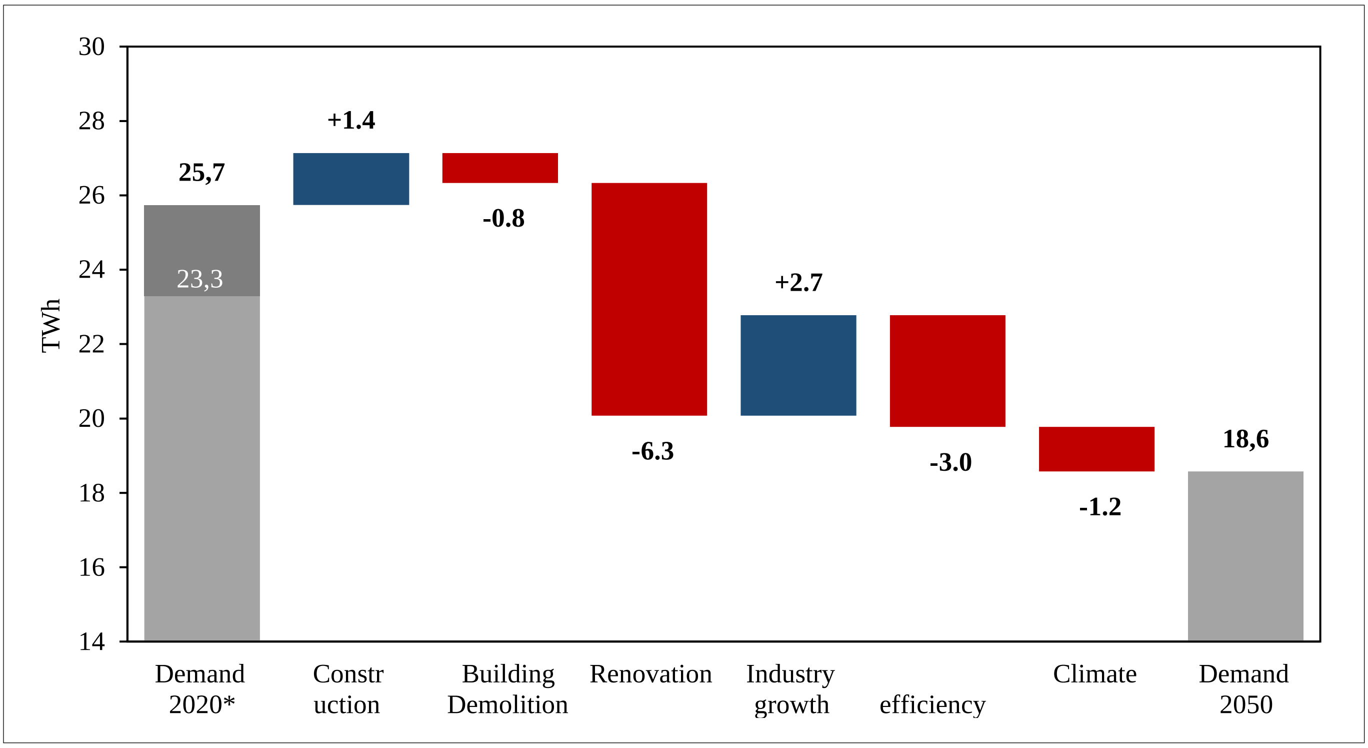
Factor	2030	2040	2050
UEC 2020	**25.739**	**25.739**	**25.739**
v1. Demolition of buildings	-262	-524	-786
v2. Construction of buildings	+482	+965	+1,447
v3. Renovation of buildings	-1,774	-4,039	-6,292
v4. Climate change	-530	-924	-1,184
v5. Industry growth	+1,321	+2,272	+2,710
v6. Industry's efficiency	-1,160	-2,158	-3,016
Forecast UEC	**23.815**	**21.330**	**18.619**
Change, total	-1,923	-4,409	-7,120
Change, %	-7.5%	-17.1%	-27.7%

Source: authors of the Study

When comparing the results of the LTRS100 scenario with the baseline scenario, it can be observed that:

- The impact of building renovation (-6.3 TWh) is almost 1.5 times greater as 1.5 times more building area is being renovated (337,000 and 84 million m^2 of buildings).
- The impact of climate change (-1.2 TWh) is 25% lower because the impact of climate change on renovated buildings is less significant than on non-renovated ones.

25 Figure. Forecast of changes in heat demand (UEC) by factors by 2050, GWh

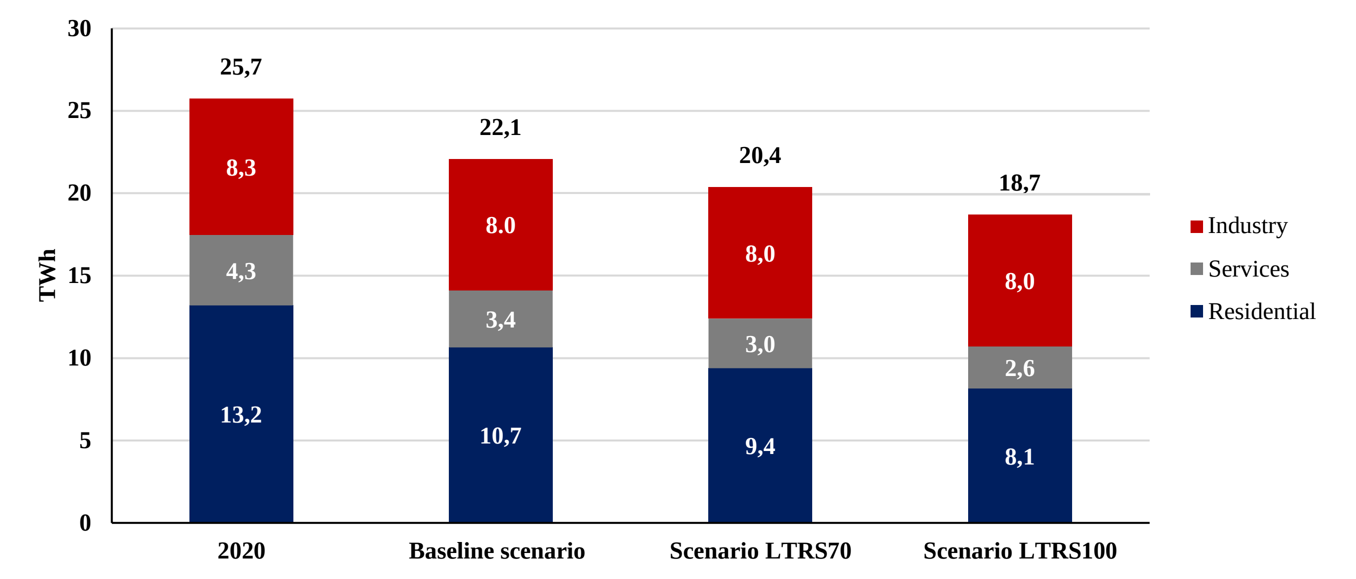


Source: authors of the Study

5.4. KEY OBSERVATIONS

The figure below shows a comparison between the forecast demand under the baseline and the alternative scenarios.

26 Figure. Forecast of heat demand (UEC) – comparison of scenarios, TWh



Source: authors of the Study

The tables below provide a sector-by-sector breakdown of the outcome of each demand forecast scenario.

122 Table. Forecast of heat demand (UEC) – Baseline scenario, GWh

Sector	2020	2030	2040	2050
Households	13.197	12.362	11.463	10.644
Services	4.269	4.060	3.763	3.435
Industry	8.273	8.433	8.387	7.967
TOTAL	**25.739**	**24.855**	**23.613**	**22.046**
	-	-3%	-8%	-14%

Source: authors of the Study

123 Table. Forecast of heat demand (UEC) – Scenario LTRS70, GWh

Sector	2020	2030	2040	2050
Households	13.197	11.934	10.568	9.352
Services	4.269	3.963	3.506	2.999
Industry	8.273	8.433	8.387	7.967
TOTAL	**25.739**	**24.330**	**22.461**	**20.317**
	-	-5%	-13%	-21%

Source: authors of the Study

124 Table. Forecast of heat demand (UEC) – Scenario LTRS100, GWh

Sector	2020	2030	2040	2050
Households	13.197	11.516	9.694	8.090
Services	4.269	3.866	3.249	2.563
Industry	8.273	8.433	8.387	7.967
TOTAL	**25.739**	**23.815**	**21.330**	**18.619**
	-	-7%	-17%	-28%

Source: authors of the Study

6. COOLING DEMAND FORECAST

Recommendation 2.4. In accordance with point 4 of Annex VIII to the EED, it is required to draw up a 30-year heating and cooling demand forecast, with more detailed information on the upcoming decade. The forecast must take into account the effect of the policy and strategy relating to energy efficiency and heating and cooling demand (e.g. long-term building renovation strategies under the Directive on the energy performance of buildings, integrated energy and climate action plans under the Management Regulation) and reflect the needs of various industry sectors.

The assessment of the potential of efficient cooling within the scope of this Study covers the long-term perspective (2021-2050). Thus, with a view to identifying optimal cooling technologies and formulating long-term efficiency enhancing tasks for the cooling sector, there is a need for a long-term cooling demand forecast.

This Chapter goes on to provide information about:

- Essential parameters of the cooling demand forecasting model (Chapter 6.1).
- Results of the simulation of the baseline scenario for long-term demand (Chapter 6.2).

6.1. FORECASTING MODEL

Simulation parameters: baseline demand level

The initial stage of the cooling demand forecast is establishing the level of baseline cooling demand that will be used as a starting point for the forecast. Cooling demand estimated during the Study for 2016-2020 is presented in the table below.

125 Table. Cooling UEC, 2015-2020, GWh

Sector		2015	2016	2017	2018	2019	2020
Cooling	Households	23	23	24	24	25	25
	Services	201	205	208	212	215	217
	Industry	360	365	386	401	408	406
	Total	**584**	**593**	**618**	**637**	**648**	**648**

Source: authors of the Study

As the calculation of cooling demand has been made with significant assumptions (see Chapter 4.7.2), the determination of the baseline level of demand in the light of trends in historical data developments is believed to have no added value. Accordingly, the estimated cooling demand for the last year (2020) (648 GWh) continues to be used as the baseline level of demand.

Simulation parameters: factors affecting demand

The analysis identified the following key factors that directly influence the change in cooling demand:

v1. A shrinking cooling consumer base – abandoned, unused, demolished buildings.

v2. A growing cooling consumer base – construction of new buildings.

v3. The change in the level of meeting the need for cooling – increasing numbers of consumers satisfying their need for cooling. v4. The effect of climate change – an increase in outdoor temperature, which causes the need for cooling to increase.

v5. The development of the industry sector – the evolution of cooling demand for production processes.

v6. Efficiency improvement of the industry sector – the development of cooling demand for production processes.

The analysis of cooling demand shows that only a small share (1-10%) of the need for cooling is currently being met. In addition, with an increasing need for cooling due to climate change, a further increase in cooling demand is expected. Accordingly, the main factors influencing the forecast of cooling demand are thought to be ‘v3. Change in the level of meeting the need for cooling’ and ‘v4. Effect of climate change’.

Modelling parameters: forecast scenarios

When modelling the long-term forecast of evolution of the main factors influencing cooling demand (‘v3. Change in the level of meeting the need for cooling’ and ‘v4. Effect of climate change’), significant assumptions are made. Accordingly, it is estimated that the development of cooling demand scenarios based on various projections for the evolution of these factors would only increase the overall number of assumptions without providing justified prospects for selecting the most probable (baseline) scenario from among various scenarios. Therefore, for the purposes of the Study, a single (baseline) scenario consisting of a set of projections of the most probable changes in the factors is developed within the framework of the long-term forecast of cooling demand.

6.2. BASELINE SCENARIO

The baseline scenario reflects the most probable long-term forecast of cooling demand. Below is a description of the main parameters of this scenario (factors affecting demand).

v1. A shrinking cooling consumer base

The impact of the shrinking cooling consumer base due to abandoned (unused) and demolished buildings is assessed first as this factor directly affects other factors, i.e. it is not useful to renovate or assess the impact of climate change on buildings that are demolished or unused. The assumptions used for the projection of factor influence are the same as those used for the projection of heating demand in the baseline scenario (Chapter 5.2).

126 Table. Impact of the shrinking building stock on cooling demand, UEC (GWh)

Subgroup	2020	2030	2040	2050
1.1. Single-family	12	-0.2	-0.4	-0.7
1.2. Multi-apartment	13	-0.2	-0.3	-0.5
2. Services	217	-2.2	-4.5	-6.7
3. Industry	406	-	-	-
Change, GWh		**-2.6**	**-5.3**	**-7.9**
Change, %	-	-0.4%	-0.8%	-1.2%

Source: authors of the Study

v2. A growing cooling consumer base

The second factor that determines the demand for cooling energy is the increase in the building stock due to newly constructed buildings. The assumptions used for the projection of the growing building stock are the same as those used for the projection of heating demand in the baseline scenario (Chapter 5.2).

The assessment of the impact of newly constructed buildings on cooling demand is based on the assumption that 15% of new residential buildings and 55% of buildings in the service sector will be cooled (more information available under ‘v3. Change in the level of meeting the need for cooling’).

127 Table. Impact of the growing building stock on cooling demand, UEC (GWh)

Subgroup	2020	2030	2040	2050
1.1. Single-family	12	+19	+38	+57
1.2. Multi-apartment	13	+19	+39	+58
2. Services	217	+183	+365	+548
3. Industry	406	-	-	-
Change, GWh		**+221**	**+442**	**+662**
Change, %	-	34%	68%	102%

Source: authors of the Study

V3. Change in the level of meeting the need for cooling

Based on Cooling technology data sheets in the 14 MSs in the EU28[66] it is forecasted that the level of the need for cooling in Lithuania will increase from 1 to 15% in the household segment and from 10% to 55% in the service sector.

128 Table. Level of meeting the need for cooling in 2020-2025, %

Sector	Unit of measurement	2020	2050
Households	per cent	1%	15%
Service sector	per cent	10%	55%

Source: authors of the Study

The estimated effect of the factor on cooling demand is presented in the table below.

129 Table. Impact of the change in the level of meeting the need for cooling by 2050, GWh

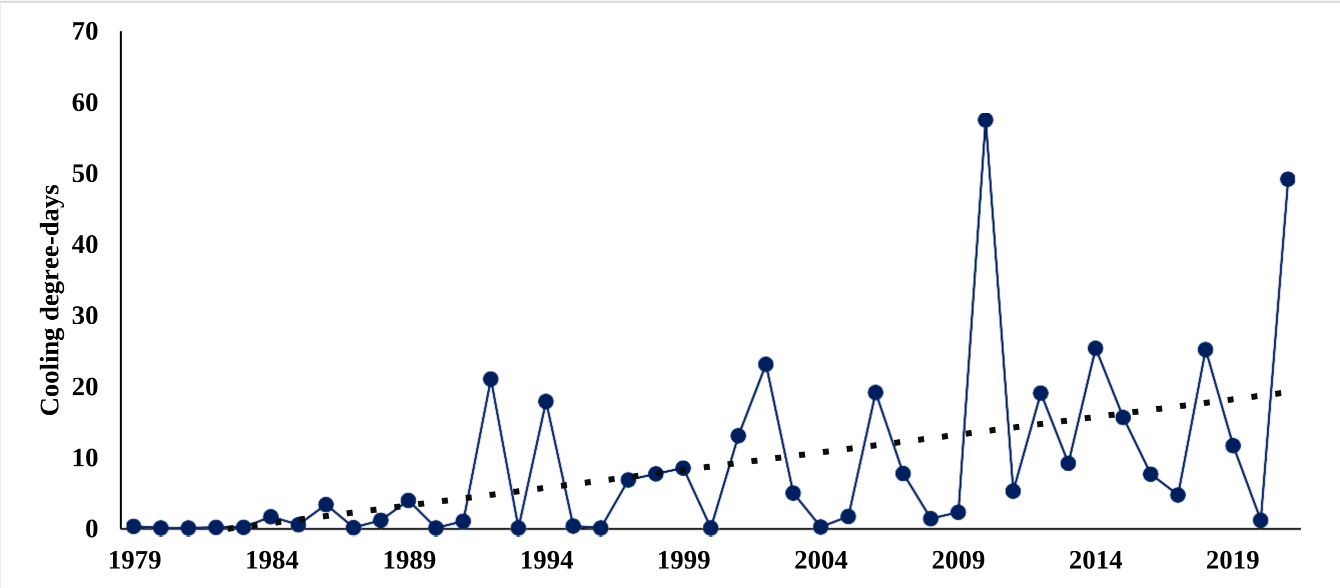
Subgroup	2020	2030	2040	2050
1.1. Single-family	12	+54	+109	+163
1.2. Multi-apartment	13	+57	+113	+170
2. Services	217	+316	+632	+948
3. Industry	406	-	-	-
Change, GWh		**+427**	**+854**	**+1,281**
Change, %	-	66%	132%	198%

Source: authors of the Study

V4. Effect of climate change

The fourth factor that determines cooling demand is the impact of climate change on average air temperature. According to Eurostat, the annual number of daily cooling degrees is increasing but the growth trajectory is not constant.

Figure 27. History of cooling degree-days in Lithuania in 1979-2021



Source: Eurostat

[66] Space Cooling Technology in Europe.

Assessing the long-term forecast of climate change effects, various studies yield different results. The study *Heating and Cooling Primary Energy Demand and CO2, Emissions: Lithuanian A+ Buildings and/in Different, European Locations*[67] conducted an analysis and assessment of data from various studies. Based on the results of this study, the need for cooling in Lithuania is projected to increase by 40% between 2020 and 2050 due to climate change.

The estimated effect of the factor on cooling demand is presented in the table below.

130 Table. Impact of climate change on cooling demand by 2050, GWh

Subgroup	2020	2030	2040	2050
1.1. Single-family	12	+11	+42	+92
1.2. Multi-apartment	13	+12	+44	+96
2. Services	217	+95	+323	+683
3. Industry	406	-	-	-
Change, GWh		**+118**	**+409**	**+871**
Change, %	**-**	13%	27%	40%

Source: authors of the Study

v5. Development of the industry sector

As the sector grows, demand for cooling is also believed to be increasing proportionately. The industry sector development forecast uses the same assumptions as in the heat demand assessment (see Chapter 5.2).

The estimated effect of the factor on cooling demand is presented in the table below.

131 Table. Impact of industry growth on cooling demand by 2050, GWh

Subgroup	2020	2030	2040	2050
1.1. Single-family	11	-	-	-
1.2. Multi-apartment	11	-	-	-
2. Services	196	-	-	-
3. Industry	406	+21	+36	+43
Change, GWh	-	**+21**	**+36**	**+43**
Change, %	-	3%	6%	7%

Source: authors of the Study

v6. Efficiency evolution in the industry sector

Like in the case of projections for the need for heat (see Chapter 5.2) energy intensity of the industry sector in Lithuania is believed to continue to decrease and to maintain the pace of the last 5 years (1.5% per year).

The estimated effect of the factor on cooling demand is presented in the table below.

132 Table. Impact of energy efficiency growth in the industry sector on cooling demand by 2050, GWh

Subgroup	2020	2030	2040	2050
1.1. Single-family	11	-	-	-
1.2. Multi-apartment	11	-	-	-
2. Services	196	-	-	-
3. Industry	406	-18	-34	-48
Change, GWh	-	**-18**	**-34**	**-48**
Change, %	-	-3%	-5%	-8%

Source: authors of the Study

[67] Valančius, K.; Grinevičiūtė, M.; Streckienė, G. Heating and Cooling Primary Energy Demand and CO_2 Emissions: Lithuanian A+

Buildings and/in Different European Locations. *Buildings* **2022**, *12*, 570. https://doi.org/10.3390/buildings12050570

Scenario outcomes

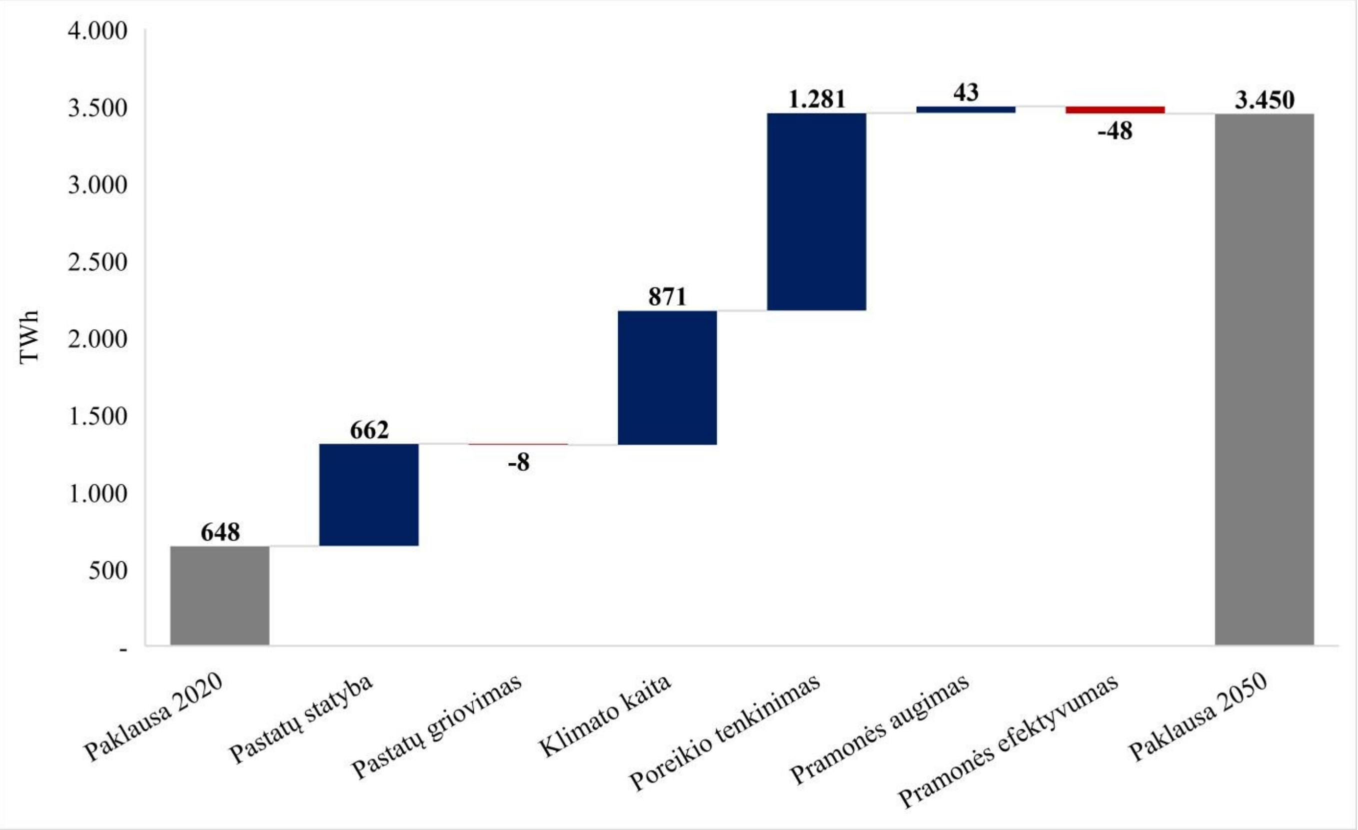
In the baseline scenario, annual cooling energy demand is projected to increase fivefold by 2050 (from 0.6 TWh to 3.4 TWh).

133 Table. Forecast of changes in cooling demand (UEC) by factors by 2050, GWh

Subgroup	2030	2040	2050
Consumption in 2020	**648**	**648**	**648**
1. Demolition	-2.6	-5.3	-7.9
2. Construction	+221	+442	+662
3. Climate	+118	+409	+871
4. Meeting the need	+427	+854	+1,281
5. Industry growth	21	36	43
6. Improving efficiency of the industry sector	-18	-34	-48
Change, total	+766	+1,701	+2,802
TOTAL	**1.414**	**2.349**	**3.450**
	218%	362%	532%

Source: authors of the Study

134 Table. Forecast of changes in cooling demand (UEC) by factors by 2050, GWh



Source: authors of the Study

6.3. KEY OBSERVATIONS

The tables below provide the aggregate outcome of the baseline forecast scenario.

135 Table. Forecast of changes in cooling demand (UEC) by factors by 2050, GWh

Subgroup	2020	2030	2040	2050
Households	25	197	409	660
Services	217	809	1.533	2.389
Industry	406	409	408	401
Total	**648**	**1.414**	**2.349**	**3.450**
Change, %		118%	262%	432%

Source: authors of the Study

To sum up the results, it can be observed that:

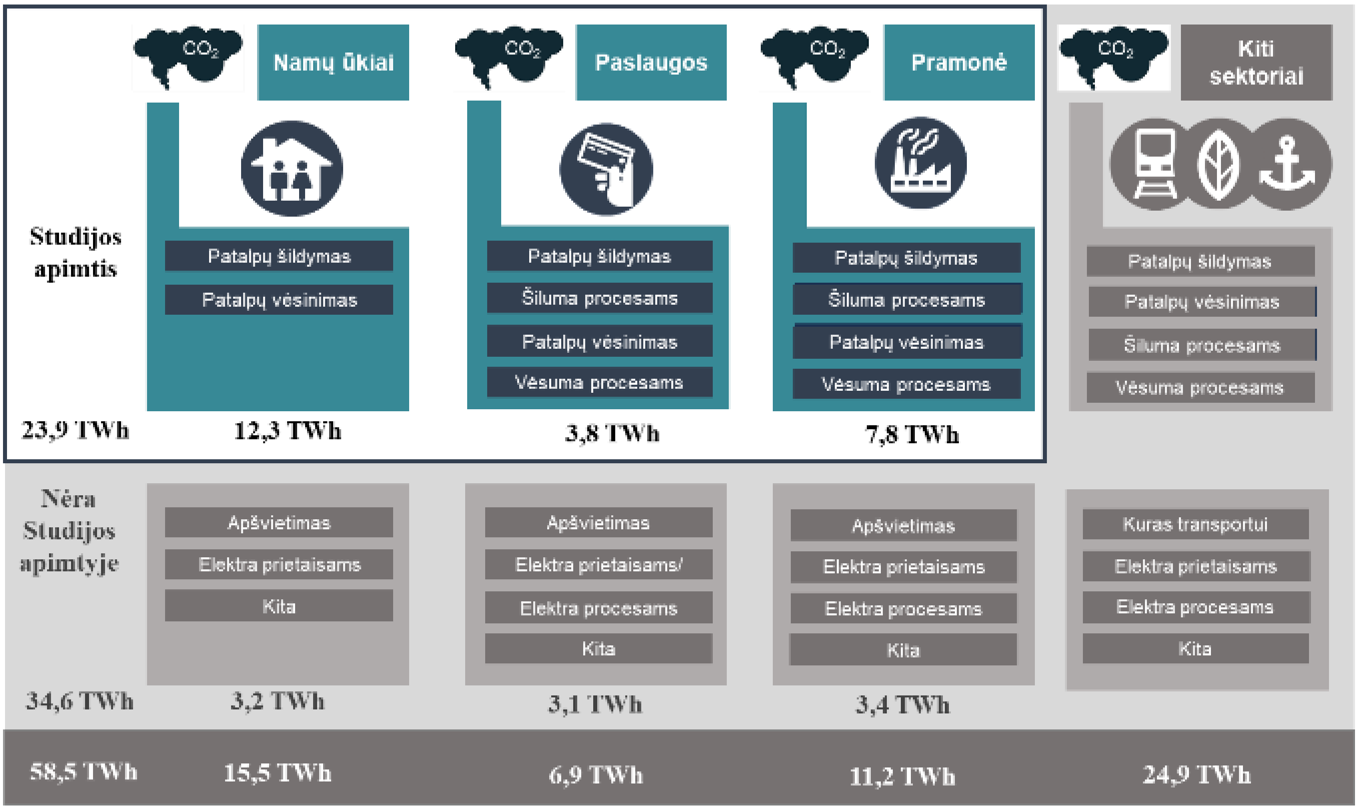
- The largest absolute increase in the need for cooling is forecasted in the service sector. Growth is largely driven by an increase in the level of meeting the need from 10% to 55%. The catalyst for the projected change is aspirations to provide quality business and public services (e.g. medical treatment, education).
- The increase in the efficiency of the industry sector will offset the increase in cooling demand due to the growth of the sector.

7. HEATING AND COOLING SUPPLY

Recommendation 2.1.2. The purpose of supply analysis is to identify technological solutions used to deliver heat and cooling. The analysis and the presentation of values should be of the same structure as the description of heating and cooling demand. The latest available data are to be provided in GWh per year. A distinction should be made between indigenous and non-indigenous resources and between renewable and fossil energy sources.

Based on our assessment, in the sectors included in the scope of the Study[68] in 2020 UEC for heating and cooling came up to 23.9 TWh (about 41% of the country's total UEC in 2020[69]).

Figure 28. Limits of the Study in terms of UEC



Source: Statistics Lithuania, authors of the Study

In accordance with the provisions of the Recommendation, the results of the analysis of heating and cooling supply are presented in the same structure (supply segments) as in the analysis of heating and cooling demand (Chapter 4).

Table 136. Heating and cooling supply segments

Sector	Supply segment		UEC 2020, GWh	
	Heating supply	Cooling supply	Heating supply	Cooling supply
Households	A1	A2	12.314	25
Services	B1	B2	3.619	217
Industry	C1	C2	7.359	406
Total			**23.292**	**648**
			23.940	

Source: authors of the Study

[68] Consuming more than 5% of total UEC for heating and cooling (see Table 3).

[69] A major part of UEC not included in the scope of the Study was transport fuel consumption: 22.8 TWh (39%), see Table 3.

7.1. HEATING SUPPLY

7.1.1. Heating supply: sectors

The table below shows the structure of Lithuania's heat supply by source of production and type of heat supply infrastructure (decentralised or district supply[70]).

Table 137. Heat UEC supply in Lithuania in 2020, GWh

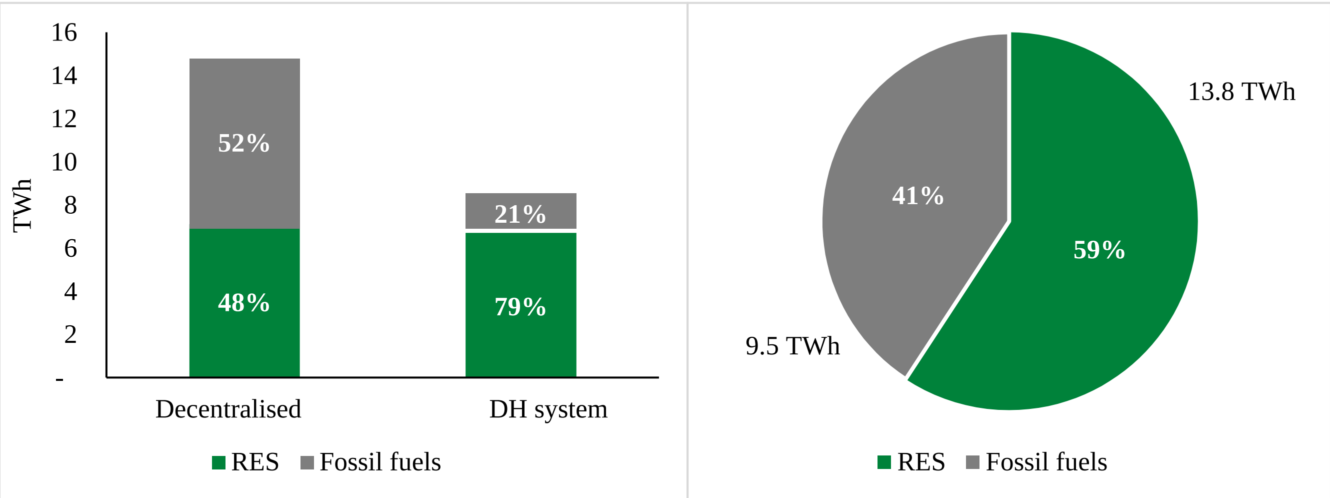
Type of source of production	Source of production	Unit of measurement	Total	Decentralised supply	District supply
FF sources	Individual boilers	GWh/year	5.891	5.891	-
	Waste heat	GWh/year	-	-	-
	Other technologies	GWh/year	1.148	198	950
	Cogeneration units	GWh/year	2.454	1.581	874
	FF sources, total		**9.494**	**7.670**	**1.824**
RES sources	Individual boilers	GWh/year	6.171	6.171	-
	Waste heat	GWh/year	113	-	113
	Cogeneration units	GWh/year	1.099	-	1.099
	Heat pumps	GWh/year	932	932	-
	Other technologies	GWh/year	5.484	-	5.484
	RES sources, total		**13.798**	**7.103**	**6.695**
TOTAL			**23.292**	**14.773**	**8.519**

Source: authors of the Study

When analysing these data, one may note that:

- At the national level, 59% of existing supply comes from RES sources.
- District heating with DH systems accounts for 37% of supply while the share of RES is 79% in the structure of this segment.
- Decentralised (individual) heating accounts for 63% while the share of RES is 48% in the structure of this segment.

Figure 29. Heat UEC supply in Lithuania in 2020, TWh



Source: authors of the Study

Below is an overview of heating supply by sector.

70 District = using district heating (DH) systems.

Households

The table below shows the structure of households' heat supply by source of production and type of heat supply infrastructure.

138 Table. Household heat UEC supply in 2020, GWh

Type of source of production	Source of production	Unit of measurement	Total	Decentralised supply	District supply
FF sources	Individual boilers	GWh/year	2.328	2.328	-
	Waste heat	GWh/year	-	-	-
	Other technologies	GWh/year	684	124	560
	Cogeneration units	GWh/year	501	-	501
	FF sources, total		**3.514**	**2.452**	**1.062**
RES sources	Individual boilers	GWh/year	4.464	4.464	-
	Waste heat	GWh/year	65	-	65
	Cogeneration units	GWh/year	631	-	631
	Heat pumps	GWh/year	509	509	-
	Other technologies	GWh/year	3.132	-	3.132
	RES sources, total		**8.801**	**4.973**	**3.828**
TOTAL			**12.314**	**7.425**	**4.889**

Source: authors of the Study

When analysing these data, one may note that in the household sector:

- District heating supply accounts for about 40% of the sector's supply while the share of RES in the production structure of this segment is about 79%.
- The remaining 60% of the sector's supply consists of decentralised heat supply while the share of RES in the production structure of the household sector is about 67%.

Service sector

The table below shows the service sector's heat supply by source of production and type of heat supply infrastructure.

139 Table. Heat UEC supply in the service sector in 2020, GWh

Type of source of production	Source of production	Unit of measurement	Total	Decentralised	District
FF sources	Individual boilers	GWh/year	1.006	1.006	-
	Waste heat	GWh/year	-	-	-
	Other technologies	GWh/year	270	59	210
	Cogeneration units	GWh/year	188	-	188
	FF sources, total		**1.464**	**1.066**	**399**
RES sources	Individual boilers	GWh/year	376	376	-
	Waste heat	GWh/year	24	-	24
	Cogeneration units	GWh/year	237	-	237
	Heat pumps	GWh/year	340	340	-
	Other technologies	GWh/year	1.176	-	1.176
	RES sources, total		**2.154**	**717**	**1.438**
TOTAL			**3.619**	**1.782**	**1.836**

Source: authors of the Study

When analysing these data, one may note that in the service sector:

- District heating supply accounts for about 51% of the sector's supply while the share of RES in the fuel mix of this segment is about 79%.
- The remaining 49% of the sector's supply consists of decentralised heat supply while the share of RES in the fuel mix of this sector is about 40%.

Industry sector

The table below shows the industry sector's heat supply by source of production and type of heat supply infrastructure.

140 Table. Heat UEC supply in the industry sector in 2020, GWh

Type of source of production	Source of production	Unit of measurement	Total	Decentralised	District
FF sources	Individual boilers	GWh/year	2.557	2.557	-
	Waste heat	GWh/year	-	-	-
	Other technologies	GWh/year	194	14	180
	Cogeneration units	GWh/year	1.765	1.581	184
	FF sources, total		**4.515**	**4.152**	**363**
RES sources	Individual boilers	GWh/year	1.331	1.331	-
	Waste heat	GWh/year	24	-	24
	Cogeneration units	GWh/year	231	-	231
	Heat pumps	GWh/year	83	83	-
	Other technologies	GWh/year	1.175	-	1.175
	RES sources, total		**2.843**	**1.413**	**1.430**
TOTAL			**7.359**	**5.565**	**1.793**

Source: authors of the Study

When analysing these data, one may note that in the industry sector:

- District heating supply accounts for about a quarter of the sector's supply while the share of RES in the production structure of this segment is about 79%.
- The remaining three quarters of the sector's supply consists of decentralised heat supply while the share of RES in the fuel mix of this sector is about 25%.

To sum up, it can be concluded that:

- The fuel mix indicators of the DH system segment already significantly exceed the efficiency criteria set out in Article 2(41) of the EED (for details see Chapter 7.1.2).
- The planned investments of about 200 MW by heat suppliers in RES infrastructure[71] will further improve these indicators.
- The greatest potential for increasing the share of supply from RES lies in decentralised heating supply (for details see
Chapter 7.1.3).

7.1.2. Heating supply: district supply

In order to assess the efficiency of existing district heating supply, it is important to define assessment criteria.

Article 2(41) of **Directive 2012/27/EU** ('the EED') states that an efficient district heating system is one that uses at least:

- 50% renewable energy; or
- 50% waste heat; or
- 75% of cogenerated heat; or
- 50% of a combination of such energy and heat.

71 See Annex 2.9.

The National Energy Independence Strategy (NEIS) identifies the development of heat generation capacity from RES as one of the country's strategic objectives and sets the following targets for the development of RES in the DH sector:

- To increase the share of RES[72] in the DH sector to 70% by 2020.
- To increase the share of RES in the DH sector to 90% by 2030.
- To increase the share of RES in the DH sector to 100% by 2050.

The **2021-2030 Energy Development Programme**, which details the strategic energy policy objectives and progress targets set out in the National Progress Plan for 2021–2030, sets the following objective:

- To implement energy efficiency improvement measures for district heating, hot water and cooling systems that would reduce GHG emissions and primary energy consumption (progress measure code 03-001-06-03-04).
- To implement measures increasing the use of RES for heat and cooling production in the DH system sector, which would reduce GHG emissions (progress measure code 03-001-06-03-05).

The Republic of Lithuania Law on the Heat Sector regulating the state management of the heat sector and the activities of heat sector entities as one of the main ones to ensure reliable and high-quality heat supply to heat consumers at the lowest cost.

To sum up the objectives for the DH sector, it can be concluded that:

- At the strategic level (national perspective), the main expectations relate to increasing the share of RES in the fuel mix and enhancing the efficiency of the system, resulting in a reduction of GHG emissions.
- At the operational level (consumer perspective), the aim is to ensure reliable and high-quality heat supply to heat consumers at the lowest cost.

Accordingly, within the scope of the Study, DH is assessed based on the following main criteria:

a) **Reliable supply** means the ability to ensure heat supply to customers according to the specified quality parameters.

b) **Competitive price** means the ability to compete with alternative (decentralised) heating solutions and maximise the potential of DH.

c) **Optimal fuel mix** means the minimised negative impact on climate (the scale of GHG emissions).

Below is an analysis of Lithuania's thermal energy supply in the district heating system according to the above indicators.

A. Reliability of supply

In accordance with the current backup heat supply conditions[73], the recovery time of heat supply (in hours) varies between 12 and 48 hours (depending on the diameter of the main pipeline), and technical possibilities of uninterrupted heat supply to customers of uninterrupted heat supply must be ensured. In the scope of the Study, we did not identify information sources that would provide actual data on district heating disruptions. However, except in isolated cases (e.g. 2006 in Telšiai[74]), Lithuania did not detect any disruptions that caused repercussions in the public space and that were not addressed within the set recovery period for heat supply.

Accordingly, it is assessed that district heating supply in all DH systems is reliable, i.e. ensuring the supply of heat to consumers based on established quality parameters.

72 RES or indigenous fuels.

73 Heat supply conditions in cases of accidents and failures, Rules for the Installation of Heat Supply Networks and Heat Points approved by Order No 1-297 of the Minister for Energy of the Republic of Lithuania of 25 October 2010.

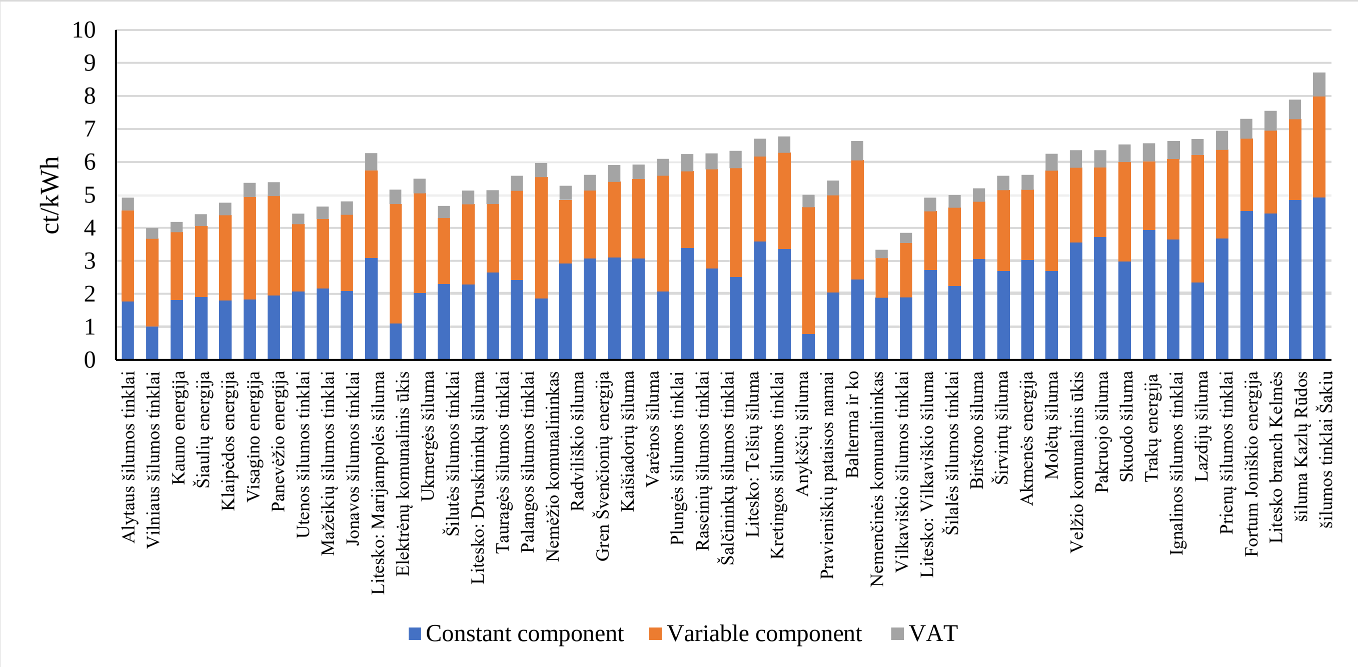
74 Information and proposals of the Commission set up by Resolution No 62 of the Government of the Republic

of Lithuania of 23 January 2006 to address the accident in Telšiai City heat installations on 20 January 2006.

B. Price competitiveness

The figure below shows average[75] heat prices as delivered by DH systems to final customers in 2020.

Figure 30. Prices of heat supplied by DH systems in 2020



Source: authors of the Study

When analysing these data, it can be noted that heat prices differ significantly, for example, the highest price (Litesko branch in Biržai) was 2.6 times higher than the lowest price (Vilkaviškio šilumos tinklai). The main factors that affect the price of heat:

- Production structure – generally speaking, the variable component of the heat price will be lower in DH systems that use more biofuel and/or have high competition between independent heat producers in DH systems;
- The amount of heat realised – generally speaking, in DH systems realising more heat the constant component will be smaller;
- Price setting circumstances – various components (e.g. inflation, fuel compensation, etc.) may be included in/excluded from the price due to heat prices set at different times.

In the scope of the Study, the competitiveness of the DH heating price is assessed by a comparative analysis method, comparing the heat price of a particular DH system with alternative (decentralised) heating solutions.

A comparison with alternative (decentralized) heating solutions is made by evaluating a typical single-family residential house, i.e. the consumer segment with the highest number of alternative heating solutions choices. The following key parameters were used in the comparative analysis:

- Surface area – 150 m^2;
- Annual thermal energy consumption – 7 MWh;
- Installed capacity of the heat production source – 6 kW;
- The useful life of the heat production source – 15 years.

75 Weighted average price in 2020.

The comparative analysis results are shown in the table below.

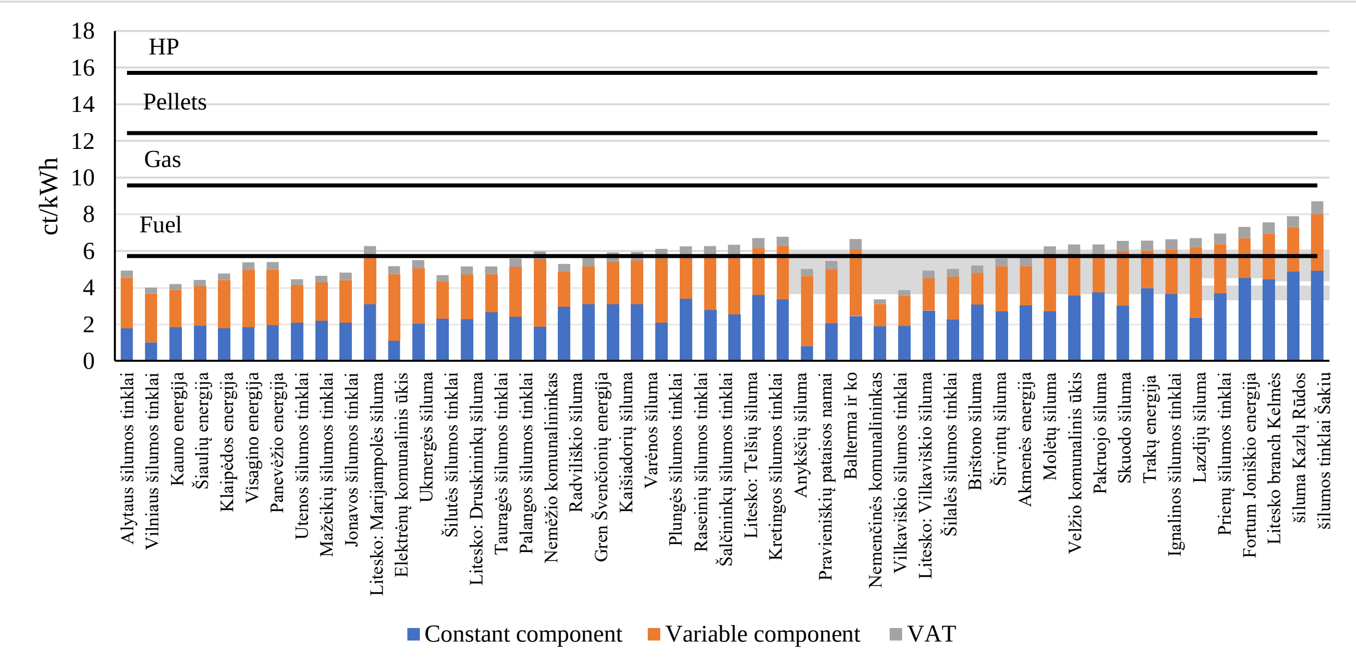
Table 141. Prices of individual (decentralised) heating solutions (2020 data)

Indicator	Unit of measurement	FF boiler (firewood)	FF boiler (pellets)	NG boiler	Heat pump
Investment	EUR	2.550	5.700	3.900	7.800
	EUR/year	170	380	260	520
Fuel	EUR/year	130	250	260	230
Operating costs	EUR/year	100	240	150	350
Total heating costs	**EUR/year**	**400**	**870**	**670**	**1.100**
Cost of heating	**ct/kWh**	**5,71**	**12,43**	**9,57**	**15,71**

Source: authors of the Study

The figure below shows a comparison between the prices of heat supplied by DH systems and the prices of heat produced by individual sources.

31 Figure. Prices of heat supplied by DH systems and heat generated from individual sources in 2020



Source: authors of the Study

It can be observed that during the period concerned:

- The heat price of the cheapest decentralised source of production (wood-fired boiler) (5,7 ct/kWh) was equal to the average DH price.
- The heat price of the cheapest individual source (a natural gas boiler) comparable in terms of quality parameters of the service (9.6 ct/kWh) was 12% higher than the DH maximum (8.7 ct/kWh) and 71% higher than the average price (5.7 ct/kWh).

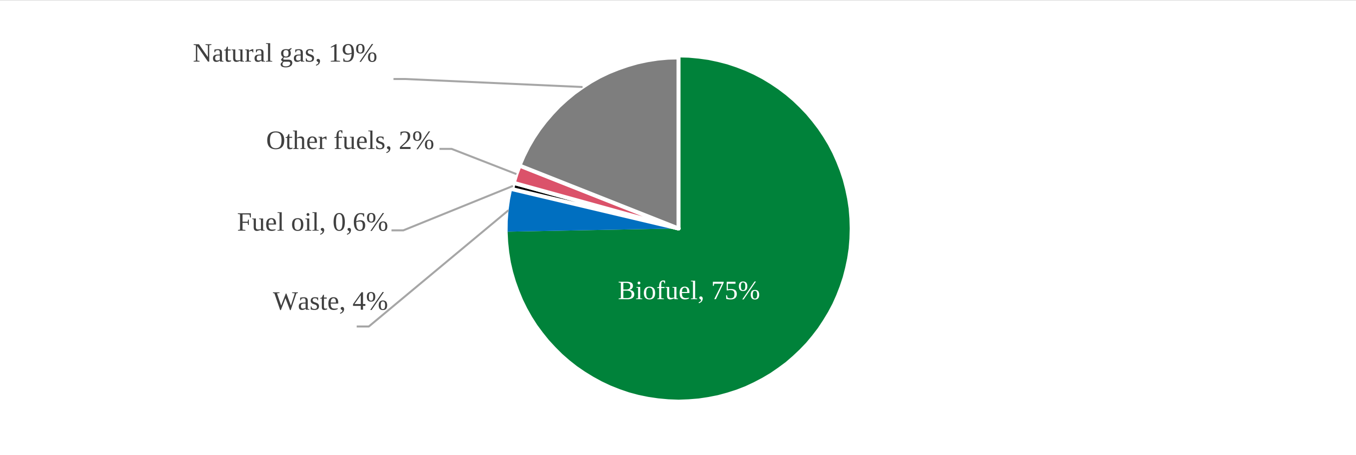
Accordingly, district heating in all DH systems is considered competitive as compared to comparable decentralised heating solutions. At the same time, a typical DH system is competitive even with a wood-fired boiler that is not comparable in terms of quality parameters of the service.

Possibilities for further improvement of DH system efficiency are analysed in Chapter 8.2.

C. Production structure

Renewable resources in district heating accounted for 75% of global heat supply in 2020 (see figure below). This indicator reveals that efficiency indicators of Lithuania's district heating supply significantly exceed the indicators set in Article 2(41) of the EED.

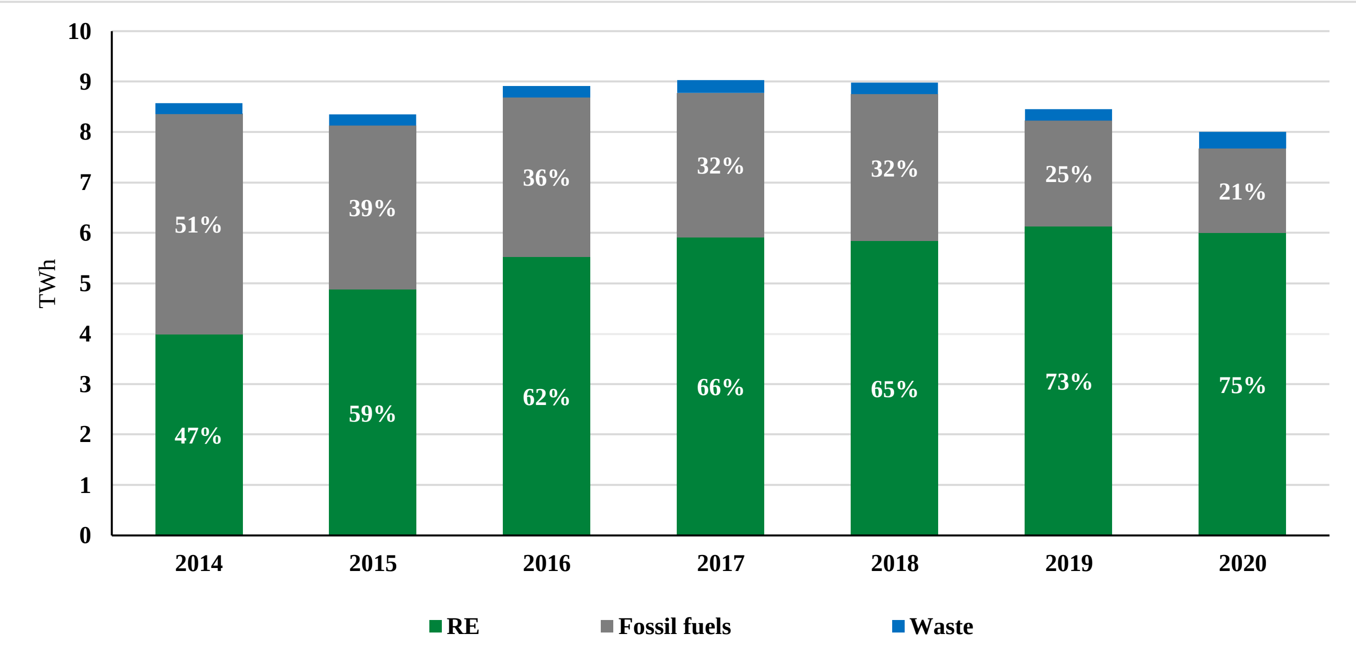
32 Figure. DH system heat generation fuel mix (2020), %



Source: Lithuanian District Heating Association

The graph below illustrates that the share of RES in the DH fuel mix has been growing consistently since 2014. Although DH consumers' need for thermal energy did not change significantly, the fuel mix in the DH sector in Lithuania has changed substantially over the period 2014–2020: the share of RES in the balance of fuel used for heat production increased from 46.4% in 2014 to 75% in 2020.

33 Figure. DH system heat generation fuel mix (2014-2020), TWh



Source: NERC, LDHA

In order to assess the progress made in the implementation of the goals for the development of RES at national level in the DH sector, we conducted an overview of the fuel mix of individual NERC-regulated DH systems. Heat producers not regulated by the NERC do not represent a significant part of DH supply (for details see Chapter 4.1.2) and are not further assessed.

142 Table. RES share in district heating

Heat suppliers	Heat quantity, GWh	RES share in 2020	Target RES share		
			2020 (70%)	**2030** (90%)	**2050** (100%)
Group I	**5.294**	**77%**			
Alytaus šilumos tinklai, AB	173	84%			
Vilniaus šilumos tinklai, AB	2.316	59%			
Kauno energija, UAB	1.095	93%			
Klaipėdos energija	681	93%			
Šiaulių energija	348	78%			
Panevėžio energija	507	95%			
Visagino energija	174	92%			
Group II	**456**	**94%**			
Jonavos šilumos tinklai	105	87%			
Marijampolės šiluma (Litesko branch)	114	90%			
Mažeikių šilumos tinklai	115	100%			
Utenos šilumos tinklai	123	98%			
Group III	**366**	**89%**			
Elektrėnų komunalinis ūkis, UAB	60	97%			
Ukmergės šiluma	55	62%			
Druskininkų šiluma (Litesko branch)	86	92%			
Palangos šilumos tinklai	50	82%			
Šilutės šilumos tinklai	63	99%			
Tauragės šilumos tinklai	52	100%			
Group IV	**367**	**74%**			
Nemenčinės komunalininkas, UAB	49	2%			
Kaišiadorių šiluma, UAB	43	63%			
Others, Group IV	275	89%			
Group V	**376**	**88%**			
Velžio komunalinis ūkis, VšĮ	13	40%			
Trakų energija, UAB	31	59%			
Others, Group V	332	93%			
Total, MW	**6.860**	**79%**			

Indicator achieved — Indicator not achieved — System inefficient

Source: NERC, authors of the Study

To sum up the data presented above, it can be noted that:

- Only 2 heat suppliers (Nemenčinės komunalininkas, UAB and Velžio komunalinis ūkis, VšĮ) do not match the definition of efficient district heating as provided for in the EED. The share of RES in the fuel mix of these heat suppliers is not 50%.
- The NEIS target for 2020 (70%) has not been met by 6 heat suppliers.
- The fuel mix of a large part of major heat suppliers (Groups I to III) is already in line with the NEIS 2030 targets.
- The fuel mix of two heat suppliers is already in line with the NEIS 2050 targets.

7.1.3. Heating supply: decentralised supply

The National Energy Independence Strategy (NEIS) does not contain set targets for the efficiency of the decentralised heat supply segment.

Article 2(41) of the Energy Efficiency Directive states that efficient decentralised heat production is the one that meets or exceeds the parameters of an efficient DH system (see Chapter 7.1.2).

Accordingly, the efficiency of existing decentralised heat supply is assessed based on the DH system efficiency parameters set out in the EED. The EED target to "use at least 50% of renewable energy" is not achieved only in the industry sector in Lithuania (see table below).

143 Table. RES share in decentralised heat production

Sector	Heat quantity, GWh	RES, %	EED indicator (50%)
Households	7.425	68%	Indicator achieved
Service sector	1.782	56%	Indicator achieved
Industry sector	5.566	26%	Indicator not achieved

Indicator achieved (green) — Indicator not achieved (pink)

Source: authors of the Study

Accordingly, it is considered that the industry sector has the greatest potential for enhancing efficiency. The chapter below provides a detailed analysis of the current supply of decentralised heating by sector.

Households

The table below shows the detailed fuel mix for decentralised supply for households.

144 Table. Household heat UEC supply (decentralised supply) in 2020, GWh

Sector	Fossil fuels						RES			Total
	Natural gas	Petroleum products	Coal	Solid fuel	Peat	Electricity (FF)	Electricity (RES)	Ambience	Biofuel	
Households	1.420	570	239	96	3	124	186	323	4.464	**7.425**
	19%	8%	3%	1%	0.04%	2%	3%	4%	60%	**100%**
	2.452						**4.973**			**7.425**
	33%						67%			100%

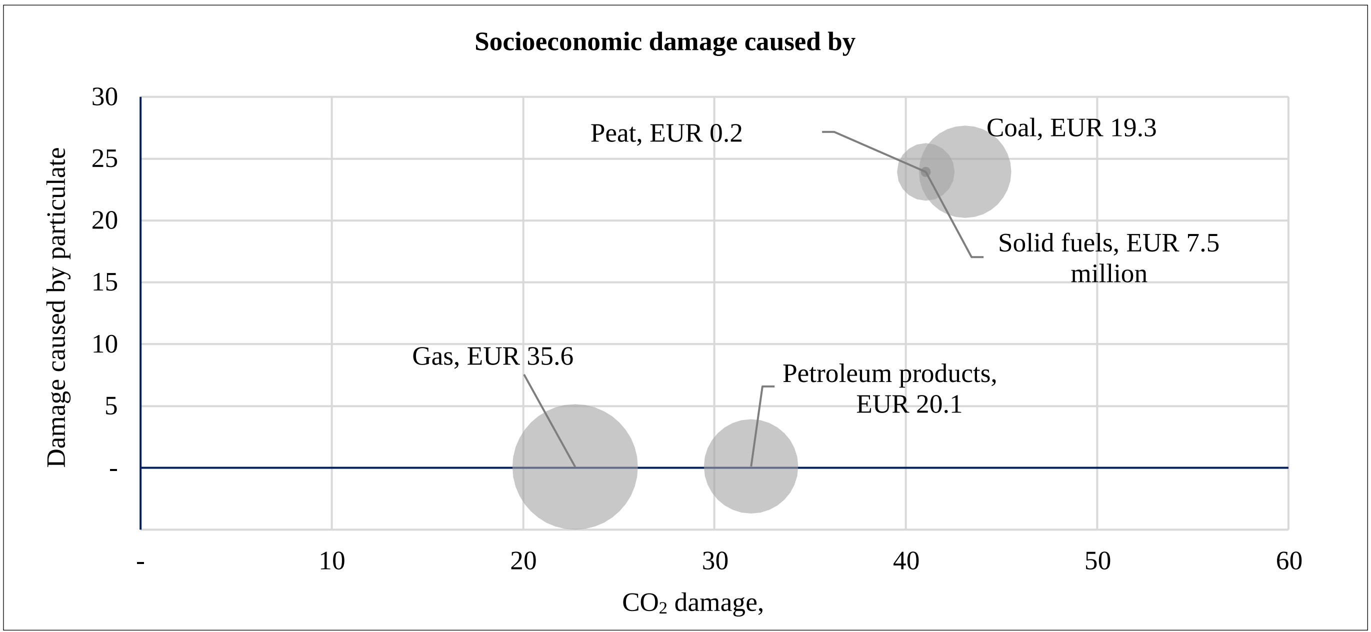
Source: authors of the Study

From the data provided, it can be observed that the mix of fossil fuels is dominated by natural gas (19%) and petroleum products (8%).

In order to set priorities for adjusting the household supply structure, we have carried out an assessment of the socioeconomic damage caused by fossil fuels during which we calculated the damage caused by GHG and particulate emissions from the combustion of fuels. Assessment results are shown in the figure below.

76 Socioeconomic damage estimates used in the assessment are set in Annex 2.7.

Figure 34. Damage caused by fossil fuels used by households in 2020, million EUR



Source: authors of the Study

To sum up, the household heating supply sector has the greatest potential to reduce socioeconomic damage in the following segments:

- Natural gas: economic and social damage due to GHG emissions about EUR 35.6 million per year.
- Petroleum products: economic and social damage due to GHG and PM emissions about EUR 20.1 million per year.
- Coal: economic and social damage due to GHG and PM emissions about EUR 19.3 million per year.

NB: Particulate matter emissions are also generated from heat production from biofuels. In the household segment, particulate matter damage is estimated at about EUR 150 million per year.

Possibilities for tapping into the potential of heating efficiency in households are assessed in more detail in Chapter 8.5.1.

Service sector

The table below shows the detailed fuel mix for decentralised supply in the service sector.

Table 145. Heat UEC supply in the service sector (decentralised supply) in 2020, GWh

Sector	Fossil fuels						RES			Total
	Gas	Petroleum products	Coal	Solid fuel	Peat	Electricity (FF)	Electricity (RES)	Ambience	Biofuel	
Services	734	27	182	56	7	59	89	252	376	**1.782**
	41%	2%	10%	3%	0.4%	3%	5%	14%	21%	**100%**
	1.066						**717**			**1.782**
	60%						40%			100%

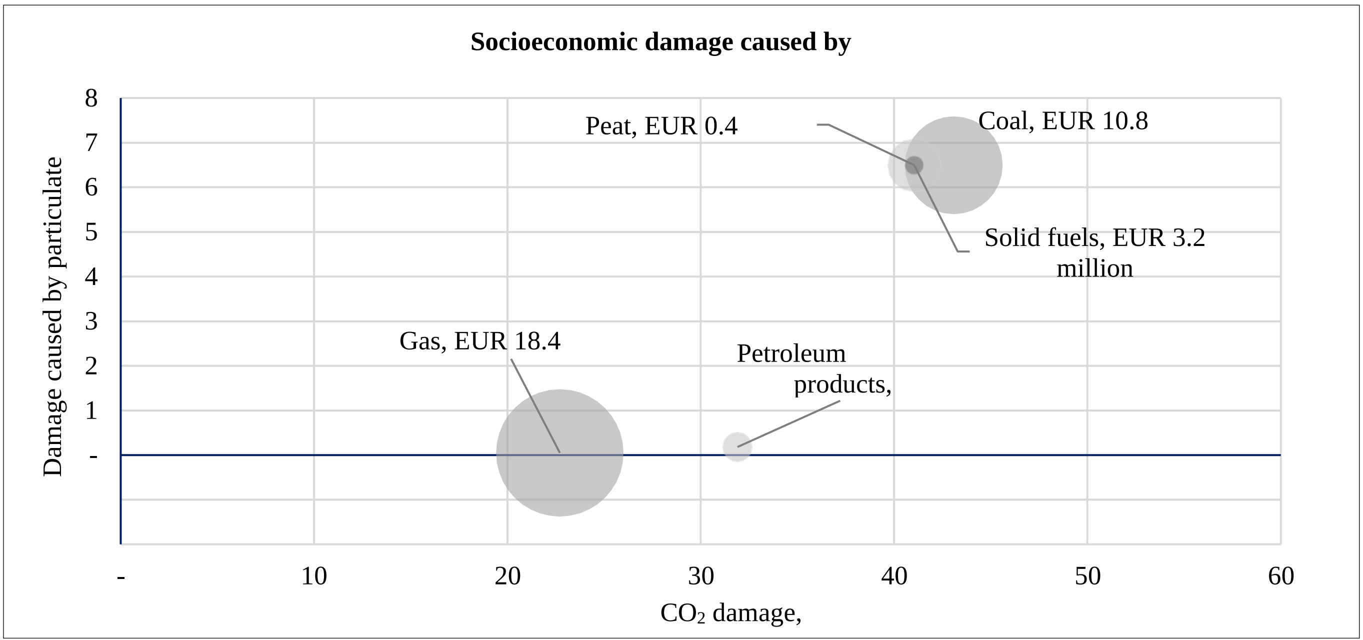
Source: authors of the Study

In order to set priorities, we have carried out an assessment of the socioeconomic damage caused by fossil fuels during which we calculated the damage caused by GHG and particulate emissions from the combustion of fuels. Assessment results are shown in the figure below.

From the data provided, it can be observed that the mix of fossil fuels is dominated by heat production from natural gas (41%) and coal (10%).

In order to set priorities, we have carried out an assessment of the socioeconomic damage caused by fossil fuels during which we calculated the damage caused by GHG and particulate emissions from the combustion of fuels. Assessment results are shown in the figure below.

Figure 35. Damage caused by fossil fuels used in the service sector in 2020, million EUR



Source: authors of the Study

To sum up, the service sector has the greatest potential to reduce socioeconomic damage in the following segments:

- Natural gas: economic and social damage due to GHG emissions about EUR 18.4 million per year.
- Coal: economic and social damage due to GHG and particulate matter emissions about EUR 10.8 million per year.
- Other solid fuels: economic and social damage due to GHG and particulate matter emissions about EUR 3.6 million per year.

It can be observed that, unlike households, the service sector is almost devoid of petroleum products (liquid fuels) – likely due to the application of tax incentives to private persons.

It is also important to note that particulate matter emissions are also generated by the production of heat from RES. Possibilities for tapping into the potential of heating efficiency in the service sector are assessed in more detail in Chapter 8.5.2.

Industry sector

The table below shows the detailed fuel mix for decentralised supply in the industry sector.

Table 146. Heat UEC supply in the industry sector (decentralised supply) in 2020, GWh

Sector	**Fossil fuels**					**RES**					**Total**
	Gas	**Petroleum products**	**Coal**	**Solid fuel**	**Electricity (FF)**	**Electricity (RES)**	**Ambience**	**Biomet.**	**Waste**	**Biofuel**	
Industry	2.890	307	800	136	14	22	61	47	23	1.265	**5.565**
	52%	6%	14%	2%	0%	0%	1%	1%	0%	23%	**100%**
	4.147					**1.418**					**5.565**
	75%					25%					100%

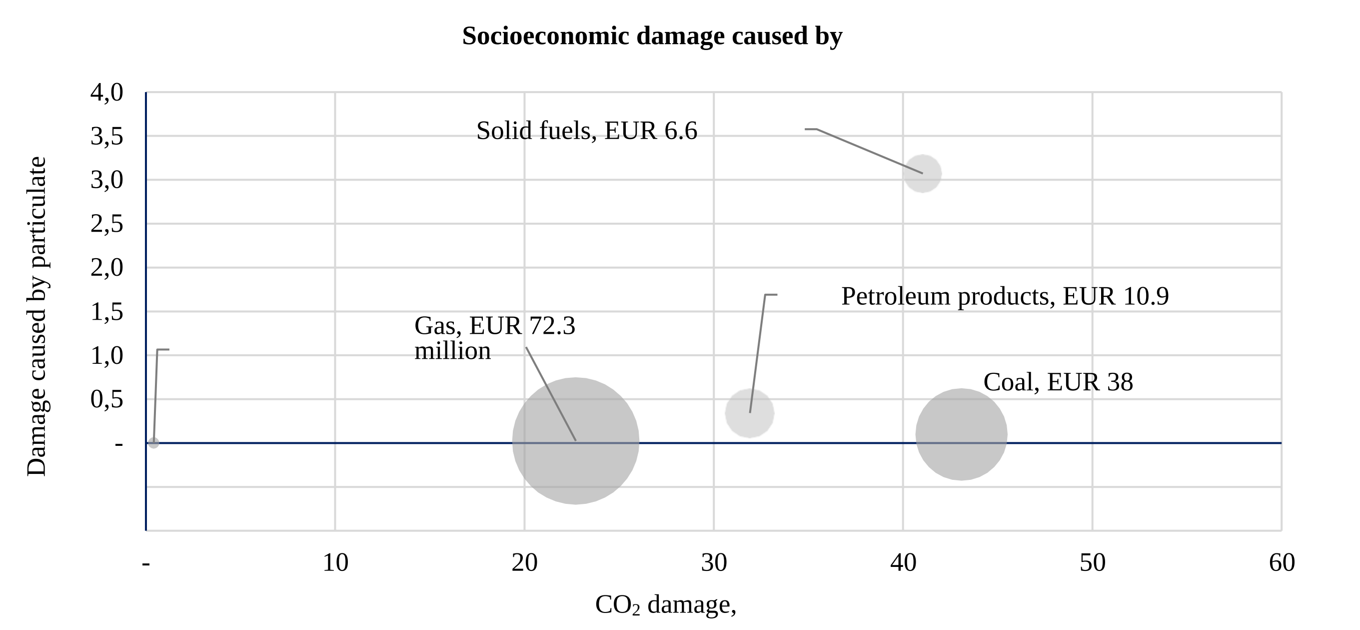
Source: authors of the Study

In order to set priorities, we have carried out an assessment of the socioeconomic damage caused by fossil fuels during which we calculated the damage caused by GHG and particulate emissions from the combustion of fuels. Assessment results are shown in the figure below.

From the data provided, it can be observed that the mix of fossil fuels is dominated by heat production from natural gas (52%) and coal (14%).

In order to set priorities, we have carried out an assessment of the socioeconomic damage caused by fossil fuels during which we calculated the damage caused by GHG and particulate emissions from the combustion of fuels. Assessment results are shown in the figure below.

Figure 36. Damage caused by fossil fuels used in the industry sector in 2020, million EUR



Source: authors of the Study

To sum up, the industry sector has the greatest potential to reduce socioeconomic damage in the following segments:

- Natural gas: economic and social damage due to GHG emissions about EUR 72 million per year.
- Coal: economic and social damage due to GHG and PM emissions about EUR 38 million per year.
- Petroleum products: economic and social damage due to GHG and PM emissions about EUR 11 million per year.
- Other solid fuels: economic and social damage due to GHG and PM emissions about EUR 7 million per year.

NB: unlike the household sector or the service sector, in the industry sector most of the heating energy is used not for heating buildings but for production processes where a specific fuel type may be important for the production process (e.g. when the process requires a certain heat temperature or a specific chemical element released during combustion).

Possibilities for tapping into the potential of heating efficiency in the industry sector are assessed in more detail in Chapter 8.5.3.

7.1.4. Heating supply: waste heat potential

Recommendation 2.2. The purpose of this stage is to identify, describe and quantify the sources of waste heat or cooling for which the technical potential has not yet been fully exploited. This could be used as an indicator of current or future heating and cooling demand. Point 2(b) of Annex VIII to the EED lists heat generating installations to be examined.

It may also be useful to describe the quality of energy produced, such as temperature (steam or hot water), which can be achieved depending on the purpose for which it is normally used. If the quantity or quality of waste heat or cold is not known, they may be assessed using an appropriate methodology based on well-documented assumptions. For example, waste heat from power generation installations can be recovered using a variety of methods and technologies.

In accordance with Annex IV to the EED, waste heat is defined as excess heat remaining after an industrial process or heat recovery.

Waste heat examples:

- data centres or retail spaces to be cooled where heat generated in the course of activity can be delivered off-site rather than discharged into the environment;
- direct use of the condenser cooling flow (e.g. heat can be supplied for heating greenhouses);
- by-products are produced from renewable energy sources used for heat production and are considered residual heat (i.e. the incineration of biodegradable waste and biomass).

Industrial waste heat may be accounted for as waste heat if:

- the purpose of heat production is the internal or external meeting of the need for heat or cold and is a by-product of other processes and has an independent energy input;
- the heat is obtained from a cogeneration plant because its use is also a measure of power cogeneration and does not constitute residual heat from unused cogeneration heat;
- the heat cannot be used internally – within the same company.

To sum up the above definitions and examples, waste heat can be divided into 2 main groups:

1. heat generated by industrial processes; and
2. heat excess (loss) resulting from the heat production process.

The results of the waste heat potential assessment are summarised in the table below.

147 Table. Summary on waste heat potential in Lithuania

Heat generation installations	Thermal power	Heat quantity, GWh/year	
		Processes	Heat generation
1. Thermal power plants, whether or not capable of being modified so as to be able to supply waste heat, with a total thermal power exceeding 20 MW	> 20 MW	Not applicable	77,9
2. Heat and power cogeneration installations of a total thermal power exceeding 20 MW	> 20 MW	Not applicable	-
3. Waste incineration plants	-	Not applicable	-
4. Power installations with a total thermal power exceeding 20 MW using RES energy for heat or cold production other than those referred to in paragraphs 1 and 2	> 20 MW	Not applicable	-
5. Power installations with a total thermal power of less than 20 MW and more than 1 MW in which heat or cooling is produced using RES energy.	1 to 20 MW	Not applicable	-
6. Industrial installations with a total thermal power exceeding 20 MW and capable of delivering waste heat	> 20 MW	70,2	Not applicable
7. Other sources of waste heat	Not applicable	252,8	-

Source: authors of the Study

Based on the results of the evaluation:

- In the segment of thermal power plants (> 20 MW), the waste heat potential to be realised is set to be 77,9 GWh, which would be realised by introducing the absorption heat pump (AHP) technology in power plants.
- The cogeneration plant (>20MW) segment has a technical waste heat potential of 55 GWh, which could be technically realised by the introduction of absorption heat pump (AHP) technology in power plants. However, taking into account the fact that economic benefits from waste heat recovery would be lower than economic damage caused by the decrease in power generation volumes, it is concluded that there is currently no waste heat potential to be realised.
- In the segment of waste incineration cogeneration plants the technical waste heat potential to be realised is set to be 71 GWh, which could technically be realised by introducing the absorption heat pump (AHP) technology in power plants. However, for the reasons mentioned above, it is also assessed that there is currently no waste heat potential to be realised.
- During the preparation of the Study, no power installations meeting the definition of Groups 4 and 5 were identified.
- Based on the results of energy consumption audits, the waste heat potential to be realised at industrial installations was 70.2 GWh.
- In other waste heat sources, the waste heat potential to be realised was 252.8 GWh.

Below are detailed results of the assessment of the waste heat potential of each group of heat generating installations referred to above.

1. Waste heat potential: thermal power plants

The first group is the loss of heat from the thermal power plant and its heat generation processes, which can potentially be collected and reused.

In order to assess the heat recovery potential lost during production processes, it is important to understand the structure of these losses and the reasons for their emergence. Heat loss of a typical water heating or steam boiler in a biofuel-run boiler house is 14 to 16% and is divided into 5 components:

- due to outgoing combustion products (q2);
- due to chemical non-combustion (q3);
- due to mechanical non-combustion (q4);
- from hot surfaces (q5);
- with ashes removed (q6).

Standard values for biofuel boiler losses are disclosed in the table below.

148 Table. Standard biofuel boiler losses

Heat loss	Standard value
q1. Boiler heat recovery share	84÷86%
q2. Heat loss due to outgoing combustion products	10÷20%
q3. Heat loss due to chemical non-combustion	0.2÷0.5%
q4. Heat loss due to mechanical non-combustion	>0.5%
q5. Heat loss from hot surfaces	2.0÷3.5%
q6. Heat loss with ash removal	0.02÷0.10%

Source: authors of the Study

It can be noted that losses with outgoing combustion products (q2) constitute the most significant share of boiler losses. The cause of losses is the humidity of biofuel, which in Lithuania reaches about 45%, therefore a significant part of fuel energy is used to evaporate the moisture contained in the fuel. Losses of this group (q2) usually account for about 83% of the total loss of the boiler, and also have the greatest technical potential to be collected and converted into useful energy. The remaining categories of losses (q3-q6) represent a negligible part of the losses and/or do not have a significant efficiency enhancing potential.

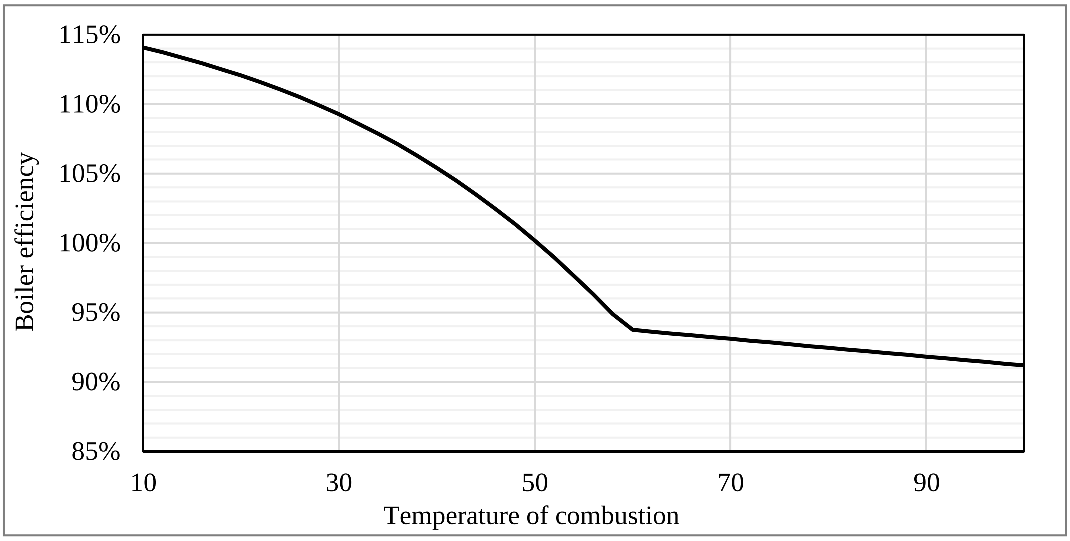
Accordingly, it is assessed that loss due to outgoing combustion products (q2) has certain efficiency enhancing potential.

Principal technological solutions to exploit the potential in this category are the following:

- Flue gas condensing economizer (FGC) technology.
- Absorption heat pump (AHP) technology.

With the help of a **flue gas condensing economizer**, part of the losses with outgoing combustion products, as well as part of the water vapour heat in larger boilers are recovered by using relatively low-temperature water from the heat network reverse line. By cooling combustion products with this water, the temperature is reached when the water vapour contained in the combustion products begins to condense. Water is characterised by high concealed heat of vaporisation, so when water vapour turns to liquid, a large amount of heat is released. The graph below shows what total efficiency of the boiler can be achieved by cooling combustion products and utilising their heat.

37 Figure. Boiler efficiency depending on combustion temperature



Source: authors of the Study

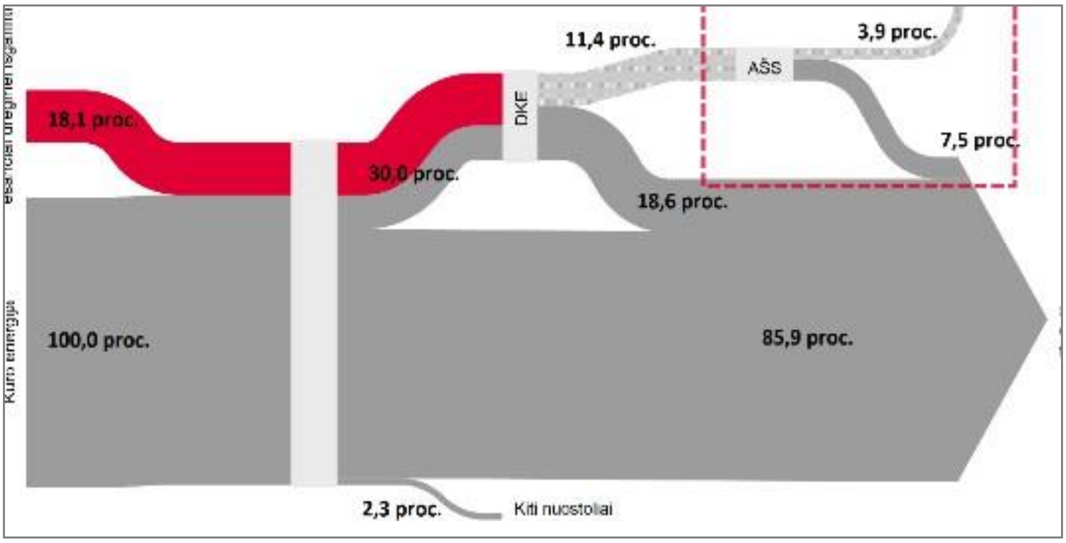
According to the collected data, the installed FGC capacity in Lithuania is 281 MW. According to the NERC data[77], FGCs are installed in the vast majority of continuously operating boiler houses and their potential is therefore already exploited.

The technological solution of **the absorption heat pump** is intended for cooling combustion products and has significant efficiency enhancing potential in biofuel boilers and theoretical potential in natural gas boilers.

<u>Biofuel installations</u>

The figure below shows a logic circuit for enhancing the efficiency of a biofuel boiler. In a typical configuration of a biofuel boiler with an FGC and cooling combustion products to approximately 45°C, the total efficiency of the boiler that can be reached is about 103%. However, as shown in the figure, cooling combustion products to ambient temperature can increase the efficiency of the boiler up to as much as 112%.

38 Figure. Logic circuit of boiler efficiency



Source: authors of the Study

Combustion products can be cooled using the absorption heat pump (AHP) technology. This technology has already been successfully implemented and used in Kaunas, Klaipėda and Panevėžys DH systems.

77 Summaries of technical indicators for heat generation.

According to the practice of heat suppliers that have implemented these technologies, the efficiency of a boiler using an absorption heat pump actually increases by 7.5%.

According to market practices, it is financially feasible for the AHPs to be deployed in biofuel boiler houses with a power of at least 16 MW. Accordingly, in the analysis of the AHP potential, we evaluated not only thermal power plants with a total thermal power of more than 50 MW (based on the Recommendations) but also identified the heat potential of thermal power plant waste in all biofuel boiler houses with a power of more than 16 MW.

Assuming that the absorption heat pump's share in the plant's capacity is 7%, we have compiled a list of potential biofuel power plants for the installation of AHPs (see table below) and evaluated potential energy savings (waste heat potential).

The technical waste heat potential was calculated assuming that a biofuel boiler house will operate at an average of 45% of its nominal capacity. The economic potential was assessed taking into account actual heat production in 2020: if actual heat production is less than 45% of the nominal heat production potential, the economic waste heat potential was calculated as 7% of actual heat production in 2020.

Table 149. Potential for waste heat from absorption heat pumps in biofuel installations

Heat producer	Municipality	Thermal power, MW	AHP potential, MW	WH potential (GWh)	
				Technical[78]	Economic
UAB Danpower Baltic Pakalniškių	Vilnius City Municipality	25,0	1,8	6,9	6,9
UAB Pramonės energija	Klaipėda City Municipality	24,8	1,7	6,8	6,0
UAB Danpower Baltic Biruliškių	Kaunas City Municipality	24,3	1,7	6,7	4,5
UAB Danpower Baltic Biruliškių	Kaunas City Municipality	24,3	1,7	6,7	6,4
UAB Danpower Baltic Paneriškių	Vilnius City Municipality	24,3	1,7	6,7	6,7
UAB Danpower Baltic Paneriškių	Vilnius City Municipality	24,3	1,7	6,7	6,7
UAB Forest Investment	Vilnius City Municipality	24,3	1,7	6,7	6,7
UAB Forest Investment	Vilnius City Municipality	24,3	1,7	6,7	6,7
UAB Danpower Baltic Zietelos	Vilnius City Municipality	23,8	1,7	6,6	6,6
AB Ignitis gamyba	Elektrėnai Municipality	20,0	1,4	5,5	4,2
AB Ignitis gamyba	Elektrėnai Municipality	20,0	1,4	5,5	-
UAB Danpower Baltic Taika	Kaunas City Municipality	20,0	1,4	5,5	2,5
UAB Aldec General	Kaunas City Municipality	20,0	1,4	5,5	4,1
UAB Biokuro energija	Panevėžys City Municipality	20,0	1,4	5,5	5,5
UAB Litesko branch Marijampolės šiluma	Marijampolė Municipality	16,0	1,1	4,4	4,4
	Total:	**335,4**	**23,5**	**92,6**	**77,9**

Source: authors of the Study, NERC, Baltpool

<u>Gas installations</u>

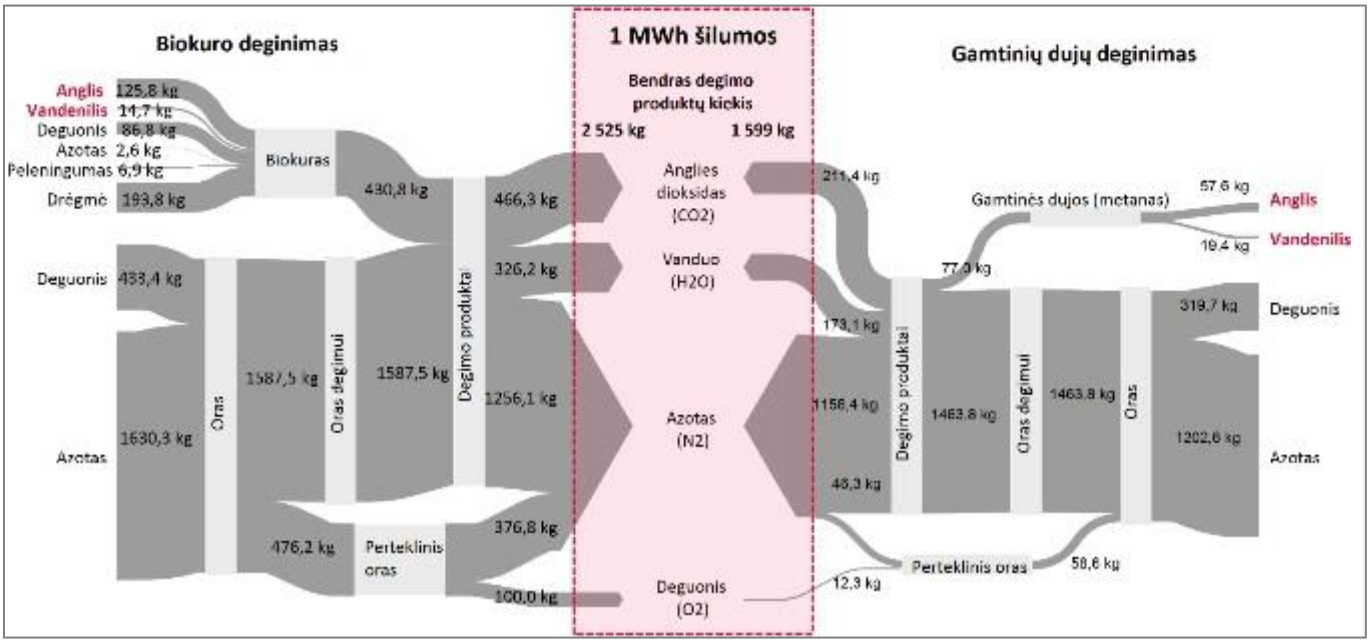
The AHP technology can be technically implemented in natural gas combustion plants but, in our opinion, has significant limitations in realising the potential in practice:

- In an efficient DH system, natural gas is used only to meet peak demand. Accordingly, the use of these sources is uneven and, as a rule, rare.
- Combustion of natural gas generates significantly less combustion products (by over one third) and water

vapour (about half) than extraction of the same amount of heat in a biofuel combustion plant (see figure below). The amount of heat energy that can be recovered with the help of the AHP decreases proportionately.

78 *It is assumed that boiler houses operate 45% of the time.*

Figure 39. Combustion products and water vapour generated during combustion



Source: authors of the Study

- Excessively low temperature in the gas boiler recirculation line while gas boilers are in use (during peak demand of the network), the temperature of heat released in the networks is quite high, accordingly, the potential of the heat flow driven by the absorption heat pump is insufficient to recover the heat.

In summary, it is estimated that in the segment of thermal power plants (>20 MW) the waste heat potential amounts to about 78 GWh per year and can be realised by implementing the AHP technology in biofuel power plants.

150 Table. Summary on waste heat potential in Lithuania

Heat generation installations	Thermal power	GWh/year
1. Thermal power plants, whether or not capable of being modified so as to be able to supply waste heat, with a total thermal power exceeding 20 MW	> 20 MW	77,9

Source: authors of the Study

2. Waste heat potential: cogeneration plants

The second waste heat potential group is the loss of heat from the cogeneration plant and its heat generation processes, which can potentially be collected and reused.

Cogeneration is the production of heat and electricity in a single technological cycle. As in the case of thermal power plants, losses with outgoing combustion products (q2) represent the most significant part of boiler losses that can potentially be captured and reused.

As in the case of thermal power plants, the FGC potential of cogeneration plants is estimated to have already been exhausted and is negligible in the case of natural gas-fired cogeneration plants. Accordingly, below is an assessment of the potential for AHP implementation in biofuel cogeneration plants.

In biofuel cogeneration plants, additional amounts of heat energy can be extracted (the waste heat potential can be realised) by using heat pumps and removing heat from turbine bearings, by additionally cooling of the resulting water condensate or combustion products.

However, in the case of a cogeneration power plant, such solutions would reduce power generation and, without assessing additional heat recovery from combustion products, would represent only a very insignificant (1-2%) share of the power plant's energy production. Accordingly, it is believed that biofuel-fired cogeneration plants operating in Lithuania

have some technical waste heat potential (29 GWh) but its realisation would not currently be economically viable.

151 Table. Waste heat potential in biofuel cogeneration units (>20 MW)

Heat producer	Municipality	Thermal power, MW	Electric power, MW	AHP potential, MW	WH potential (GWh)	
					Technical	Economic
AB Vilniaus šilumos tinklai	Vilnius City Municipality	60	17	5	21	-
AB Šiaulių energija	Šiauliai City Municipality	27	11	3	10	-
UAB Alytaus šilumos tinklai	Alytus City Municipality	20	5	2	7	-
UAB Foksita	Kaunas City Municipality	30	5	2	10	-
UAB Idex taikos elektrinė	Kaunas City Municipality	20	5	2	7	
Total:		**157**	**43**	**14**	**55**	-

Source: authors of the Study, NERC, Baltpool

Accordingly, it is believed that cogeneration plants operating in Lithuania (>20 MW) do not have significant waste heat potential.

152 Table. Summary on waste heat potential in Lithuania

Heat generation installations	Thermal power	GWh/year
2. Heat and power cogeneration installations of a total thermal power exceeding 20 MW	> 20 MW	-

Source: authors of the Study

3. Waste heat potential: waste incineration plants

The third waste heat potential group is waste incineration plants where heat generation processes lose heat which can potentially be collected and reused.

Lithuania currently has 3 waste incineration cogeneration plants established in major cities of Lithuania – Vilnius, Kaunas and Klaipėda.

153 Table. Waste heat potential in waste incineration plants

Heat producer	Municipality	Thermal power, MW	Electric power, MW	AHP potential, MW	WH potential (GWh)	
					Technical	Economic
UAB Kauno kogeneracinė jėgainė	Kaunas City Municipality	70	26	7	26	-
UAB Gren Klaipėda	Klaipėda City Municipality	65	20	6	23	-
UAB Vilniaus kogeneracinė jėgainė	Vilnius City Municipality	60	20	6	22	-
Total:		**195**	**66**	**19**	**71**	**-**

Source: authors of the Study, NERC, Baltpool

The power and work schedules of power plants are chosen in such a way that they burn virtually all municipal and industrial waste remaining in the country after sorting. Accordingly, it is believed that there is no potential for new waste incineration plants in the territory of Lithuania in the future.

As in the case of biofuel-fired cogeneration plants (see subsection above), the loss reduction potential within the production process technically exists (with the introduction of the AHP technology) but is not economically justified due to the reduction of electricity generation volumes. Accordingly, it is believed that waste incineration cogeneration plants operating in Lithuania do not have significant waste heat potential.

154 Table. Summary on waste heat potential in Lithuania

Heat generation installations	Thermal power	GWh/year
3. Waste incineration plants	-	-

Source: authors of the Study

Although in accordance with the definition provided by the EED and the Guidelines, waste heat is not considered to be thermal energy produced with a view to sale, it is worth noting that due to the specificity of waste incineration there is an additional potential for energy use. The main priorities of waste incineration plants are waste recovery and power generation while heat production is considered to be a lower priority, as the need for it may fluctuate significantly, and waste incineration plants have technical possibilities to generate heat even without supplying it to the DH system.

Accordingly, in practice, there are situations when DH systems do not accept heat produced by waste incineration plants, therefore, heat is simply thrown into the atmosphere using coolers. Technically, such heat could be supplied directly to industrial consumers (not connected to DH systems) or stored in seasonal heat reservoirs. However, these solutions have significant technical limitations: industrial consumers usually require an energy flow adapted to industrial processes, which is difficult to match with heat supply according to the results of the heat procurement auction, and heat storage projects are not yet a wide-spread technology in the domestic market.

4 – 5 Waste heat potential: high- and medium-capacity RES installations

The fourth group of waste heat potential is other high-capacity (over 20 MW) energy installations (other than thermal and cogeneration plants) where heat or cold is generated using RES energy and where lost heat can potentially be collected and reused.

The fifth group of waste heat potential includes other medium-capacity (between 1 and 20 MW) energy installations (other than thermal and cogeneration plants) where heat or cold is generated using RES energy and where lost heat can potentially be collected and reused.

During the preparation of the Study, no power installations meeting the definition of waste heat of Groups 4 and 5 were identified.

6. Waste heat potential: industrial installations

The sixth and last group of waste heat potential is industrial installations with a total thermal power exceeding 20 MW and capable of delivering waste heat. Unlike the groups evaluated above, this waste heat group is distinguished by the fact that waste heat is generated in non-heat production facilities.

According to the RESD, waste heat and cold is unavoidable heat or cold generated as by-product in industrial or power generation installations, or in the tertiary sector, which would be dissipated unused in air or water without access to a district heating or cooling system, where a cogeneration process has been used or will be used or where cogeneration is not feasible.

The main challenge in assessing the potential for realising industrial heat is that the heat recovery potential is highly dependent on the specific industry sector concerned or even on a specific production technology. Accordingly, it is believed that the waste heat potential in the industry sector can only be reliably calculated at the level of individual undertakings.

Article 8 of the EED states that all large enterprises must undergo regular energy audits. According to the Republic of Lithuania Law on Improving Energy Efficiency, a large enterprise is an enterprise having more than 250 employees and its annual income exceeding EUR 40 million or the book value of assets exceeding EUR 27 million. The table below provides data on energy audits for undertakings with a thermal equipment capacity of more than 20 MW[79].

79 Source: EPA database.

155 Table. Amount of waste heat identified during energy audit of industrial enterprises

Company name	Energy audit performed	Power, MW	Identified WH potential, MWh
AB Orlen Lietuva	Yes	2.884	No data
AB Achema	Yes	193	22.330
AB Klaipėdos nafta	Yes	190	No data
AB Klovainių skalda	No	190	No data
AB Akmenės cementas	Yes	>100	No data
AB Palemono keramikos gamykla	No	96	No data
UAB Marijampolės pieno konservai, Kalvarija Unit	Yes	91	9.310
UAB Orion Global PET	Yes	84	24.086
AB Nordic Sugar Kėdainiai	No	75	No data
UAB Neo Group	Yes	74	164
VĮ Ignalinos atominė elektrinė	Yes	67	No data
UAB Lietuvos cukrus	No	50	No data
AB Grigeo Klaipėda	Yes	45	1.062
AB Žemaitijos pienas	Yes	45	2.445
AB Lifosa	Yes	44	No data
UAB Technology projects	No	39	No data
AB Grigeo	Yes	38	3.203
AB Amilina	Yes	37	2.236
UAB Philip Morris Lietuva	Yes	33	No data
UAB Marijampolės pieno konservai, Marijampolė Factory	Yes	29	1.360
UAB Mars Lietuva	Yes	29	4.004
AB Klaipėdos mediena	Yes	26	No data
UAB Fegda	Yes	26	No data
UAB Plungės kooperatinė prekyba	Yes	25	No data
Total		**4.510**	**70.200**

Source: authors of the study, Lithuanian Energy Agency, Environmental Protection Agency

To sum up, it is estimated that the waste heat potential of industrial installations with a total thermal input of more than 20 MW from which waste heat can be supplied amounts to about 70 GWh per year.

156 Table. Summary on waste heat potential in Lithuania

Heat generation installations	Thermal power	GWh/year
6. Industrial installations with a total thermal power exceeding 20 MW and capable of delivering waste heat	> 20 MW	70,2

Source: authors of the Study

7. Other sources of waste heat

The study also analysed other potential sources of waste heat:

a. Data centres.
b. Food trade.
c. Waste water treatment plants.
d. Food production businesses.
e. Cooled buildings in the service sector.
f. Cooled residential buildings.

Methods of assessment

The assessment of the potential of these waste heat sources was carried out based on the results of a study by the Universities of Halmstad and Aalborg entitled *ReUseHeat*. In the course of the study *ReUseHeat*, waste heat data of the EU countries were collected and a waste heat map was prepared where the geographical location, quantity of waste heat generation and the company's sector can be determined.

The parameters of the waste heat sources concerned are summarised in the table below.

157 Table. Parameters of waste heat sources

WH source	WH temperature	Seasonality	Constancy
a. Data centres	25-35°C	No	Constant
b. Food trade	40-70°C	None	Constant
c. Waste water treatment	8-15°C	None	Constant
d. Food production	20-40°C	None	Constant
e. Service sector buildings	30-40°C	During the warm season only	Not constant
f. Residential buildings	30-40°C	During the warm season only	Not constant

Source: authors of the Study, study ReUseHeat

When assessing the potential of waste heat, the model used is that waste heat is supplied to third-generation DH systems (normally operating within the range of 70-100°C). Accordingly, it is estimated that only heat generated in food trade businesses (if the refrigerant CO_2 is used in the heat pump) could be supplied to the grid without an additional heat pump. For using waste heat from other sectors, the third-generation heat network requires a heat pump.

Evaluation results

According to the ReUseHeat database, the total potential of the WH sources examined is about 3 TWh per year.

158 Table. Waste heat potential (other sources), GWh per year

Source	Waste heat		Energy for heat pumps
	Existing[81]	Recovered[82]	
a. Data centres	278	389	111
b. Food trade	472	472	-
c. Waste water treatment	1.222	1.861	639
d. Food production	19	28	9
e. Service sector buildings	111	194	83
f. Residential buildings	47	72	25
Total	**2.149**	**3.017**	**868**

Source: authors of the Study, study ReUseHeat

In order to identify the waste heat potential to be realised, data from the *ReUseHeat* database on WH sources within 2 km of the DH areas were used. The technical potential of these sources is estimated at about 1.4 TWh per year.

[80] Moreno D., Nielsen S. & Persson U. (2022). The European Waste Heat Map. ReUseHeat project – Recovery of Urban Excess Heat. Last update: 31 May 2022

[81] Heat emissions.
[82] Recovered quantity of waste heat (supplied by heat pump to third-generation DH systems).

159 Table. Waste heat potential (other sources at <2 km from DH systems), GWh per year

Source	Waste heat		Energy for heat pumps	Waste heat potential	
	Existing	Recovered		Technical	Realised
a. Data centres	194	306	112	306	30.6 (10%)
b. Food trade	278	278	-	278	83.4 (30%)
c. Waste water treatment	472	694	222	694	138.8 (20%)
d. Food production	6	9	3	9	-
e. Service sector buildings	44	67	23	67	-
f. Residential buildings	25	38	13	38	-
Total	**1.020**	**1.391**	**371**	**1.391**	**252.8 (18%)**

Source: authors of the Study, study ReUseHeat

Below is information on the main assessment assumptions and calculation methods used.

a. Data centres

Waste heat can be used with heat pumps. Estimating that waste heat temperature reaches about 25-35°C and the temperature of the cogenerate in the heat network reaches 85°C, the heat pump can reach a coefficient of performance of up to 5.9.

Based on information from the ReUseHeat database, it is estimated that the technical potential of waste heat from data centres located at <2 km from the DH area is about 306 GWh per year. This figure is calculated on the basis of statistics on national electricity consumption of data centres according to NACE classification[83]. According to *DataCenterMap* data, 12 data centres (9 in Vilnius, 1 in Kaunas and 2 in Šiauliai) were identified in Lithuania.

In order to assess which part of the technical WH potential would be economically feasible to realise, it is necessary to carry out an analysis of the specific situation (an assessment of the return on investment). Research in this area has shown that return on investment needed to realise the waste heat potential of small and medium-sized data centres is not economically attractive. Accordingly, for the purposes of the Study, it is estimated that by 2050 10% of the technical waste heat potential identified (30.6 GWh) could be realised.

b. Food trade

Waste heat temperature reaches 40 to 70°C. If the refrigerant CO_2 is used in the heat pump, the heat generated could be supplied to the grid without an additional heat pump.

Based on information from the *ReUseHeat* database, it is estimated that the technical potential of waste heat from food trade businesses located at <2 km from the DH area is about 278 GWh per year. The size was calculated on the basis of *OpenStreetMap* data – 16 retail chains were identified in Lithuania; their buildings were divided into five groups by surface area and, respectively, the waste heat potential was calculated for each category.

Table 147. Shopping centres identified in ReUseHeat study by surface area and key assumptions

Surface area of shopping centres	100-400 m^2	401-1,000 m^2	1,001-2,500 m^2	2,501-5,000 m^2	>5,000 m^2
Number of shopping centres	98	152	210	108	35
Maximum cooling capacity per SC, kW	60	150	240	300	400
Need for heat in summer per SC, MWh	6	17	39	83	222
Need for heat in winter per SC, MWh	17	61	153	328	869

Source: study ReUseHeat

83 Eurostat data for 2015, which were adjusted to distinguish between the need for electricity for data centres by country, taking into

account the evolution of the global need for electricity for data centres since 2015.

The estimated amount of waste heat may differ significantly from the actual one due to building use particularities, i.e. indoor temperature maintained, hot water consumption, efficiency of existing heating and cooling equipment, door systems, etc. Therefore, in order to assess which part of the technical WH potential would be economically feasible to realise, it is necessary to carry out an analysis of the specific situation (an assessment of the return on investment).

Taking into account that waste heat of some food trade businesses could be supplied without additional investments in the heat pump, it is estimated that by 2050 10% of waste heat (83.4 GWh) could be realised.

c. Waste water treatment

The average annual temperature of treated waste water is estimated to be around 12°C and ranges from 8°C to 15°C throughout the year. Accordingly, for this heat to be collected and suitable for transmission to third-generation district heating networks with temperatures up to 85°C, a heat pump is required. The coefficient of performance of the heat pump where the temperature of treated waste water is 8-12°C would be up to 4.7-4.9 COP.

Based on information from the *ReUseHeat* database, it is estimated that the technical heat potential of waste water treatment plants located at <2 km from the DH area (21 out of 75 waste water treatment plants fall into this range) is
about 694 kWh/year. The amount is calculated using the data collected under the Urban Waste Water Treatment Directive on nominal and actual load for EU-28 waste water treatment plants and the statistics collected by the Swedish District Heating Association[85].

In order to assess what share of the technical WH potential would be economically justified for realisation, it is necessary to carry out an analysis of the specific situation (an assessment of the return on investment) and take into account the fact that in Lithuania, when winter is cold, waste water is additionally heated in order to ensure the continuous operation of processes and the recovery of biomethane at optimal temperatures. Accordingly, the waste heat potential is likely to be lower, especially in the cold season. Furthermore, additional investments are needed to realise the potential to eliminate dissolved substances (e.g. ferric phosphate), the deposition of which on the heat exchanger boosts operating costs.

The Study estimates that 20% of the technical waste heat potential identified could be realised by 2050.

d. Food production

Waste heat in the food production sector is generated in industrial installations when generating cold for refrigerators, freezers and equipment for the production of food products. Based on information from the *ReUseHeat* database, it is estimated that the technical potential of waste heat from food production businesses located at <2 km from the DH area is about 9 GWh per year. For the purposes of the Study, this potential is assessed as negligible.

e–f. Cooled residential buildings and cooled buildings in the service sectors

Based on information from the *ReUseHeat* database, it is estimated that the technical potential of waste heat from cooled residential and commercial buildings located at <2 km from the DH area is about 105 GWh per year.

The analysis of cooling demand carried out during the Study identified a significant lack of actual cooling data. Accordingly, for the purposes of the Study, it is estimated that in order to identify the waste potential in this segment to be realised, it is necessary to carry out both an analysis of the specific situation (an assessment of the return on investment) and the improvement of the quality of the cooling consumption dataset.

84 Waterbase_UWWTD_v6_20171207.mdb. European Environment Agency, Copenhagen

85 Energy supply to district heating and cogeneration – older statistics. Statistics for energy supply for the years 2009-2015. Energiföretagen

7.2. COOLING SUPPLY

The table below shows the structure of Lithuania's heat supply by source of production and type of heat supply infrastructure (decentralised or district supply[86]).

160 Table. Cooling UEC supply in Lithuania in 2020

Type of source of production	Source of production	Unit of measurement	Total	Decentralised supply	District supply
FF sources	Individual boilers	GWh/year	-	-	-
	Waste heat	GWh/year	-	-	-
	Other technologies	GWh/year	96	96	-
	Cogeneration units	GWh/year	-	-	-
	FF sources, total		**96**	**96**	**-**
RES sources	Individual boilers	GWh/year	-	-	-
	Waste heat	GWh/year	-	-	-
	Cogeneration units	GWh/year	-	-	-
	Heat pumps	GWh/year	408	408	-
	Other technologies	GWh/year	144	144	-
	RES sources, total		**552**	**552**	**-**
TOTAL			**648**	**648**	**-**

Source: authors of the Study

When analysing these data, one may note that:

- At national level, all cooling energy consumed is produced in individual (local) heat production sources.
- Cooling generated by individual sources is produced using the heat pump technology.

It is important to note that due to the lack of actual data, the energy need for cooling was calculated using significant assumptions (for details see Chapter 4.7.2) – the calculations of cooling supply were also based on the same assumptions.

The table below shows cooling supply data by sector.

161 Table. Cooling UEC supply in Lithuania in 2020

Sector	Unit of measurement	Total	Decentralised supply	District supply
Households	GWh/year	25	25	-
Service sector	GWh/year	217	217	-
Industry sector	GWh/year	406	406	-
TOTAL		**648**	**648**	**-**

Source: authors of the Study

86 Using district cooling (DC) systems.

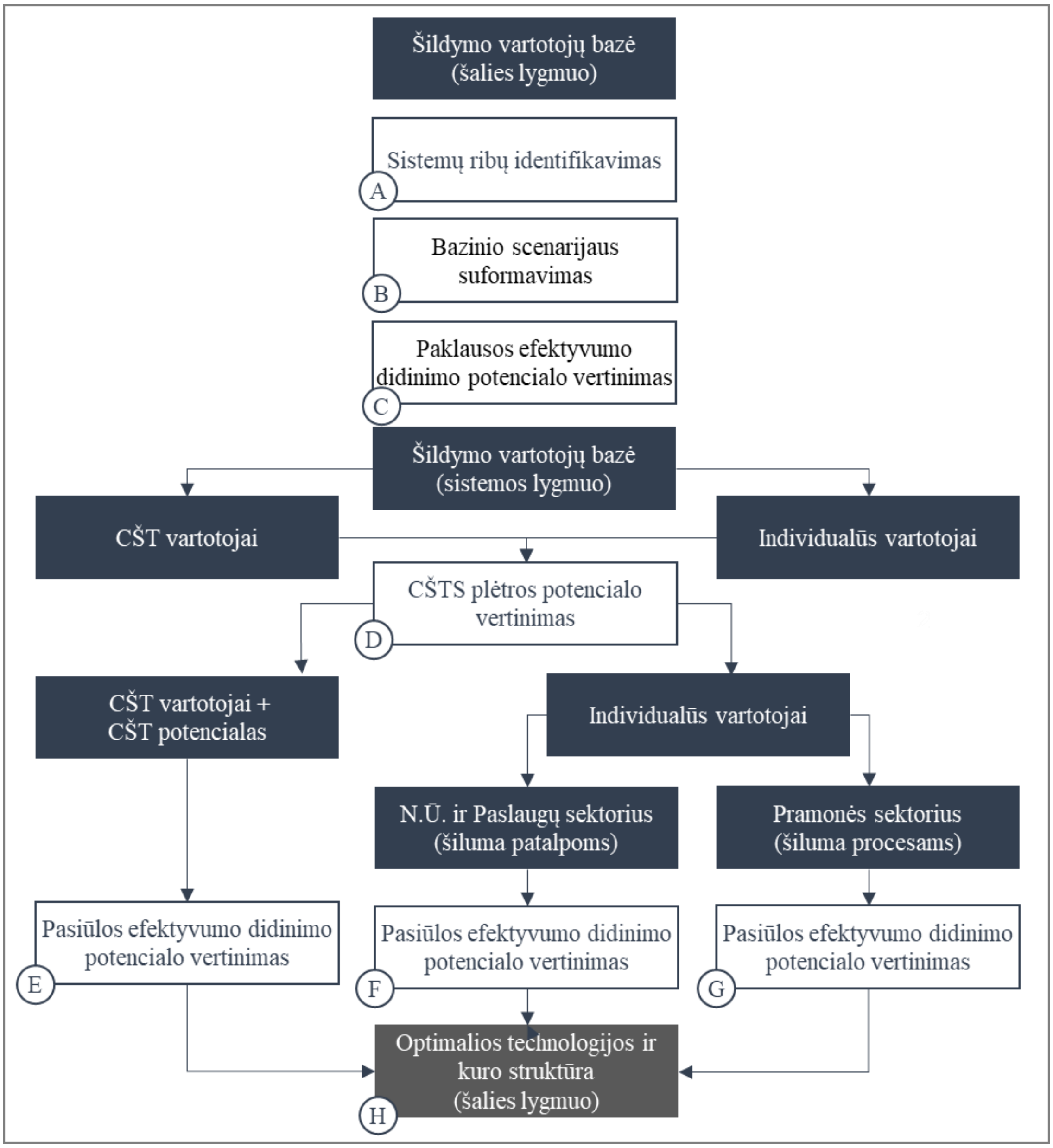
8. ASSESSMENT OF THE POTENTIAL FOR EFFICIENT HEATING

Recommendation 4.1.1. Member States may use various means to analyse the economic potential of heating and cooling technologies but the method must:

- apply throughout the territory of the country;
- be based on a cost-benefit analysis;
- apply when identifying alternative scenarios for more efficient and renewable heating and cooling technologies, including the development of baseline and alternative scenarios for national heating and cooling systems;
- be used to cover a wide range of technologies such as industrial waste heat and cooling, waste incineration, high-efficiency cogeneration, other renewable energy sources, heat pumps and heat loss reduction in existing centralised networks; and
- be applied taking into account socioeconomic and environmental factors.

A logic circuit of the cost-benefit model for assessing efficient heating options is shown in the figure below:

Figure 40. Assessment model for the potential for efficient heating



Source: authors of the Study

Stage A. Geographical and system delimitation

The first stage identifies geographical and system boundaries by defining groups of heat consumers and suppliers whose energy exchanges are or may be significant. An assessment of efficient heating options is carried out at the level of each system identified.

The results of Stage A are presented in Chapter 8.1.

Stage B. Drawing up the baseline scenario

In the second stage, a baseline scenario is drawn up:

- An analysis of strategic objectives for the entire energy sector and specifically for the heat sector is carried out. The analysis identifies (and, where appropriate, calculates) the heat sector target indicators and their target values for 2050 (Chapter 8.2.1);
- Scenarios for the development of the sectors concerned (Chapter 8.2.2) are evaluated;
- The parameters for the baseline scenario are set (Chapter 8.2.3).

Stage C. Assessment of the potential for enhancing consumption (demand) efficiency

At this stage, the potential for enhancing heating efficiency is assessed, distinguishing between:

- Heating energy used for heating buildings (households and the service sector);
- Heating energy used in production processes (the industry sector). The

results of Stage C are presented in Chapter 8.3.

Stage D. Assessment of the potential for development of district supply

The National Energy Independence Strategy (NEIS) identifies the existence of well-developed DH systems in all cities as one of the strong points of Lithuania's energy. The strategic objective set in the NEIS is to provide at least 90% of the buildings located in cities with heat from district heating systems by 2050.

Within its scope, this Study also estimates that in areas with sufficient heat intensity, an optimally functioning DH system is a more efficient alternative than the entirety of decentralised heating solutions operating in a similar area. This assessment is based on three main aspects[87]:

- Reduced demand for installed heat production capacity;
- Economies of scale when installing heat production equipment;
- Lower operating costs.

Therefore, within the assessment model for the potential for efficient heating:

- For consumers connected to the DH system, the alternative of disconnecting from the DH system is not assessed.
- For consumers not connected to the DH system, the potential for connection to the DH system is assessed as a first step – consumers for whom connection to the DH system is assessed as an economically viable alternative are considered potential consumers of the DH system within the scope of the Study. For these consumers, connecting to the DH system is seen as an optimal technological alternative. Accordingly, this consumer segment is included in the assessment of technological alternatives to individual heating sources.
- An assessment of the potential for enhancing efficiency of DH systems (**Stage E**) is carried out for the entire DH system consumer base (connected and potential DH system consumers).
- For consumers for whom connection to the DH system is not an economically viable alternative, the assessment of technological alternatives to individual heating sources (**Stages F-G)** is taken further.

The results of this stage are presented in Chapter 8.4.1.

87 For details see Annex 2.4.

Stage E. Assessment of the potential for enhancing efficiency of DH systems

At this stage, on the basis of a cost-benefit analysis, the potential for enhancing efficiency of each DH system is assessed, taking into account two main efficiency criteria: infrastructure efficiency and fuel mix sustainability.

The results of this stage are presented in Chapter 8.4.2.

Stage F. Assessment of the potential for enhancing efficiency of decentralised consumers (households and the service sector)

The demand for heat from decentralised customers can be met through various heating solutions. The range of the most cost-effective heating technologies is determined based on a cost-benefit analysis assessing:

- resources used as an energy source (e.g. waste heat, biomass or electricity);
- technology used to convert energy resources into energy for the benefit of consumers (e.g. heat recovery or heat pumps);

the results of the stage are presented in Chapter 8.5.1 (Households) and Chapter 8.5.2 (Service sector).

Stage G. Assessment of the potential for enhancing efficiency of decentralised consumers (the industry sector)

The industry sector differs from the service sector or households in that a major share of heat consumption is not related to the heating of buildings but to the need for heat for industrial processes. As part of industrial processes requires specific heat parameters (e.g. temperature, supply stability, time to meet demand, specific fuel demand) for the assessment of technological alternatives, it is necessary to take into account the relevant practical constraints. The range of the most cost-effective heating technologies is determined based on a cost-benefit analysis.

The results of Stage E are presented in Chapter 8.5.3.

Stage G. Summary of assessment results

A summary of the results of the assessment of efficient heating potential is given in Chapter 8.6.

8.1. GEOGRAPHICAL AND SYSTEM BOUNDARIES

Recommendation 4.1.1.

A geographically defined area must be fully representative of the area under assessment, i.e. the administrative territory of the Member State concerned. In an area delimited by geographical boundaries, Member States should identify synergies of heat and cooling demand with heat and cooling from waste and renewable energy sources.

System boundaries are a much more local concept. They must define a unit or a group of heat and cooling consumers and suppliers whose energy exchanges are or may be significant. The systems thus defined will be analysed within their boundaries (using CBA) in order to determine whether the implementation of a given heating and cooling supply option is cost-effective.

Geographical boundaries

Although the area defined within common geographical boundaries must correspond to the administrative territory of the Member State concerned, for large Member States it is recommended to subdivide their territory into regions (e.g., NUTS-1) to facilitate the drawing up of maps and plans and to take account of different climate zones.

The entire territory of the Republic of Lithuania (about 65,000 km^2) is classified as NUTS-1 level. The entire territory of Lithuania falls within the cool temperate climate zone. Although the climate impact of the Baltic Sea is felt in the western part of the country, energy consumption of buildings differs from the rest of the country by only 2%[88]. Since climate-related differences in energy consumption between the western part and the rest of the country are not significant, the entire territory of the Republic of Lithuania within the scope of this Study is considered as one geographical area.

System boundaries

System boundaries define a group of heat and cooling consumers and suppliers whose energy exchanges are or may be significant.

The analysis of heating demand (Chapter 4.1) has established that about 33% of the total area of the heating consumer base is connected to DH systems while the DH system segment itself is seen as a significant and constantly growing group of heat consumers and suppliers.

The development of DH systems at national level is planned and carried out at the level of individual municipalities, which, based on special plans of the heat sector, organise the supply of heat to heat consumers according to their needs for space heating, ventilation and hot water preparation.

Accordingly, within the scope of this Study, the territory of each municipality is treated as a separate system within the limits of which an assessment of efficient heating possibilities will be carried out. The table below provides data on systems and heat consumers within their boundaries[89].

88 Study on drawing up the long-term strategy for channelling investments to the renovation of the national stock of residential and commercial buildings owned both publicly and privately.

89 The determination of the number of heat consumers is detailed in Chapter 4.1.1.

162 Table. System boundaries

No	System	Number of consumers	No	System	Number of consumers
S1	Vilnius City Municipality	44.951	S31	Rokiškis District Municipality	7.563
S2	Kaunas City Municipality	35.268	S32	Anykščiai District Municipality	7.709
S3	Kaunas District Municipality	29.181	S33	Biržai District Municipality	7.450
54	Vilnius District Municipality	28.238	S34	Joniškis District Municipality	7.293
S5	Klaipėda District Municipality	19.261	S35	Švenčionys District Municipality	7.383
S6	Šiauliai District Municipality	13.205	S36	Šalčininkai District Municipality	7.296
S7	Šiauliai City Municipality	12.558	S37	Pasvalys District Municipality	7.100
S8	Panevėžys District Municipality	12.264	S38	Jurbarkas District Municipality	6.745
S9	Alytus District Municipality	10.971	S39	Varėna District Municipality	6.643
S10	Kėdainiai District Municipality	10.596	S40	Pakruojis District Municipality	6.311
S11	Mažeikiai District Municipality	10.394	S41	Lazdijai District Municipality	6.255
S12	Marijampolė Municipality	10.381	S42	Molėtai District Municipality	6.341
S13	Kretinga District Municipality	9.891	S43	Šilalė District Municipality	5.779
S14	Radviliškis District Municipality	10.010	S44	Skuodas District Municipality	5.210
S15	Vilkaviškis District Municipality	9.965	S45	Palanga City Municipality	4.925
S16	Panevėžys City Municipality	9.679	S46	Kupiškis District Municipality	5.041
S17	Tauragė District Municipality	9.573	S47	Alytus City Municipality	4.789
S18	Klaipėda City Municipality	9.215	S48	Ignalina District Municipality	4.926
S19	Raseiniai District Municipality	9.440	S49	Akmenė District Municipality	4.745
S20	Trakai District Municipality	9.395	S50	Zarasai District Municipality	4.797
S21	Telšiai District Municipality	9.349	S51	Elektrėnai Municipality	4.515
S22	Ukmergė District Municipality	8.781	S52	Širvintos District Municipality	4.498
S23	Utena District Municipality	8.494	S53	Druskininkai Municipality	3.986
S24	Prienai District Municipality	8.176	S54	Kalvarija Municipality	3.049
S25	Šilutė District Municipality	8.140	S55	Kazlų Rūda Municipality	2.811
S26	Jonava District Municipality	7.975	S56	Pagėgiai Municipality	2.033
S27	Kelmė District Municipality	8.146	S57	Rietavas Municipality	2.043
S28	Plungė District Municipality	7.925	S58	Visaginas Municipality	1.217
S29	Kaišiadorys District Municipality	7.895	S59	Birštonas Municipality	1.033
S30	Šakiai District Municipality	7.851	S60	Neringa Municipality	697
				Total	**547.351**

Source: authors of the Study

From the data provided, it can be noted that the number of consumers of top 10 municipalities is 40% of the total number of heat consumers.

8.2. DRAWING UP THE BASELINE SCENARIO

Recommendation 3.1. A specific heating and cooling policy must be consistent with the five dimensions of the Energy Union, in particular in the area of energy efficiency:

1. decarbonisation including reducing and absorbing GHG emissions through trajectories of the sector's share of renewable energy compared to FEC,
2. energy efficiency including the contribution to the EU 2030 energy efficiency target and the 2030, 2040 and 2050 indicative targets,
3. energy security including the diversification of sources of supply, increasing the resilience and flexibility of the energy system and reducing import dependency,
4. the internal energy market including improving interconnection, the transmission infrastructure, competitive prices and policies geared towards consumer participation and reducing energy poverty,
5. research, innovation and competitiveness including the contribution to private research and innovation and the use of clean technologies.

Member States must describe how energy efficiency and GHG emission reductions in the heating and cooling sector are consistent with those five aspects and quantify them where justified and possible.

8.2.1. Strategic objectives for the heating sector

The heat supply system is an integral part of the general energy sector, technically and energy flow-wise closely connected to the power grid, fuel supply and other systems. Accordingly, the objectives of the heating sector are examined in the context of the overall objectives of the energy sector at national level.

Objectives for the energy sector for 2050

The National Energy Independence Strategy (NEIS) identifies four priority strands for increasing energy independence:

1. Reducing the impact on climate change and ambient air pollution;
2. Reliability;
3. Competitiveness;
4. Participation of the country's business in energy progress.

The following four strands correlate directly with the main dimensions of the National Energy and Climate Action Plan (NECAP) set out in the Energy Union Governance Regulation:

1. Decarbonisation;
2. Energy efficiency;
3. Energy security;
4. The internal energy market;
5. Research, innovation and competitiveness.

Specifically for the heat sector, the NECAP provides that:

- the main goal of Lithuania in the heat sector is a consistent and balanced renovation (optimisation) of district heating systems, ensuring efficient heat consumption, reliable and economically attractive (competitive) supply and production, enabling the introduction of modern and environmentally friendly technologies using local and renewable energy sources, ensuring the flexibility of the system and a favourable environment for investment.

- In accordance with good practice in EU countries, Lithuania should promote the transition to fourth generation (4G) district heating by integrating solar power plants into district heating networks and promoting the use of excess and waste heat for heating buildings.
- By 2030, Lithuania will seek to ensure that district heating produced from renewable and local energy sources accounts for 90% of total district heating supply.

A summary of the main long-term objectives of the energy sector is presented in the table below.

163 Table. Lithuania's strategic documents regulating energy targets

Legislation	Objective/target assessment criterion	2030	2040	2050
National Energy Independence Strategy (NEIS)	Decrease in PEC and FEC intensity (compared to 2017)	1.5-fold	-	2.4-fold
	RES share in FEC	45%	-	80%
	Share of RES in individually heated households	80%	-	-
	Reduce GHG emissions as compared to 1990	40%	-	95%
National Energy and Climate Action Plan for 2021-2030 (NECAP)	GHG reduction targets as compared to 1990 levels	-40%	-	-
	Primary energy consumption (Mtoe) Final energy consumption (Mtoe) Final energy savings (TWh)	5,4 4,5 27	-	-
National Progress Plan for 2021-2030 (NPP)	Share of households that devote a significant part of their income to energy costs	8.6%	-	-
	Change in GHG emissions of installations with non-centralised heat generation or up to 20 MW capacity as compared to 2005 emissions, %	-15%	-	-
	Change in household PM2.5 emissions as compared to 2005 emissions	-36%	-	-
	Energy savings in the building stock as compared to 2020, GWh	10,366	-	-

Source: authors of the Study

To summarise the analysis of strategic objectives, the following key objectives for the energy sector for 2050 can be highlighted:

164 Table. Objectives for Lithuania's energy sector for 2050

Sector	Objective	Target indicators (2050)
Lithuania, total	Decrease in PEC and FEC intensity (compared to 2017)	2.4-fold
	GHG emissions reduction (compared to 1990)	95%
	RES share in FEC	80%

Source: authors of the Study

Strategic objectives for the heating sector for 2050

Some of the above objectives have not been broken down at sectoral level. Values[90] of the heat sector targets for 2050 distinguished (calculated) from the country's overall targets for the purposes of the Study are presented in the table below.

165 Table. Energy targets for the heat sector for 2050

Sector	Objective	Target indicators (2050)		
		Set	Calculated	
Heat sector	T1. Decrease in FEC intensity	-	2.4-fold	18.8 TWh
	T2. Decrease in PEC intensity	-	2.4-fold	20.6 TWh
	T3. GHG emissions	0%	0%	0 kt CO_2
	T4. RES share in the DH sector	100%	100%	100%
	T5. RES share in the decentralised sector	-	90%	90%

Source: authors of the Study

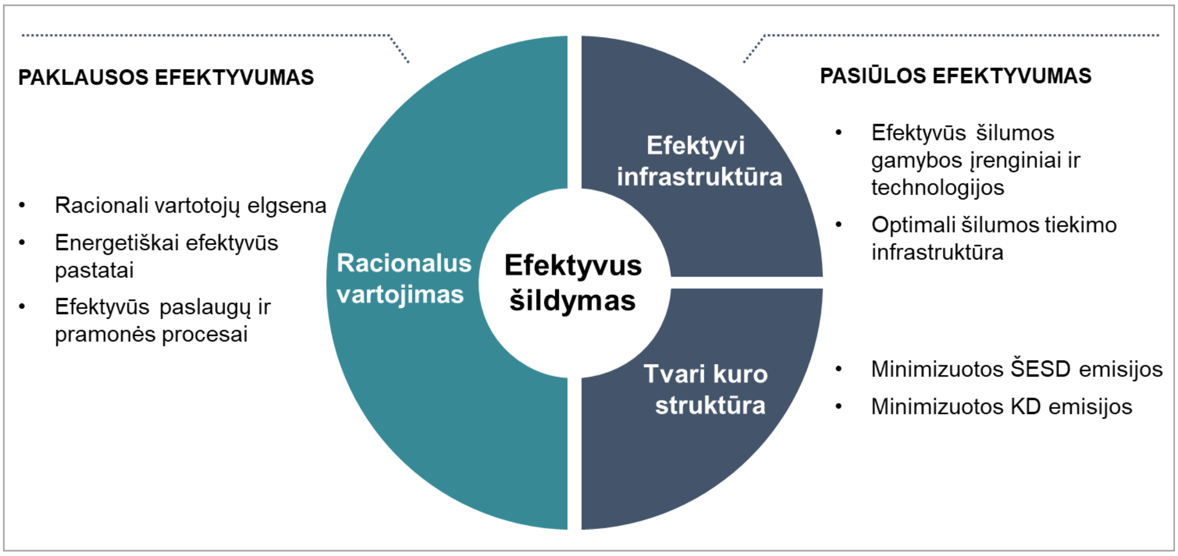
90 Detailed information is provided in Annex 2.3.

To sum up the objectives described above, three main expectations can be formulated for the area of heating energy efficiency:

1. Rational consumption: a key measure to reduce FEC intensity (Target T1).
2. Efficient infrastructure: a key measure to reduce PEC intensity (Target T2).
3. Sustainable fuel mix: a key measure to reduce GHG emissions (Targets T3 to T5).

In terms of the energy supply chain, these expectations are divided into two groups: enhancing the efficiency of heating demand and enhancing the efficiency of heating supply (see figure below).

41 Figure. Assessment model for the potential for efficient heating

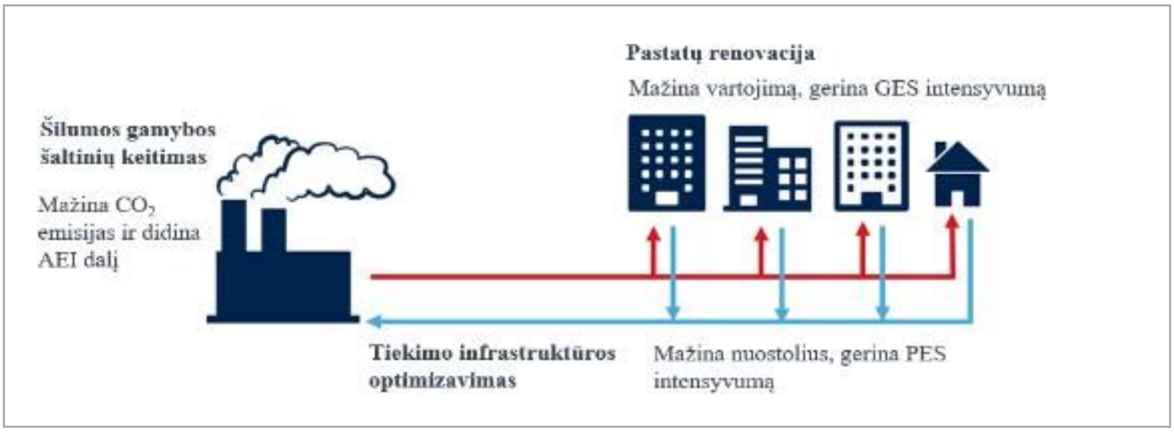


Source: authors of the Study

An illustrative example of enhancing the efficiency of heating demand and supply and a link with target indicators is shown in the figure below:

- Renovation of buildings connected to the DH system rationalises heat demand (reduces heat consumption) and has a significant positive effect on the decrease of FEC intensity.
- The optimisation of the supply infrastructure (pipelines) of DH systems reduces supply losses and has an additional positive effect on the decrease of PEC intensity.
- Replacement of heat sources boosts the share of RES in the fuel mix and reduces GHG emissions.

42 Figure. Illustration of efficiency solutions in the heating and cooling sector



Source: authors of the Study

It is important to note that the results of enhancing demand efficiency have a direct impact on supply indicators – successful renovation of buildings reduces heat FEC. With the decrease in FEC, the consumption of polluting fuels is also decreasing – the need for investment in switching sources of polluting fossil fuels is also decreasing accordingly.

The scope of the Study evaluated three main scenarios of the renovation process (for details see Chapter 5):

- Optimistic (LTRS100): by 2050, 100% of the surface area of buildings to be renovated under the LTRS will be renovated.
- Realistic (LTRS70): by 2050, 70% of the surface area of buildings to be renovated under the LTRS will be renovated.
- Conservative (LTRS40): by 2050, 40% of the surface area of buildings envisaged in the LTRS will be renovated.

The modelling results show that the 2050 targets to reduce the intensity of heat sector's FEC (and consequently PEC) by 2.4 times (T1-T2) could only be achieved in the optimistic renovation scenario.

However, in accordance with the precautionary principle and in order to be prepared for a less optimistic pace of renovation of the building stock, for the purposes of this Study the conservative (LTRS40) scenario is used as the main (baseline) scenario. In this scenario, efficiency enhancing tasks and policy measures are planned.

NB: The preparation for the conservative demand drop scenario allows for the development of the required policy measures to enhance supply efficiency, also in the event that the LTRS renovation targets are not fully met. In this way, even if the sectoral targets for reducing FEC and PEC intensity are not fully met, the GHG emission reduction targets would still be achievable.

Link between the heating sector and other energy sectors

The heat supply system is closely related to the power and fuel supply systems. A significant part of the fuel mix of the heating sector consists of natural gas (29% in 2020) and a steadily growing share of electricity (5% in 2020). Accordingly, it is important to take into account the most likely scenarios for the development of the gas and electricity sectors when defining tasks for enhancing the efficiency of the heating sector (for details see Chapter 8.2.2).

8.2.2. Development scenarios for the sectors concerned

As in the case of the heat sector, scenarios and objectives for the development of the gas and electricity sectors are set out in the National Energy Independence Strategy (NEIS) and the National Energy and Climate Action Plan (NECAP). The strategic documents below provide an overview of the planned development of the gas and electricity sectors and the potential impact on the heat sector.

Development of the electricity sector

The electricity sector is considered in strategic planning documents as one of the main factors ensuring the country's competitiveness and energy security. The NEIS has the following main objectives in the field of electricity:

- Synchronisation of the Lithuanian electricity system with the European electricity system and ensuring an advanced electricity market.
- Electricity generation in Lithuania.
- Ensuring the adequacy of Lithuania's capacities.
- Smart and sustainable development of the electricity system.

The indicators set for the achievement of these strategic objectives for 2050 are as follows:

- 100% of the country's total final electricity consumption will come from local electricity.
- 100% of electricity in the consumption balance will consist of electricity produced from RES.
- 50% of electricity consumers will use electricity produced from RES for their own needs.

To sum up, it can be concluded that the main goal for 2050 is for Lithuania to consume only domestic electricity produced from RES. In order to assess the probability of achieving this goal, an analysis of the current situation was carried out:

- According to NERC data[91], in 2020 5.1 TWh of electricity was produced in Lithuania, with the share of RES amounting to 48.6% (with an additional 14.9% generated at Kruonis PSP) and achieving the RES targets for 2020. At the same time, electricity imports were still 2.2 times higher (11.3 TWh).
- However, the development of electricity production from RES has been accelerating rapidly in recent years. According to the assessment of the Ministry of Energy[92], after the implementation of the measures currently planned, Lithuania would already secure electricity needs from local generation in 2030 where 93% would be produced using RES, i.e. the 2050 targets have been reached almost 20 years in advance. This trend is confirmed by a more than threefold increase in solar power generation capacity in 2020 (see Annex 2.13).
- A similar conclusion can be found in the Study on scenarios for the development of the Lithuanian electricity sector for 2020-2050[93] commissioned by Litgrid in 2020, which states that the above-mentioned 2050 targets can be achieved in full.

To sum up, within its scope the Study estimates that the 2050 strategic objective for the electricity sector will be achieved, i.e. 100% of electricity consumed in the heat sector will be produced in Lithuania using RES.

Development of the gas sector

The use of gas is envisaged in the NEIS as one of the factors ensuring the country's competitiveness and energy security. At the same time, the main objective of the NEIS in the field of natural gas is to ensure a technically sound and diversified supply of natural gas to domestic customers at cost-effective and competitive prices. The targets set for the achievement of this strategic objective are as follows:

- Adoption of a decision on ensuring long-term import of liquefied natural gas into Lithuania in 2018.
- Establishment of the regional natural gas market in 2020.
- The Lithuanian-Polish gas interconnection (GIPL) project was implemented in 2021.
- The development and maintenance of the natural gas network and infrastructure focus on the security and competitiveness of the system, the reduction of network maintenance costs and the more efficient use of existing infrastructure.
- Capacities of the liquefied natural gas cluster and the liquefied natural gas excellence centre are being fully developed in Lithuania.
- In accordance with the principles of sustainable development, a transition towards energy production from clean sources is ensured to not have negative consequences for the industry, business and households consuming natural gas.

The provisions of the NEIS have also been transposed to shorter-term strategic planning documents.

The Gas Transmission System Development Plan for 2022-2030[94] sets out the following principal objectives and results to be achieved.

91 NERC, 2020 Electricity and Gas Sector Overview.

92 https://enmin.lrv.lt/lt/naujienos/iki-2030-m-beveik-1-mlrd-euru-zaliosios-energetikos-pletrai-ir-energetiniam-efektyvumui.

93 https://www.litgrid.eu/index.php/naujienos/naujienos/-litgrid-atveria-scenarijus-2050-iesiems-zalioji-kryptis-lems-lietuvos-energetikos-ateiti/31371.

94 https://www.ambergrid.lt/uploads/structure/docs/217_ff384019c75d609a47f179ea253ee9bb.pdf.

166 Table. Objectives of the gas transmission system development plan for 2022-2030

Objective	Target outcome (2030)
Adapt the transmission network for green gas market access	Opportunities to transport hydrogen and gas mixture according to new national and cross-border standards
Implement the strategic projects envisaged in the NEIS in a timely manner and to the extent foreseen	NEIS/NECAP strategic projects completed in a timely manner and to the extent of 100% as foreseen
	Increased regional integration with neighbouring countries (LV, EE, FI, PL)
Ensure efficient management of the gas system by adapting it to RES integration	Amount of RES gas entering the gas system (with guarantees of origin) – 0.95 TWh
Significantly reduce the impact of activities on the environment	Reduced environmental impact of activities (CO2 , CH4 emissions, etc.) by two thirds as compared to the baseline year.
Enable gas sector transformation by integrating RES	Amount of RES gas entering the gas system (with guarantees of origin) – 0.95 TWh

Source: Amber Grid

In addition to these objectives, the following strands for long-term gas transmission system development are envisaged:

- A common Lithuanian-Latvian-Estonian-Finnish tariff zone in operation, extending it at a later stage through final agreements with Poland and creating joint integration solutions between all the countries.
- New products being transported: biomethane, a mixture of hydrogen and methane, and, in the longer term, pure hydrogen.
- Opportunities open for trade in guarantees of origin for biomethane between these countries. In the long term, a common European system of guarantees of origin for crude gases (including hydrogen) put into operation.

To sum up the objectives described above, it can be concluded that the main direction of the natural gas sector is to transform the natural gas system by adapting it to secure transportation of renewable energy sources (biomethane, methane-hydrogen mixture and pure hydrogen).

In order to assess which technologies and at what level to transform the gas system is optimal, studies and research are being carried out at global, EU and national level:

- The EU's hydrogen and non-fossil gas proposals[95] aim to facilitate the transition from fossil natural gas to renewable sources and low-carbon gases, in particular biomethane and hydrogen, as well as to enhance the resilience of the gas system. The proposal stipulates that national network development plans should be based on a common scenario for the electricity, gas and hydrogen sectors.
- The EU hydrogen strategy[96] states that hydrogen produced from renewable energy sources will be critical to achieving the EU's climate-neutral economy by 2050. The strategy also aims to integrate hydrogen by decarbonising industry, transport, energy production and buildings across Europe.

95 European Commission, 15 December 2021 proposals: Regulation and Directive on common rules for the internal markets in renewable and

natural gases and in hydrogen.

96 European Commission, 8 July 2020. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions on a hydrogen strategy for a climate-neutral Europe.

The Roadmap for the development of the gas transmission network published by the European Network of Transmission System Operators for Gas (ENTSOG) for 2050 provides the following principal alternatives to the development of the gas transmission system in each country and the directions for the development of the technologies necessary for their implementation.

167 Table. Roadmap for the development of the gas transmission network for 2050

Network configuration	Pros	Cons
1. Methane[97] combined with the CCUS technology[98]	There are no changes to the consumer infrastructure	Limited supply of biomethane. In absence of a sufficient supply of biomethane, technologies (CCUS) are needed for the capture of GHG emissions.
2. Methane and hydrogen mixing (in combination with the CCUS technology)	Requires few changes to the consumer infrastructure (with the part of H_2 in the mixture up to 10%)	Requires changes to the consumer infrastructure (depending on the part of H2 in mixture[99]): • <10% – basically no modifications necessary; • 10-20% – modifications required; • >20% – further research is needed.
3. Hydrogen	Fully eliminated GHG emissions (no capture technologies are necessary)	A fundamental transformation of the consumer and supply (gas network) infrastructure is needed

Source: ENTSOG

When analysing the information provided, one may note that:

- The first option requires the least changes in both consumer and gas supply infrastructure. However, there is still a strong probability that GHG emissions would not be reduced sufficiently and would need to be eliminated by other technologies.
- The third option would eliminate GHG emissions but requires the greatest technological breakthrough and fundamental transformation in both consumer and gas supply infrastructure.

For the purposes of the Study, taking into account the main electricity development scenario (100% domestic production from RES), it is projected that the gas sector configuration in 2050 will correspond to the interim gas sector development scenario, i.e. the gas system will be adapted to transport the renewable gas and hydrogen mixture.

Taking into account the above EU's and Lithuania's strategic objectives and the chosen scenario for the development of the electricity and gas network, within its scope this Study predicts that by 2050 the electricity and gas network will be fully developed. The structure of the gas mixture supplied through gas networks in Lithuania will consist of:

- 80% of renewable gas[100]. Of which: 50% – synthetic methane and hydrogen produced using RES electricity (Segment A in the figure below), 30% – indigenous or imported biomethane (Segment B in the figure below).
- 20% natural gas and liquefied natural gas (Segment C in the figure below).

The balance of natural gas in the overall gas structure is envisaged in order to prepare for a scenario where the quantities of local RES electricity (surplus economically justifiable for the production of hydrogen and hydrogen products) and biomethane are insufficient. With sufficient quantities of these resources, natural gas consumption could be reduced or completely eliminated (see alternative scenario AS-1).

97 Biomethane and synthetic methane.

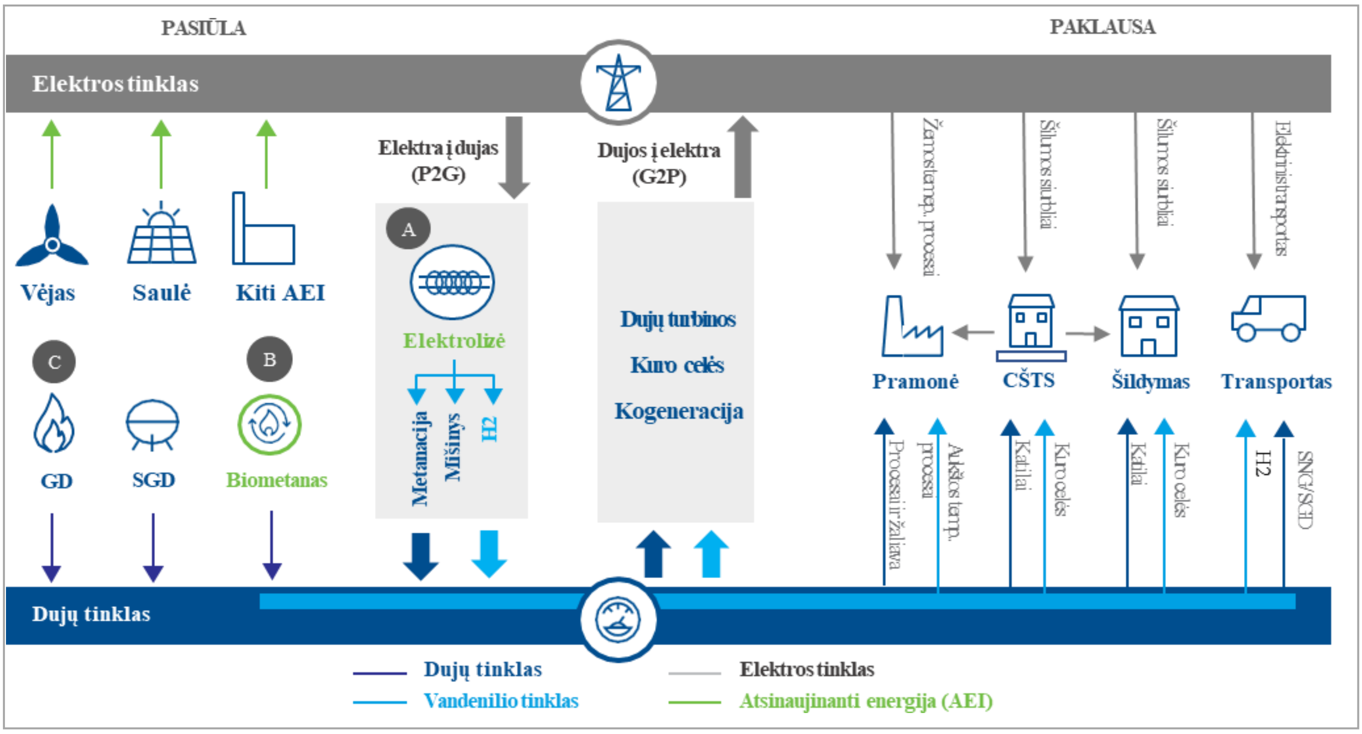
98 CCUS – Carbon Capture, Utilisation, and Storage.

99 In the industry sector the use of gas for production processes calls for a separate assessment.

100 Renewable gases are gases produced from biomass including biomethane, and hydrogen produced from renewable sources.

The figure below shows the principal circuit of a hybrid (electricity and gas) energy system.

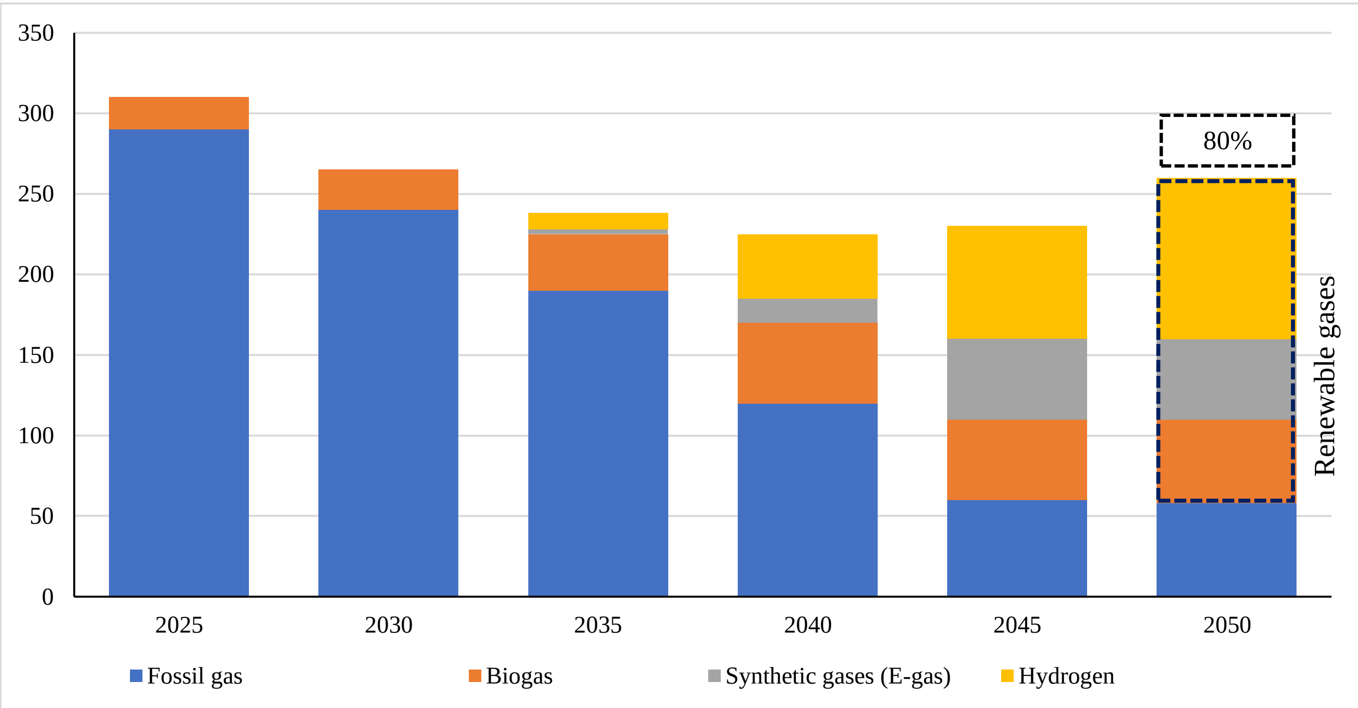
43 Figure. Hybrid electric-gas power system



Source: ENTSOG

The projected composition of the gas mixture for 2050 is in line with the proposals for hydrogen and non-fossil gas modelled in the EU for 2050. The EU's gaseous fuel structure, in which renewable gases also make up about 80% of the gas mixture (MIX scenario):

44 Figure. EU gaseous fuel consumption in 2050



Source: European Commission, PRIMES model, MIX scenario

8.2.3. Parameters of the baseline scenario

Essential parameters of the baseline scenario (2050):

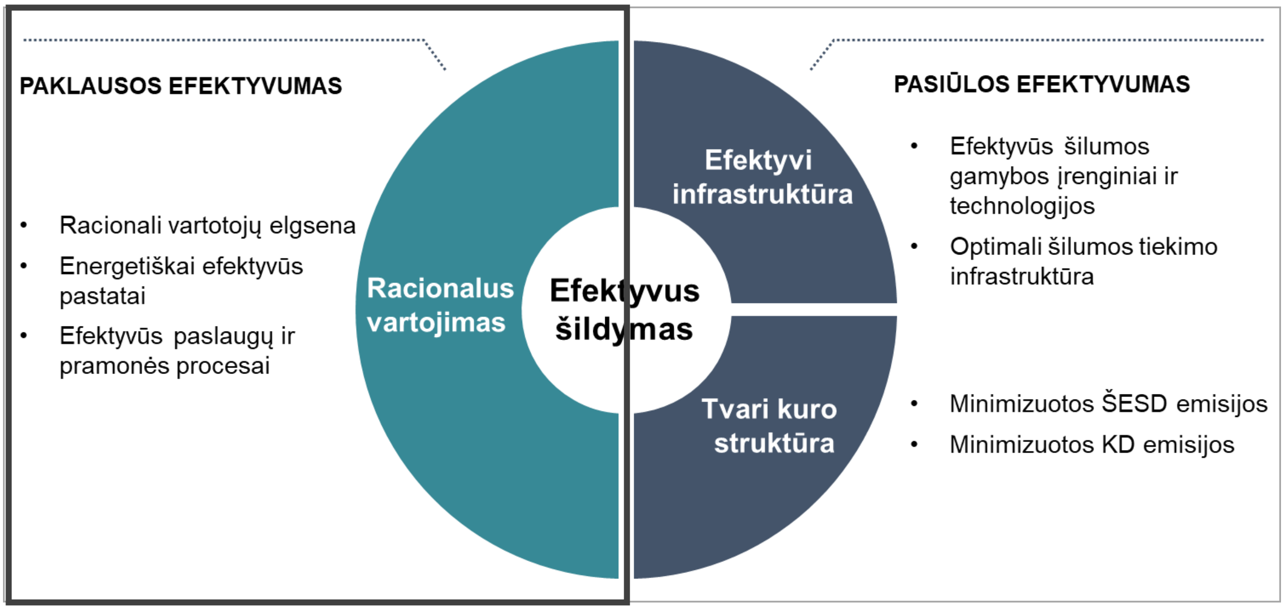
1. in 2050, 100% of electricity consumed in the heat sector is produced in Lithuania using RES.
2. Structure of the gas mixture supplied by gas networks:
   - 80% renewable gas. Of which: 50% – synthetic methane and hydrogen produced using RES electricity, 30% – indigenous or imported biomethane.
   - 20% natural gas and liquefied natural gas.
3. Generating heat from electricity is cheaper than from gas mixture.
4. Biofuels are considered to be climate-neutral.
5. 40% of the building surface area of buildings to be renovated under the LTRS is renovated.

8.3. POTENTIAL FOR ENHANCING CONSUMPTION/DEMAND EFFICIENCY

Enhancing efficiency of the heating sector comprises two principal strands: enhancing efficiency of heating consumption (demand) and enhancing efficiency of heating supply (for details see Chapter 8.2).

The first step in assessing the potential for enhancing efficiency of the heating sector is the analysis of the potential for enhancing heating efficiency.

45 Figure. Assessment model for the potential for efficient heating



Source: authors of the Study

To sum up the results of the analysis of current demand (for details see Chapter 4), it can be observed that:

- about two thirds of heating energy used for heating buildings (households and the service sector).
- about one third of heating energy used in production processes (the industry sector).

Thermal energy for heating buildings

When assessing the use of heating energy for the heating of buildings, it can be concluded that consumption efficiency is low since a major share of the building stock is of energy performance classes D and lower (see table below).

Table 168. Heating UEC in 2020, GWh

Sector	EPC						Total, GWh	Total, %
	<D	C	B	A	A+	A++		
1. Households	10.345	1.043	832	58	33	3	**12.314**	53%
2. Service sector	2.417	589	546	44	23	0	**3.619**	16%
3. Industry sector[101]	5.773	724	790	37	32	2	**7.359**	32%
Total	**18.535**	**2.357**	**2.168**	**139**	**87**	**6**	**23.292**	100%
Total, %	80%	10%	9%	1%	0%	0%	100%	

Source: authors of the Study

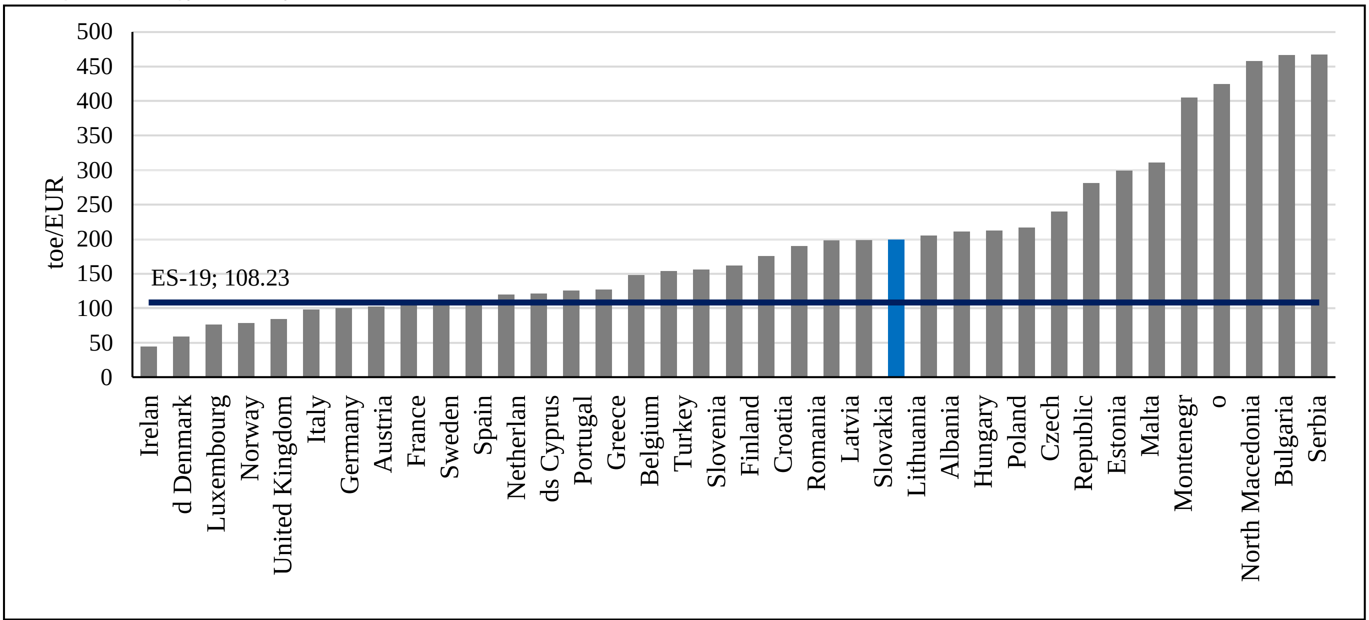
Accordingly, the baseline heating demand forecast scenario (LTRS40) foresees that 134,700 buildings (33.5 million m^2) will be renovated by 2050 (equivalent to 40% of the surface area of buildings to be renovated under the LTRS). As a result, thermal energy consumption (UEC) will decrease by 2.5 TWh.

101 In the industry sector most heat is used for processes rather than space heating.

Thermal energy for industrial processes

When assessing the use of heating energy for industrial processes in the industry sector, it is important to take into account the fact that energy intensity in Lithuania in 2020 was 84% higher than the EU-19 average.

46 Figure. Energy intensity in 2020, toe/EUR GDP



Source: Eurostat

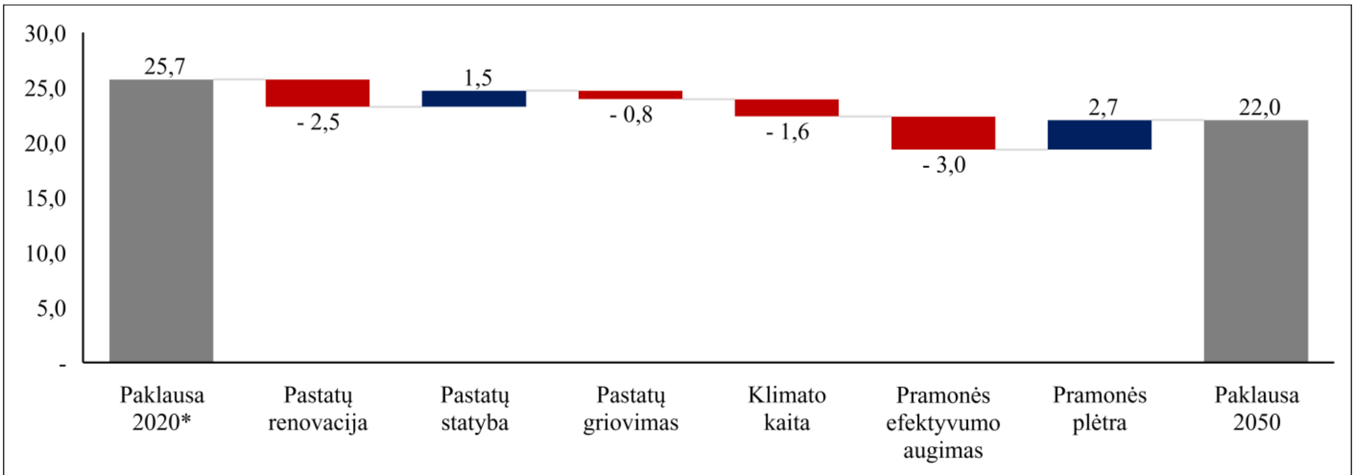
Accordingly, the baseline scenario of the heating demand forecast (LTRS40) foresees that the industry sector will seek to remain competitive at EU level and is estimated to reach the EU-19 average by 2050 through higher value-added production and energy efficiency enhancing measures. As a result, thermal energy consumption (UEC) will decrease by 3.0 TWh.

General thermal energy forecast

As described above, the greatest potential for enhancing energy efficiency is in building renovation and decreasing energy intensity in industry. At the same time, heat demand is affected by other factors – climate change, changes in the building stock, and industrial development. Detailed information on the heating demand forecast and its scenarios is provided in Chapter 5.

Changes in demand in the baseline scenario according to the factors influencing demand are presented in the figure below.

47 Figure. Evolution of heat demand UEC in 2020-2050, TWh



Source: authors of the Study

The main changes in demand by sectors analysed are presented in the table below.

Table 169. Evolution of heat demand UEC in 2020-2050, GWh

Sector	DH system	Households	Services	Industry	Total
Demand in 2020[102]	**9.480**	**7.948**	**2.053**	**6.257**	**25.739**
Renovation of buildings	-1,138	-1,109	-269	-	**-2,517**
Construction of buildings	+740	+570	+170	-	**+1,481**
Demolition of buildings	-346	-379	-61	-	**-786**
Climate change	-704	-701	-159	-	**-1,564**
Improving efficiency of the industry sector	-735	-	-	-2,281	**-3,016**
Industrial development	+1,108	-	-	+1,602	**+2,710**
Demand in 2050	**8.406**	**6.328**	**1.734**	**5.577**	**22.046**

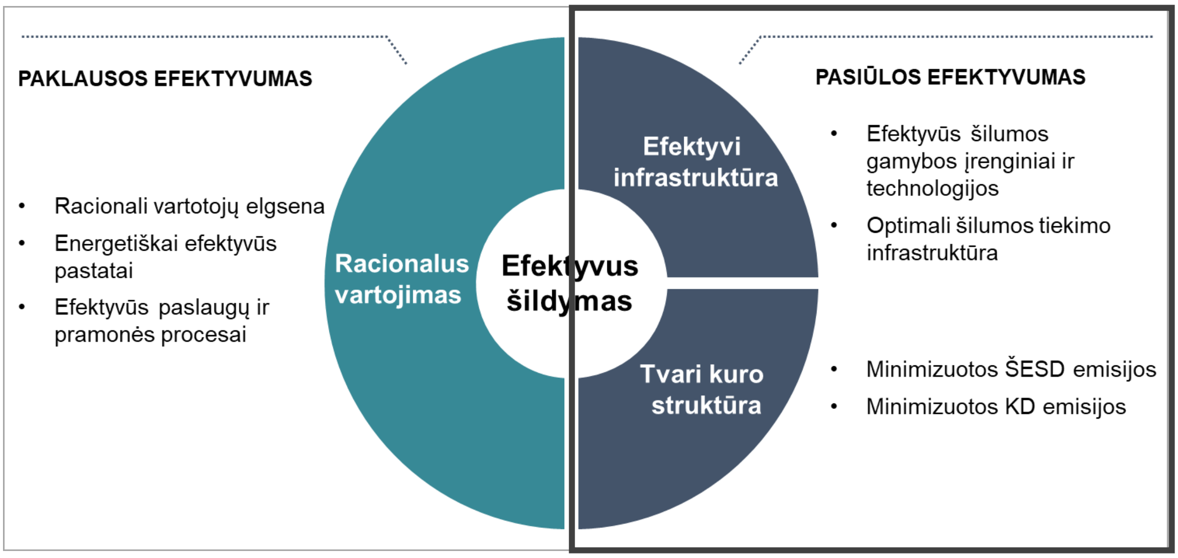
Source: authors of the Study

102 The reference year calculated as the average for 2018, 2019 and 2021.

8.4. POTENTIAL FOR ENHANCING DISTRICT SUPPLY EFFICIENCY

The first step in assessing the enhancing of heating supply efficiency is assessing the potential for enhancing district heating efficiency.

48 Figure. Assessment model for the potential for efficient heating



Source: authors of the Study

The National Energy Independence Strategy (NEIS) sets a strategic goal of supplying at least 90% of buildings in urban areas with heat from district heating systems (DH systems) by 2050.

Within its scope, the Study also estimates that in areas with sufficient heat intensity, an optimally functioning DH system is a more efficient alternative than the entirety of decentralised heating solutions operating in a similar area[103], i.e. it is a priority technological alternative.

This assessment is based on the possibility of DH systems using the same or even more advanced technologies with additional efficiency enhancing factors:

- Reduced demand for installed heat production capacity;
- Economies of scale when installing heat production equipment;
- Lower operating costs.

This assessment is also supported by an analysis of the competitiveness of district heating prices (Chapter 7.1.2). Accordingly, when assessing the possibilities for efficient heating, the alternative of disconnecting from the DH system is not assessed for consumers connected to the DH system.

The assessment of the potential for enhancing efficiency of district heating was carried out in two stages:

- **Stage1. Assessment of the development potential of DH systems**: for consumers not connected to DH systems, the potential for connection to DH systems is assessed. Consumers whose connection to DH systems is seen as an economically justified alternative are considered potential DH system consumers within the scope of the Study. For these consumers, the connection to the DH system is assessed as an optimal technological alternative (no assessment of other technological alternatives is carried out).
- **Stage 2. Assessment of the potential for enhancing efficiency of DH systems**: performed at the level of each individual system, for the entire DH system consumer base (connected and potential DH system consumers).

103 More information is provided in Annex 2.4.

8.4.1. Assessment of the development potential of district heating

The objective of this step is to assess, as a principle, the number of consumers (currently using individual heating sources) to be connected to a particular DH system. The assessment is carried out at the level of the individual system (municipality).

At national level, heat supply is a public service, the proper organisation of which is the responsibility of municipalities. The service is organised based on special municipal plans for the heat sector drawn up in accordance with the provisions of the Law on the Heat Sector, the Law on Territorial Planning and the Rules for the Preparation of Special Plans for the Heat Sector.

Special heat sector plans (SHSP) in the territory of a specific municipality implement the strategic objectives and progress objectives of the national energy policy as set out in the National Progress Plan and the heat sector measures planned in the national development programmes.

Accordingly, in order to identify, within the limits of a separate system, the consumers for whom the connection to DH systems is seen by the municipality itself (responsible for the organisation of the public service) as an economically justifiable alternative, we conducted a survey of municipalities asking them to submit the approved SHSPs in an electronic format that could be transferred to the heating and cooling map.

Of the 60 municipalities, two submitted approved SHSPs in the electronic format that could be transferred to the heating and cooling map: Klaipėda Region Municipality (S5) and Molėtai Region Municipality (S42). Nine references were also received to documents stored in the TPDRIS system as well as nine documents in non-editable format. The total number of users of these systems is <33% of the total number of heat consumers.

Moreover, based on the data of the report by the National Audit Office[104], only 10% of municipal special plans in the heat sector are updated in accordance with the procedure laid down by law[105]:

- 55% of municipalities (33 out of 60) updated their special heat plans more than 7 years ago.
- 25% of municipalities (16 out of 60) did that more than 10 years ago.
- 10% of municipalities (6 out of 60) have not made their special plans for the heat sector available to the public.

Accordingly, it is estimated that the potential for the development of DH systems based on special heat sector plans cannot be assessed within the scope of the Study.

In order to assess the development potential of DH systems as a principle and to illustrate the possibilities of using the heating and cooling map as a tool, we carried out an assessment of the development potential of DH systems based on an algorithm.

The logic of the algorithm is in line with the NERC principle that the development of DH is encouraged when the addition of new consumers does not increase the supply price component for existing consumers, i.e. the impact of the investments required for connection is offset by increased volumes of heating consumption due to the addition of new consumers.

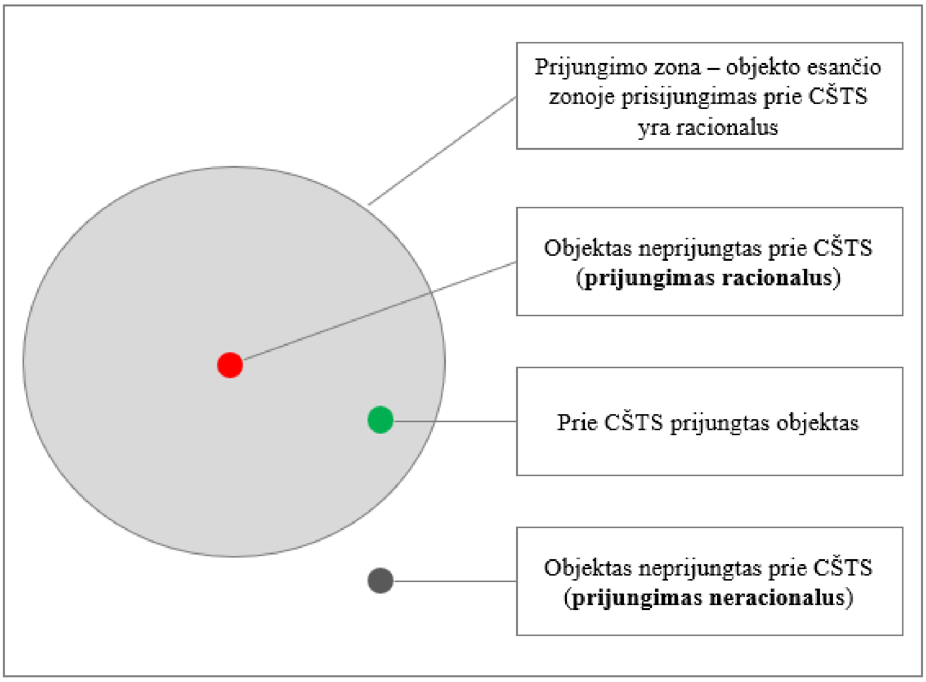
The essence of the algorithm is to calculate the maximum radius in which it would be rational to invest in the development of the supply infrastructure (pipeline), taking into account the need for heat for decentralised consumers. If there is an object connected to the DH system at that calculated distance (within the connection area), i.e. there is DH system infrastructure, it is considered reasonable to connect the decentralised consumer to the DH system.

104 National Audit Office, assessment report 'Assessment of district heating supply', 2022.

105 A heating sector business undertakes to update the SHSP at least every 7 years and not later than within 12 months from the entry into force of the NPP or its amendments.

The logic circuit of the algorithm is shown in the figure below.

49 Figure. Identification scheme for buildings to be connected to the DH system



Source: authors of the Study

The algorithm assesses the connection potential to the DH system in the following critical steps (for details see Annex 2.5):

a) Within the limits of a separate system, the maximum capacity of the need for heat for each decentralised consumer in households and the service sector[106] is calculated;

b) Taking into account the consumer's need for heat, the maximum possible distance ('the connection area') at which each decentralised consumer can be connected to the DH system without increasing the heat price for existing DH system consumers is calculated;

c) The results are evaluated:

- If the consumer 'x' in the connection area is a consumer connected to the DH system, the user 'x' is considered to have the potential to be connected to the DH system by attributing the attribute 'to be connected' to the consumer 'x'.
- Similarly, if the consumer 'x' in the connection area is a consumer to be connected to the DH system, the user 'x' is also considered to have the potential to be connected to the DH system by attributing the attribute
'to be connected' to the consumer 'x'.

Assessment results are shown in the table below.

106 The assessment of the potential for connecting industrial buildings to DH system cannot be carried out due to a lack of consumption data.

170 Table. Algorithm results, number of buildings

No	System	Number of consumers			Consumers to be connected, number	Consumers to be connected, %
		Total, number	incl. DH sys, No	incl. DH sys, %		
S1	Vilnius City Municipality	44.951	7.972	18%	941	2%
S2	Kaunas City Municipality	35.268	4.271	12%	815	2%
S3	Kaunas District Municipality	29.181	265	1%	31	0%
54	Vilnius District Municipality	28.238	-	-	7	0%
S5	Klaipėda District Municipality	19.261	-	-	-	-
S6	Šiauliai District Municipality	13.205	158	1%	16	0%
S7	Šiauliai City Municipality	12.558	1.243	10%	224	2%
S8	Panevėžys District Municipality	12.264	13	0%	3	0%
S9	Alytus District Municipality	10.971	-	-	-	-
S10	Kėdainiai District Municipality	10.596	356	3%	31	0%
S11	Mažeikiai District Municipality	10.394	-	-	-	-
S12	Marijampolė Municipality	10.381	660	6%	51	1%
S13	Kretinga District Municipality	9.891	-	-	8	0%
S14	Radviliškis District Municipality	10.010	-	-	-	-
S15	Vilkaviškis District Municipality	9.965	194	2%	36	0%
S16	Panevėžys City Municipality	9.679	1.425	15%	139	1%
S17	Tauragė District Municipality	9.573	350	4%	22	0%
S18	Klaipėda City Municipality	9.215	-	-	-	-
S19	Raseiniai District Municipality	9.440	248	3%	16	0%
S20	Trakai District Municipality	9.395	-	-	-	-
S21-60	Other mun.	232.915	6.029	3%	637	0.3%
	Total	**547.351**	**23.184**	**4.2%**	**2.977**	**0.5%**

Source: authors of the Study

171 Table. Algorithm results, heat demand, GWh

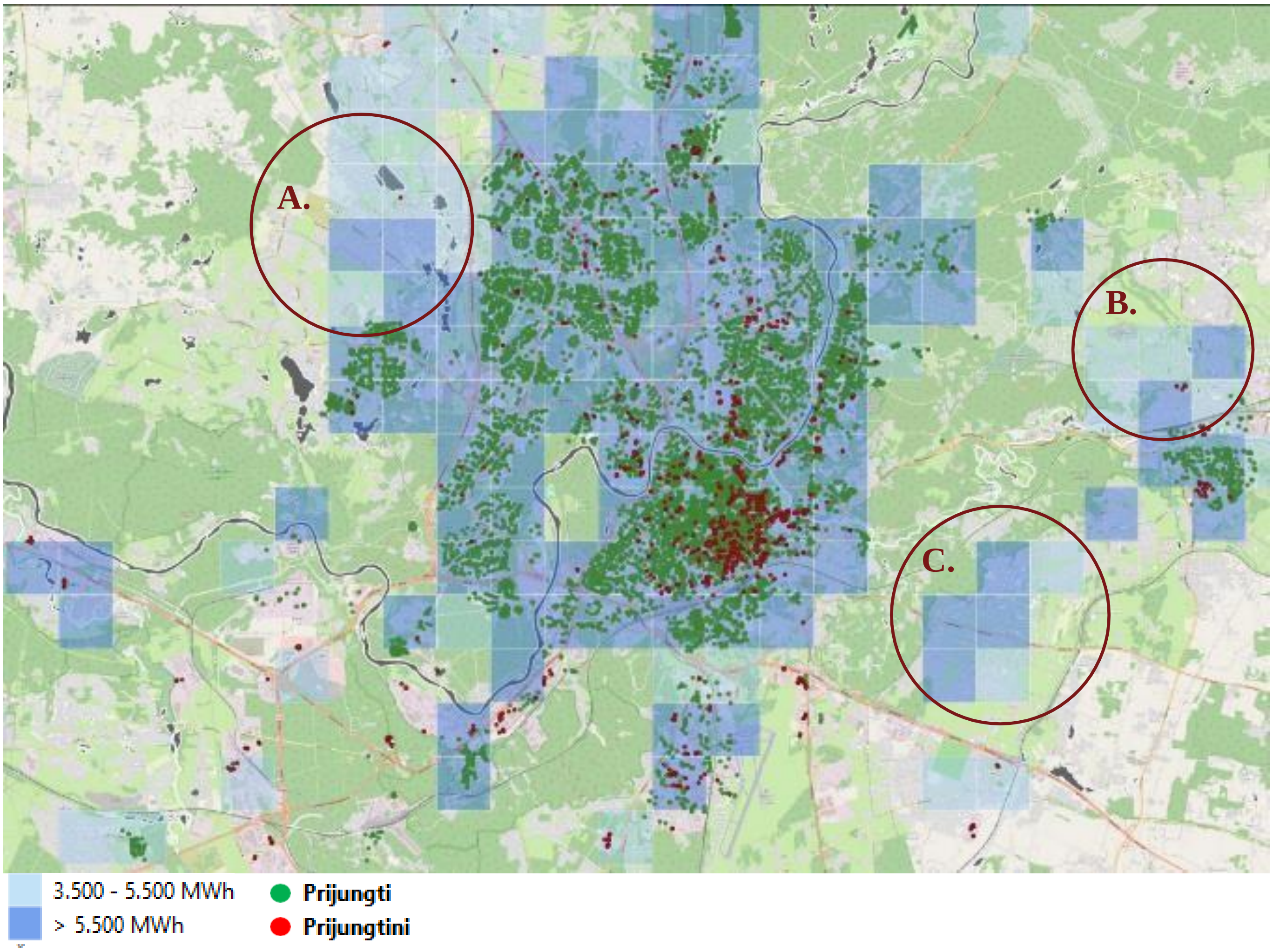
No	System	Heat consumption			Consumers to be connected, GWh	Consumers to be connected, %
		Total, GWh	incl. DH sys, GWh	incl. DH sys, %		
S1	Vilnius City Municipality	4.507	2.242	50%	114	3%
S2	Kaunas City Municipality	2.379	1.006	42%	143	6%
S3	Kaunas District Municipality	606	43	7%	5	1%
54	Vilnius District Municipality	578	-	-	-	-

S5	Klaipėda District Municipality	630	-	-	-	-
S6	Šiauliai District Municipality	269	28	10%	2	1%
S7	Šiauliai City Municipality	731	314	43%	29	4%
S8	Panevėžys District Municipality	226	-	-	-	-
S9	Alytus District Municipality	155	-	-	-	-
S10	Kėdainiai District Municipality	543	79	15%	4	1%
S11	Mažeikiai District Municipality	633	-	-	-	-
S12	Marijampolė Municipality	450	111	25%	7	2%
S13	Kretinga District Municipality	221	-	-	1	0%
S14	Radviliškis District Municipality	289	-	-	-	-
S15	Vilkaviškis District Municipality	183	25	14%	2	1%
S16	Panevėžys City Municipality	862	295	34%	14	2%
S17	Tauragė District Municipality	267	41	15%	3	1%
S18	Klaipėda City Municipality	1.414	-	-	-	-
S19	Raseiniai District Municipality	192	33	17%	2	1%
S20	Trakai District Municipality	185	-	-	-	-
S21-60	Other mun.	7.972	1.126	14%	90	1%
	Total	**23.292**	**5.343**	**23%**	**416**	**1.8%**

Source: authors of the Study

Below, for the illustration of the results, are the results of the assessment of the development potential of the two largest DH systems in the form of a map.

50 Figure. Map for assessing Vilnius DH system development potential

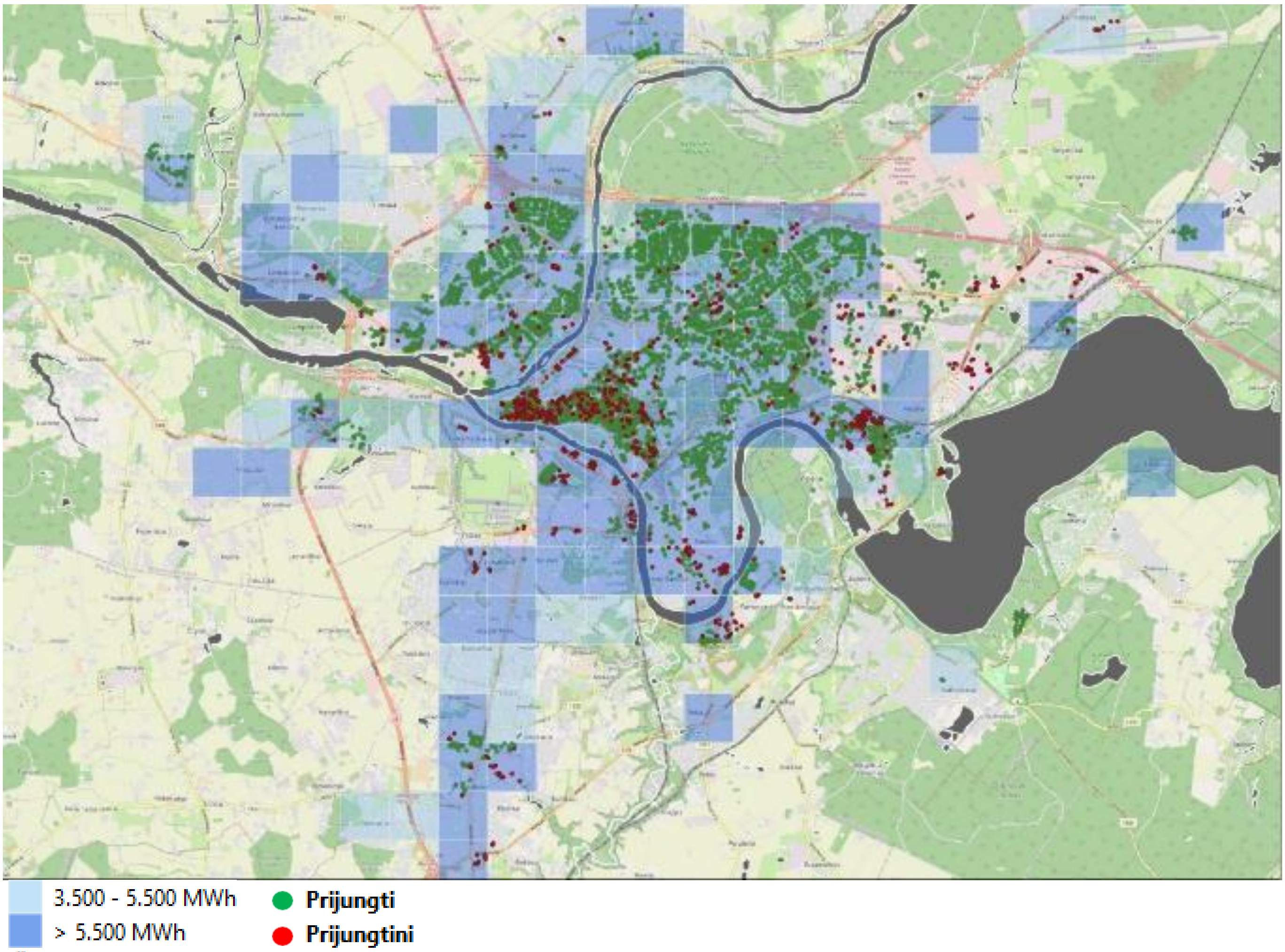


Source: authors of the Study

In analysing the data of Vilnius DH system, it can be noted that:

- A major part of DH system infrastructure is within the area of >5,500 MWh/km^2.
- Buildings marked in red are located in the DH system area and the algorithm identifies them as having the potential to be connected to the DH system. Note that a higher concentration of such buildings is in the area of the Old Town where the decision to choose decentralised heating can be influenced not only by the needs of consumers but also by technical restrictions.
- Three districts within the area of >5,500 MWh/km^2: A. Buivydiškės-Zujūnai, B. Kalnėnai-Pavilnys, C. Galgiai in the long run could be seen as directions for developing DH systems.

51 Figure. Map of Kaunas heat demand density



Source: authors of the Study

In analysing the data of Kaunas DH system, it can be noted that:

- A major part of DH system infrastructure is also within the area of >5500 MWh/km^2.
- Buildings marked in red are located in the DH system area and the algorithm identifies them as having the potential to be connected to the DH system. A higher number of such buildings is in the central area of the city where the decision to choose district heating can be influenced not only by the needs of consumers but also by heritage conservation restrictions.
- Several districts with a heat consumption density of >5,500 MWh/km^2 can be identified around Kaunas City and be seen as viable for the development of DH systems in the long term. For example, the settlement of Ramučiai and the nearby territory of a FEZ, the villages of Rokai and Ringaudai and other areas.
- Attractive for the expansion of the existing network is the left bank of the Nemunas near Aleksotas District.

Summary

To sum up the results of the assessment of the potential for the development of district heating, it can be concluded that with the assumptions used and the logic of the algorithm (seeking that the addition of new consumers would not cause an increase in the supply price component for existing consumers) the current potential for the development of DH systems is exploited efficiently – the potential of decentralised consumers to be connected does not exceed 2% of the total number of DH system consumers.

The Study further estimates that by 2050 no fewer consumers will be connected to the DH system than identified in the assessment of the potential for DH systems. Changes in demand by sectors analysed are presented in the table below.

172 Table. Evolution of heat demand UEC due to the DH system development in 2050, GWh

Sector	DH system	Households	Services	Industry	Total
Demand in 2050	**8.406**	**6.328**	**1.734**	**5.577**	**22.046**
Connection to the DH system	+650	-279	-371	-	-
Demand in 2050	**9.056**	**6.049**	**1.364**	**5.577**	**22.046**

Source: authors of the Study

It is important to note that the DH system demand covers various types of services according to applicable regulation and technical parameters. The table below provides a breakdown of actual demand in 2020 and projected demand for 2050.

173 Table. Thermal energy in 2020 and in 2050 (UEC), GWh

Type of service	2020		2050	
	UEC	SEC	UEC	SEC
Space heating (regulated by the NERC)	6.860	8.102	7.156	8.137
Space heating (regulated by municipalities)	200	211	207	218
Steam (non-regulated)	1.515	1.545	1.747	1.782
DH systems, total	**8.575**	**9.858**	**9.110**	**10.138**
Scope of the Study, total	8.519	9.792	9.056	10.076
Outside of the scope of the Study (other sectors)	56	66	54	61

Source: NERC, Statistics Lithuania, authors of the Study

NB:

- Based on the data collected, the heat demand of the industry sector at consumer level cannot be reliably estimated. Accordingly, only consumers in households and the service sectors were analysed in the assessment of the development potential of DH systems.
- Systems for which no consumption data have been provided by heat suppliers have not been evaluated (see Annex 3.2 for DH data).
- The evaluation was carried out in order to achieve the objectives set in the Study and to illustrate the possibilities of using a map as a tool – heat suppliers of a particular system are responsible for the final decisions on the development of DH system infrastructure.

8.4.2. Assessment of the potential for enhancing district heating efficiency

The assessment of the potential for enhancing DH system efficiency was carried out in line with the main strategic objectives of the heating sector (for details see Chapter 8.2):

- Reduce FEC and PEC intensity (T1-T2).
- Reduce GHG emissions (T3).
- Increase the share of RES in heat production (T4-T5).

The objective of this phase is to assess, as a principle, the performance targets to be achieved by a given DH system and to compare them with existing ones in order to identify potential efficiency gaps and the way to reduce them.

The potential for enhancing supply efficiency of the DH sector was assessed in the following steps:

a. Analysis of existing (2020) supply efficiency indicators.

b. Prioritising efficiency enhancement in line with the long-term objectives of the sector.

c. Formulation of efficiency enhancing tasks.

a. Analysis of existing (2020) supply efficiency indicators

Key performance indicators of district heating supply efficiency are summarised below.

174 Table. DH system supply efficiency indicators in 2020

Fuel	UEC	PEC	CO_2	PM	Emissions		SE damage (EUR million)		
	GWh	GWh	t/MWh	g/MWh	kt CO_2	tPM	CO_2	PM	Total
SFF	49	63	0,36	389	23	24	3	0,2	3
Natural gas	1.699	2.147	0,20	3	430	7	49	0,1	49
Total FF	**1.747**	**2.210**	**-**	**-**	**452**	**31**	**52**	**0,2**	**52**
RES gas	-	-	-	3	-	-	-	-	-
Biofuel	6.109	7.702	-	238	-	1.830	-	14	14
Waste	574	743	0,20	11	147	8	17	0,1	17
Waste heat	89	105	-	-	-	-	-	-	-
Solar collectors	-	-	-	-	-	-	-	-	-
Electricity (HP)	-	-	-	-	-	-	-	-	-
Ambience (HP)	-	-	-	-	-	-	-	-	-
Total RES	**6.772**	**8.550**	**-**	**-**	**147**	**1.838**	**17**	**15**	**31**
TOTAL	**8.519**	**10.760**	**-**	**-**	**599**	**1.869**	**68**	**15**	**83**

Source: authors of the Study

The evaluation of existing performance indicators shows that:

- District heating UEC is 21% lower than PEC. The main reason for this difference is mains heat loss.
- The socioeconomic DH system damage is caused by three sources of fuel: gas (CO_2 damage of EUR 49 million), waste (CO_2 damage of EUR 17 million) and biofuels (PM damage of EUR 14 million).

<u>Network losses</u>

In 2020, during heat transfer to consumers, about 1.2 TWh of heat was lost in the pipelines, which accounted for 15% of the quantity of heat supplied to DH networks. This indicator did not meet the goal of reducing heat losses to 14% as set out in the National Programme for the Development of the Heat Sector for 2015-2021[107] approved by the Government (equivalent to 1.12 TWh in 2020).

107 Approved by Resolution No 284 of the Government of the Republic of Lithuania of 18 March 2015.

In order to assess the potential for reducing supply losses, an overview of heat suppliers' losses in 2020 was drawn up and its results are presented in the table below.

175 Table. Losses on district heating network (heating of buildings), 2020

Heat suppliers	Heat quantity, GWh	Network losses, %	Comparative analysis
Group I	**5.294**	**14.6%**	
Alytaus šilumos tinklai, AB	173	16.7%	
Vilniaus šilumos tinklai, AB	2.316	13.6%	
Kauno energija, UAB	1.095	16.2%	
Klaipėdos energija	681	13.6%	
Šiaulių energija	348	17.4%	
Panevėžio energija	507	15.3%	
Visagino energija	174	10.5%	
Group II	**456**	**15.7%**	
Jonavos šilumos tinklai	105	15.0%	
Marijampolės šiluma (Litesko branch)	114	19.4%	
Mažeikių šilumos tinklai	115	15.3%	
Utenos šilumos tinklai	123	13.1%	
Group III	**366**	**18.1%**	
Elektrėnų komunalinis ūkis, UAB	60	18.0%	
Ukmergės šiluma	55	13.8%	
Druskininkų šiluma (Litesko branch)	86	18.9%	
Palangos šilumos tinklai	50	22.2%	
Šilutės šilumos tinklai	63	20.1%	
Tauragės šilumos tinklai	52	15.4%	
Group IV	**367**	**16.1%**	
Šalčininkų šilumos tinklai, UAB	25	27.1%	
Other Group IV suppliers (9 companies)	342	15.3%	
Group V	**376**	**15.4%**	
Kazlų Rūdos šilumos tinklai, UAB	13	21.0%	
Vilkaviškio šiluma, UAB	13	20.4%	
Other Group IV suppliers (17 companies)	350	15.0%	
Total, MW	**6.860**	**15.0%**	

Group average and below — Above group average

Source: NERC, authors of the Study

When analysing the above data on heat loss by individual heat suppliers, it can be observed that:

- Only 5 of 17 largest heat suppliers (Groups I-III) have technological losses below the target of 14%.
- Technological losses of 5 heat suppliers exceed 20%.
- Relative losses are the lowest among heat suppliers supplying the most heat (Group I).

When assessing the potential for loss reduction, it is important to take into account the current state of supply (pipeline) infrastructure – based on the LDHA data[109], by 2020 about 42% of the pipelines in Lithuania had been replaced by industrially pre-insulated tubeless pipes of a new type but the same share (about 41%) were old pipes installed in inaccessible problematicducts from the Soviet era (1960 -1990).

It can therefore be concluded that there is technical potential to reduce losses in non-modernised pipelines. However, when analysing the possibilities for realizing this potential, it is important to assess the fact that the cost of investments required

108 Thermal energy supplied by heat suppliers for heating as heat transfer agent (regulated activity) excluding heat supply to industry (in the form of steam).

109 LDHA, Overview of the Lithuanian district heating sector in 2020.

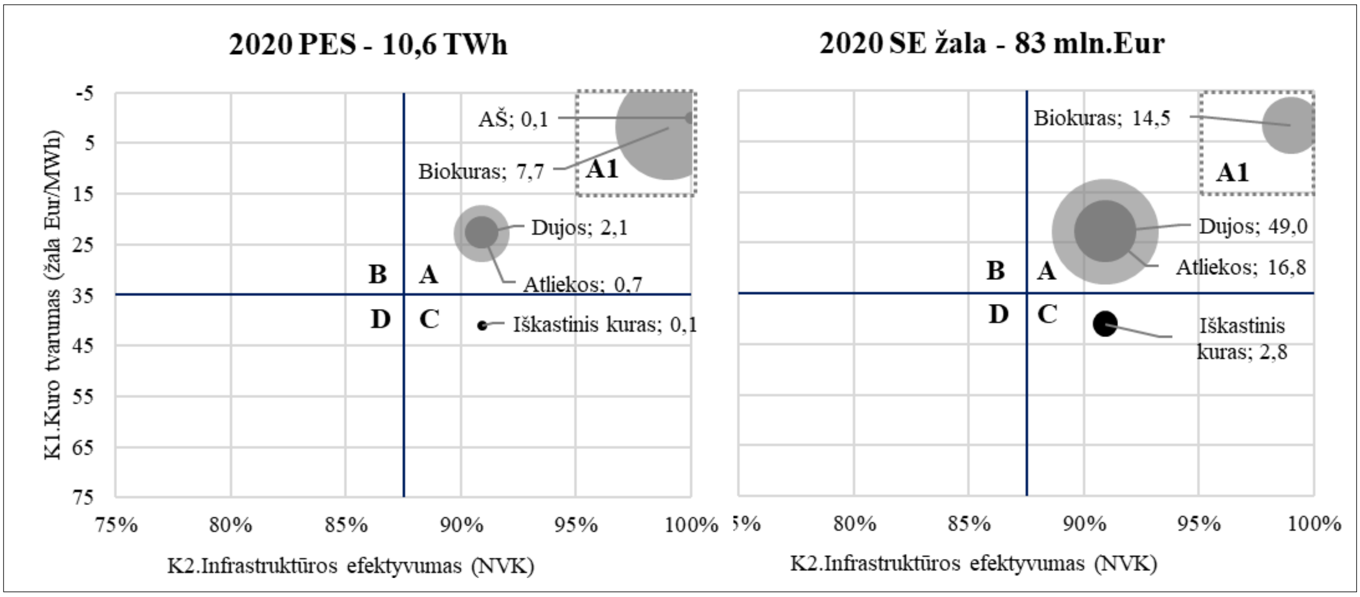
for upgrading the mains is increasing, so the cost of reducing losses may outweigh the benefit, i.e. there is no financial return on investment. Since the goal of reducing losses is not an end in itself, under such market conditions, heat suppliers do not initiate investment projects that are not financially viable (which would increase the price of heat to consumers) and only invest in pipelines in critical condition in order to ensure reliable heat supply.

For the purposes of this Study, it is estimated that, in the long run, the issue of losses will be addressed in order to achieve the goal of switching to fourth generation (4G) district heating by adapting DH networks to operate in low-temperature mode. It is estimated that if a significant part of district heating supply is transformed into the 4G network, actual losses in Lithuania's DH systems will not exceed 12% (the current level in the Scandinavian countries[110]).

Socioeconomic damage

The graph below reveals segments of district heating supply efficiency based on fuel source efficiency and relative pollution.

Figure 52. DH system supply efficiency indicators in 2020



Source: authors of the Study

Square C: relatively polluting fuel and high-efficiency supply. This segment generates the largest relative DH socioeconomic damage (EUR/MWh). The segment includes fossil fuel boilers (CO_2 and PM emissions damage: about 43 EUR/MWh).

Square A: relatively low-pollution fuel and high-efficiency supply. This segment generates low relative socioeconomic damage (EUR/MWh). The segment includes:

- natural gas boilers (CO_2 and PM emissions damage: about 23 EUR/MWh).
- Waste incineration plants (CO_2 and PM emissions damage: about 23 EUR/MWh).

Square A1: the highest efficiency supply generates the least socioeconomic damage. The segment includes biomass boilers (PM emissions damage: about 2 EUR/MWh).

110 Ibid.

The assessment of socioeconomic damage in absolute terms shows that:

- 60% of total estimated socioeconomic damage (about EUR 49 million) is caused by natural gas boilers. The source of damage is CO_2 emissions.
- 20% of total estimated socioeconomic damage (about EUR 17 million) is caused by waste incineration plants. The source of damage is CO_2 and PM emissions.
- 17% of total estimated socioeconomic damage (about EUR 14 million) is caused by heat sources burning biofuel. The source of damage is PM emissions.

b. Priorities for enhancing efficiency

Taking into account the results of the evaluation of the analysis of existing efficiency indicators and the long-term objectives set for the sector, the following priorities for enhancing district heating efficiency are defined:

1. Enhance efficiency of heat networks and reduce losses in networks.
2. Eliminate relatively polluting sources of production by encouraging migration from Squares C and A to Square A1.

These priorities are in line with the NECAP provision to promote the transition of district heating to fourth generation (4G) district heating by integrating solar power plants into district heating networks and promoting the use of excess and waste heat for heating buildings.

c. Efficiency enhancing tasks

Enhancing demand efficiency

The baseline scenario (LTRS40) estimates that by 2050 the demand for district heating will increase by 652 GWh (PEC):

- Due to the implementation of environmental factors and demand efficiency enhancing measures (Chapter 8.3), heat UEC demand of DH systems would decrease by about 0.1 GWh.
- The development of DH systems (Chapter 8.4.1) would boost UEC by about 0.7 TWh.

Enhancing supply efficiency

The tasks for enhancing supply efficiency described below are defined taking into account the projected change in demand and the established priorities for enhancing efficiency.

176 Table. Tasks for enhancing DH system efficiency, PEC, GWh

Fuel	PEC 2020	Demand (LTRS40)	Efficiency enhancing tasks (EET)				PEC 2050
			1	2	3	4	
SFF	63	3	-64	-	-1	-	-
Natural gas	2.147	130	-1,870	-392	-15	-	-
Total FF	**2.210**	**133**	**-1,934**	**-392**	**-17**	**-**	**-**
RES gas	-	-	-	-	-	-	-
Biofuel	7.702	482	-2,244	392	-116	-289	5.953
Waste	743	32	806	-	-27	-	1.554
Waste heat	105	5	126	-	-7	262	499
Solar collectors	-	-	285	-	-	-	285
Electricity (HP)	-	-	684	-	-	-	684
Ambience (HP)	-	-	1.784	-	-	-	1.784
Total RES	**8.550**	**519**	**1.474**	**392**	**-150**	**-26**	**10.759**
TOTAL	**10.760**	**652**	**-460**	**-**	**-167**	**-26**	**10.759**

Source: authors of the Study

EET 1. Enhancing heat supply efficiency (heat transfer agent) Objective: increase the share of RES in heat production.

In order to assess the efficiency enhancement potential of integrating RES production sources into DH systems, an optimal set of production technologies for each DH system supplying thermal energy for heating as heat transfer agent[111] has been simulated in the following sequence:

1. Based on actual and forecast heat demand (for details see Chapter 5.2), the need for heat in a particular DH system, the typical annual schedule of the need for heat and capacity of the need for heat were calculated.
2. Existing heat production installations and their capacities were identified (for details see Chapter 7.1.2).
3. Waste heat sources and their heat supply potential were identified (for details see section 7.1.4).
4. Characteristics of heat demand limiting the use of waste heat were identified.
5. Taking into account the results of the cost-benefit analysis of technological alternatives, the optimal distribution of sources in a given system and the required heat capacity to be developed were calculated for each specific technology.

The modelling results by individual system are presented in the table below[112]. Details of the assumptions and results used for the modelling are given in Annex 2.6.

177 Table. Results of the simulated optimisation of heat supply production (heating of buildings) (demand in 2050)

Heat suppliers	Waste heat	Solar collectors	Heat pumps	Waste	Biofuel	Total
Group I	**253**	**155**	**1.287**	**1.423**	**3.165**	**6.283**
Vilniaus šilumos tinklai	99	51	465	535	1.601	2.750
Kauno energija	44	37	225	456	538	1.300
Klaipėdos energija	63	13	107	432	191	806
Panevėžio energija	19	26	269	-	287	602
Šiaulių energija	14	-	80	-	319	413
Alytaus šilumos tinklai	7	10	76	-	112	206
Visagino energija	8	18	65	-	117	207
Group II	**19**	**26**	**222**	**-**	**273**	**541**
Marijampolės šiluma (Litesko)	5	6	56	-	67	135
Utenos šilumos tinklai	5	10	53	-	77	146
Mažeikių šilumos tinklai	5	5	57	-	69	136
Jonavos šilumos tinklai	4	5	55	-	60	125
Group III	**13**	**26**	**192**	**-**	**204**	**435**
Druskininkų šiluma (Litesko)	4	-	44	-	54	102
Šilutės šilumos tinklai	3	10	27	-	35	74
Elektrėnų komunalinis ūkis	3	14	22	-	33	72
Ukmergės šiluma	-	-	47	-	18	65
Tauragės šilumos tinklai	2	2	25	-	32	62
Palangos šilumos tinklai	2	-	26	-	32	60
Group IV	**-**	**24**	**266**	**-**	**144**	**434**
Group V	**2**	**7**	**335**	**-**	**100**	**445**
Total RES	**285**	**236**	**2.468**	**1.412**	**3.891**	**8.294**
Total PEC	**285**	**236**	**2.468**	**1.554**	**4.284**	**8.824**

Source: authors of the Study

111 Heat energy supply to the industry in the form of steam is assessed below, see EET 2.

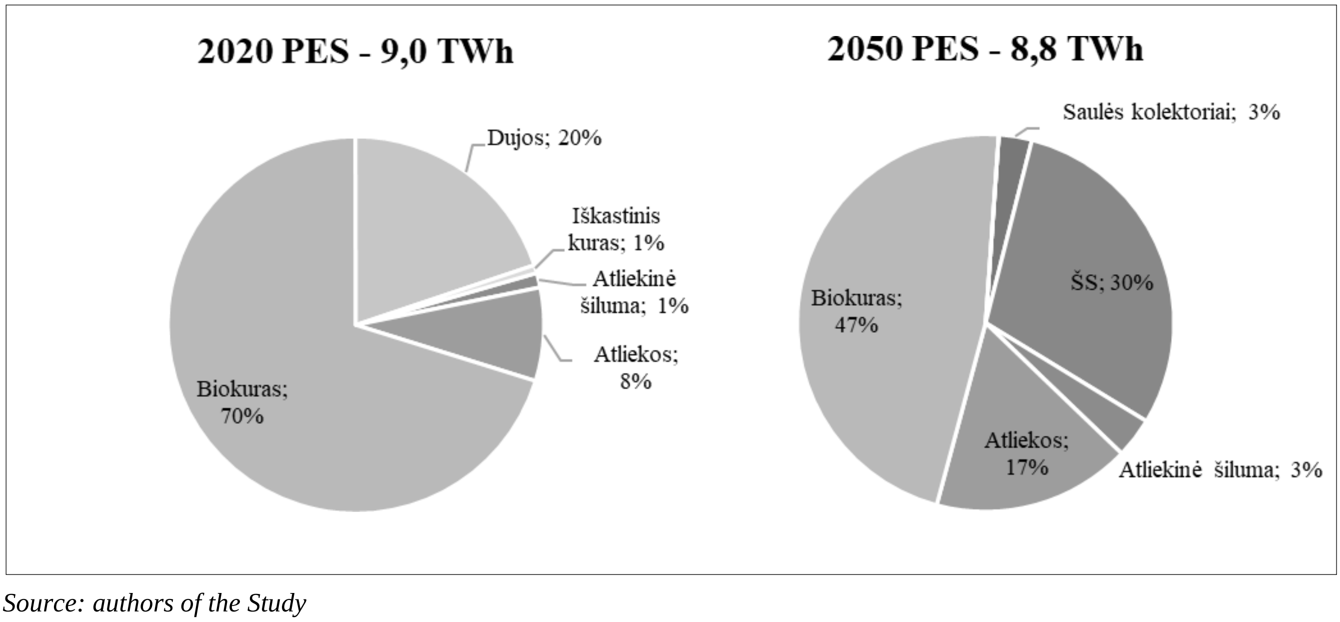
112 The figures in the column under EET-1 reflect the difference between the existing heat production structure and the simulated optimal set of technologies (to meet the forecast demand level for 2050).

To sum up the results of the simulation, the expected changes in the heat production structure are described below:

- **Waste heat.** It is estimated that full economic potential of waste heat identified in energy generating installations is integrated into existing DH systems (for details see Chapter 7.1.4). It is assumed that most of waste heat energy will be generated during the summer period when the need for cooling increases.
- **Solar collectors.** The technology of solar collectors and heat accumulators is assessed individually in all major DH systems, taking into account the specifics of each DH system and the possibility to allocate larger areas of land for the installation of collectors. The highest priority is attributed to heat production of waste heat and solar collectors.
- **Waste incineration.** It is estimated that the maximum capacity of Vilnius, Kaunas and Klaipėda waste incineration plants will be reached[113]. No additional waste incineration capacity is foreseen.
- **Heat pumps.** Heat pump modelling shows this technology to have one of the highest priorities for heat generation after waste incineration plants. In addition, it is assumed that heat pumps will be used in combination with Power to Heat solutions (‘P2H’), i.e. when the price of electricity in the network falls to the minimum values (in case of excess electricity production from RES), the heat generation priority of the heat pump becomes higher than heat production in waste incineration plants.
- **Biofuel.** It is estimated that biofuel production sources (both cogeneration and water heating boilers running on SM2-SM3 fuel) will form the remaining part of the supplied heat structure. It is also noted that it is planned to maintain biofuel capacities at a similar level throughout Lithuania, however, the installation of new capacities is not planned or is planned only in exceptional cases, i.e. in systems where currently a significant share of heat is produced from natural gas and the entire demand cannot be met by the heat pump technology.
- **Natural gas and fossil fuels.** After the simulation, there are still systems in which the use of natural gas or other fossil fuels will remain at the coldest outdoor air temperature during peak demand. Meeting demand at such peaks is assumed to be possible using biofuel pellet combustion technology. It is therefore considered that fossil fuels will no longer exist in DH systems. Biofuel pellets in the total biofuel balance will account for about 12% of all heat produced from biofuels, or about 6.3% of total demand for DH systems.

An illustration of the heat production structure potential identified during the simulation is shown in the figure below.

Figure 53. Assessment model for the potential for efficient heating



Source: authors of the Study

113 In 2020 Vilnius waste incineration plant was not yet operational while Kaunas waste incineration plant was operational for less than a full

year.

Simulation for major DH systems (the total of 35) was carried out individually for each system depending on its size, investments already made in the renovation of the heat sector and other specific characteristics of each system. Simulation of small DH systems (mainly systems with instantaneous demand not exceeding 1 MW) was carried out in a simplified manner, providing for the installation of fully automated boiler houses in the systems using a combination of technologies – heat pump – pellet boiler (production-wise giving priority to the HP technology). In this case, it is estimated that around 84% of the heat in such DH systems will be produced using HF technologies, while the rest will be produced using biofuel pellet-burning boilers.

In order to realise the full production potential of RES, the following policy measures will be implemented to integrate all identified types of heat production sources.

Policy measures to be implemented	PM3. Upgrade and/or replace worn-out biofuel boilers with other RES technologies PM4. Promote the use of biofuels for the production of heat energy in district heating systems PM5. Promote the use of RES for the production of DH heat energy PM6. New biofuel combustion plants in the district heating supply sector PM7. Promote the use in the district heating sector of waste heat generated in industry, in the waste sector or due to cooling energy PM30. Feasibility assessment of the development of district cooling networks

EET 2. Enhancing heat supply efficiency (steam)

Objective: to eliminate the consumption of natural gas in the production of district heat.

This efficiency enhancing task is already being implemented. Most of the steam supplied to industry for the technology is produced by biofuel boilers. Since, unlike heat energy for heating buildings, natural gas is not used to meet peak demand, it is projected that the rising price of emission allowances and the accompanying policy measures promoting decarbonisation will lead to a complete phasing-out of natural gas from district steam supply technology.

Policy measures to be implemented	PM1. Renovate and/or modernise the heat transmission network and its installations/elements PM2. Modernisation of the heat metering system

EET 3. Reduction of supply losses

Objective: to reduce the volume of fuel and primary energy.

This efficiency enhancing task is already being implemented – a significant part of heat networks has been renovated or replaced with EU support and losses have been reduced to 14-15%. In order to reduce losses further, measures to upgrade networks will be continued. In addition to encouraging more efficient use of heat by final consumers, heat metering will be modernised. It is projected that if the measures planned are implemented and a significant part of district heating supply is transformed into the 4G network, actual losses will not exceed the average level of the Scandinavian countries (12%).

Policy measures to be implemented	PM1. Renovate and/or modernise the heat transmission network and its installations/elements PM2. Modernisation of the heat metering system

EET 4. Use of waste heat capacity

Objective: to increase the use of waste heat in heat production.

After integrating the waste heat potential generated by heat production sources (see EET 1) the next step is to integrate waste heat generated by industrial and service users, i.e. outside the DH system. To this end, related technical and legal constraints should be eliminated.

It is projected that once the planned measures have been implemented, the full realisable waste heat potential identified would be connected to the DH system (Chapter 7.1.4, 7. Other sources of waste heat).

Policy measures to be implemented	PM7. Promote the use in the district heating sector of waste heat generated in industry, in the waste sector or due to cooling energy PM29. Changes in the regulatory environment for waste heat

These efficiency enhancing tasks would achieve the following decentralised heating supply indicators[114].

Table 178. Heat supply indicators in the DH sector in 2050

Fuel	UEC	PEC	GHG	PM	Emissions in 2050		Damage in 2050 (EUR million)		
	GWh	GWh	t/MWh	g/MWh	kt CO_2	tPM	CO_2	PM	Total
Fossil fuels	-	-	0,36	389	-	-	-	-	-
Natural gas	-	-	0,2	3	-	-	-	-	-
Total FF (2050)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
RES gas	-	-	-	3	-	-	-	-	-
Biofuel	4.945	5.953	-	238	-	1.417	-	11	11
Waste	1.245	1.554	0,2	11	308	17	35	0,1	35
Waste heat	439	499	-	-	-	-	-	-	-
Solar collectors	252	285	-	-	-	-	-	-	-
Electricity (HP)	603	684	-	-	-	-	-	-	-
Ambience (HP)	1.572	1.784	-	-	-	-	-	-	-
Total RES (2050)	**9.056**	**10.759**	**-**	**-**	**308**	**1.434**	**35**	**11**	**46**
TOTAL (2050)	**9.056**	**10.759**	**-**	**-**	**308**	**1.434**	**35**	**11**	**46**
Total RES (2020)	6.772	8.550	-	-	147	1.838	17	15	31
TOTAL (2020)	8.519	10.760	-	-	599	1.869	68	15	83

Source: authors of the Study

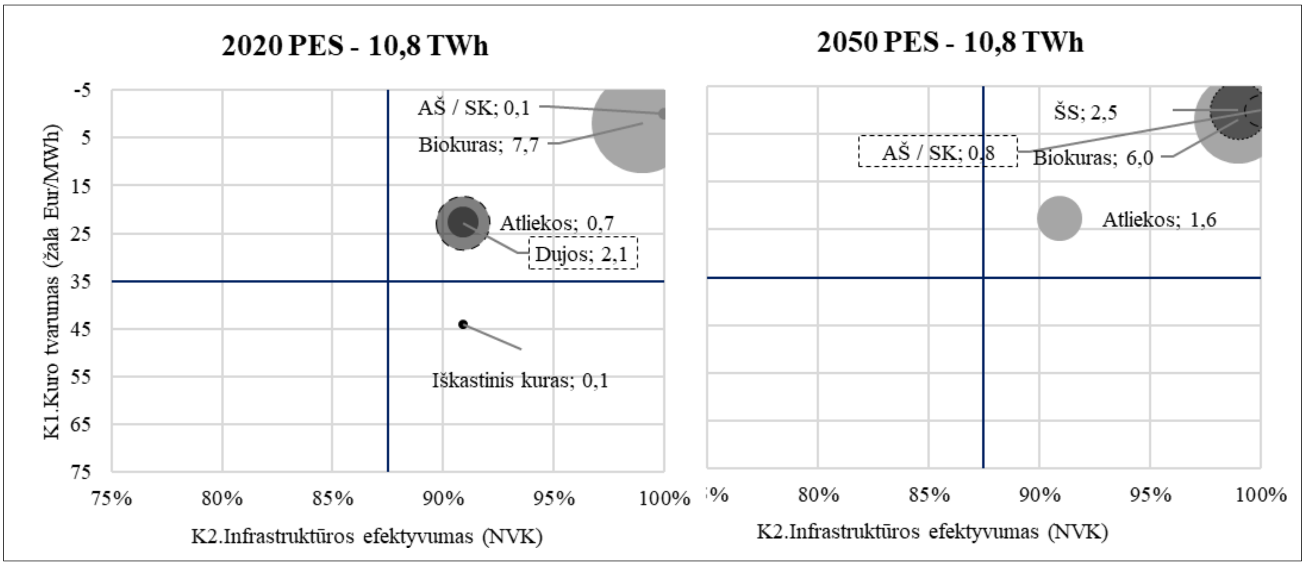
The evaluation of the indicators presented shows that, following the planned efficiency enhancing tasks for 2050:

- CO_2 emissions would decrease by 50% (from 599 to 308 ktCO_2).
- Total socioeconomic damage would be reduced by 44% (from EUR 83 million to EUR 46 million).

A graphical illustration of supply indicators for 2050 is shown in the figure below (based on supply efficiency criteria: K2. Infrastructure efficiency and K3. Fuel mix sustainability).

114 For comparability purposes, 2020 GHG and PM estimates are used.

54 Figure. DH system heat supply transformation in 2050



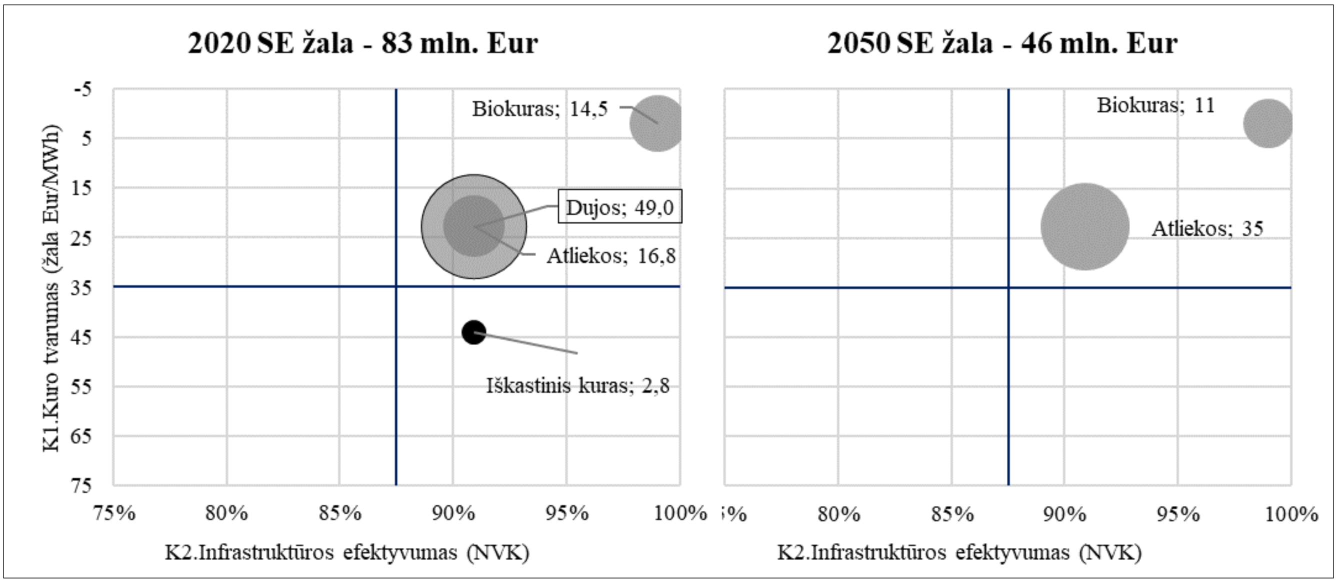
Source: authors of the Study

The implementation of the planned efficiency enhancing tasks for 2050 is estimated to lead to the following:

- Relatively polluting fuels and low efficiency supply would be eliminated (all supply would be in Square A).
- The supply of fossil fuels would be reduced to 0.8 TWh (non-renewable share of waste).

As a result, socioeconomic damage would decrease from EUR 83 million to EUR 46 million.

55 Figure. Change in the socioeconomic damage of the DH system heat supply



Source: authors of the Study

The remaining socioeconomic damage would be caused by two reasons: CO_2 emissions from waste incineration and PM emissions from biofuel boilers.

As for PM emissions from biofuel boilers, it is important to take into account that most of HP system production sources are currently equipped with advanced technologies for filtering and cleaning exhaust fumes (relative PM damage is four times lower than in the segment of households with an efficient biofuel boiler). Accordingly, the potential for reducing PM emissions could be associated with a further development of these technologies and the tightening of the regulatory environment.

When analysing the remaining CO_2 emissions from waste incineration plants, it is important to assess that in accordance with the European Waste Directive, energy recovery from waste is higher in the waste management hierarchy than landfilling, i.e. incineration of waste and related CO_2 emissions are a better alternative than landfilling of waste and related CO_2 emissions and other harmful substances, some of which enter the atmosphere and some of which remain in the ground but at higher concentrations and practically without the possibility of their being removed.

Accordingly, in the case of insufficient sorting of waste, it is reasonable to consider alternative measures for the management of CO_2 emissions. As CO_2 emissions are associated with three high-capacity waste incineration plants, it is estimated that the introduction of carbon capture, utilisation and storage (CCUS[115]) technologies can be considered as promising in an enabling regulatory and fiscal environment.

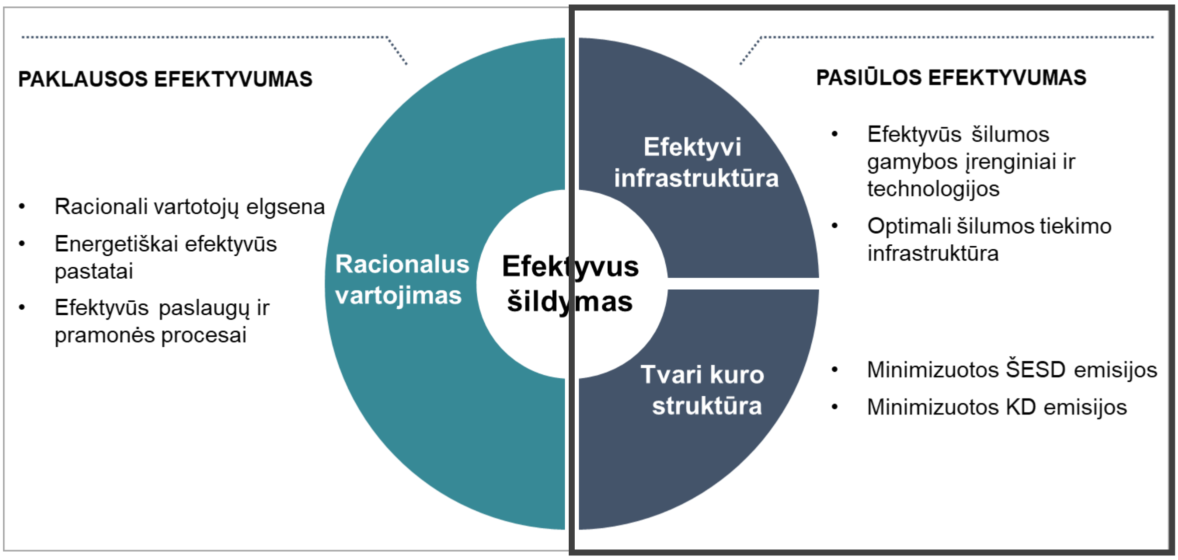
NB: The baseline scenario assumes that biofuels will continue to be treated as climate-neutral. With this approach changing and in absence of alternative, economically viable fuels, carbon dioxide capturing, utilisation and storage technologies could also be considered for this fuel segment.

115 *Carbon Capture, Utilisation and Storage.*

8.5. POTENTIAL FOR ENHANCING DECENTRALISED SUPPLY EFFICIENCY

The second step in assessing the enhancing of heating supply efficiency is assessing the potential for enhancing decentralised heating efficiency.

56 Figure. Assessment model for the potential for efficient heating



Source: authors of the Study

As in the district heating segment, the assessment of the potential for enhancing the efficiency of decentralised heating has been carried out in line with the main strategic objectives (Chapter 8.1):

- To reduce FEC and PEC intensity.
- To increase the share of RES in heat production.
- To reduce GHG emissions.

The evaluation was carried out at sectoral level:

- Households (Chapter 8.5.1).
- Service sector (Chapter 8.5.2).
- Industry sector (Chapter 8.5.3).

8.5.1. Households

The potential for enhancing supply efficiency of households was assessed in 3 stages:

a. Analysis of existing (2020) supply efficiency indicators.
b. Prioritising efficiency enhancement in line with the long-term objectives of the sector.
c. Formulation of efficiency enhancing tasks.

a. Analysis of existing (2020) supply efficiency indicators

Key performance indicators of decentralised household supply efficiency are summarised below.

Table 179. Decentralised heat supply indicators in households in 2020

Fuel	UEC	FEC	GHG	PM	Emissions		SE damage (EUR million)		
	GWh	GWh	t/MWh	g/MWh	kt CO_2	tPM	CO_2	PM	Total
Coal	239	287	0,38	1.433	109	412	12	7	19
Solid fuel	99	119	0,36	1.433	43	170	5	3	8
Petroleum products	570	627	0,28	7	175	4	20	0,1	20
Natural gas	1.420	1.562	0,20	4	311	7	35	0,1	36
Total FF	**2.328**	**2.595**	**-**	**-**	**638**	**593**	**73**	**10**	**83**
RES gas	-	-	-	-	-	-	-	-	-
Biofuel	2.232	2.455	-	504	-	1.237	-	21	21
Biofuel (n.k.)	2.232	2.902	-	2.664	-	7.730	-	129	129
Waste	-	-	-	-	-	-	-	-	-
Electricity (HP)	235	235	-	-	-	-	-	-	-
Ambience (HP)	399	399	-	-	-	-	-	-	-
Total RES	**5.097**	**5.990**	**-**	**-**	**-**	**8.967**	**-**	**150**	**150**
TOTAL	**7.425**	**8.585**	**-**	**-**	**638**	**9.560**	**73**	**160**	**232**

Source: authors of the Study

The evaluation of existing performance indicators shows that:

- UEC is 14% lower than FEC, largely due to inefficient biofuel boilers[116], accounting for 34% of total decentralised household FEC.
- 65% (EUR 150 million) of total estimated socioeconomic damage is caused by particulate emissions from biomass boilers. More than 4/5 of this amount consists of PM emissions from inefficient boilers.
- 15% (EUR 36 million) of total estimated socioeconomic damage is caused by CO_2 emissions from natural gas boilers.
- The remaining 20% (EUR 47 million) of socioeconomic damage is caused by CO_2 and PM emissions from other fossil fuels.

NB:

- PM emissions from biofuels used in the household sector (g/MWh) are up to 10 times higher than in the DH sector. The difference is due to a more efficient biofuel combustion process and the filters used in the DH sector. It is also estimated that due to the differences in stack heights, the damage from PM emissions in households is more than twice as great.
- Within the scope of the study, the estimate of particulate emissions damage for biofuel boilers applies regardless of the urban area of the boiler concerned. It is likely that the socioeconomic damage caused by particulate matter in the area of a higher population density (urban) is greater than in the countryside.
- Similarly, estimating the amount of socioeconomic damage, a significant assumption is made that about 50% of biofuel boilers are inefficient. More data on the physical location and actual efficiency of decentralised production sources could lead to a recalculation of the level of socioeconomic damage.

116 Functional operation factor (FOF) of approximately 70%.

The graph below reveals segments of household supply efficiency based on fuel source efficiency and relative pollution.

Square D: relatively most polluting fuel and low-efficiency supply. This segment generates the highest relative socioeconomic damage (EUR/MWh). The segment includes:

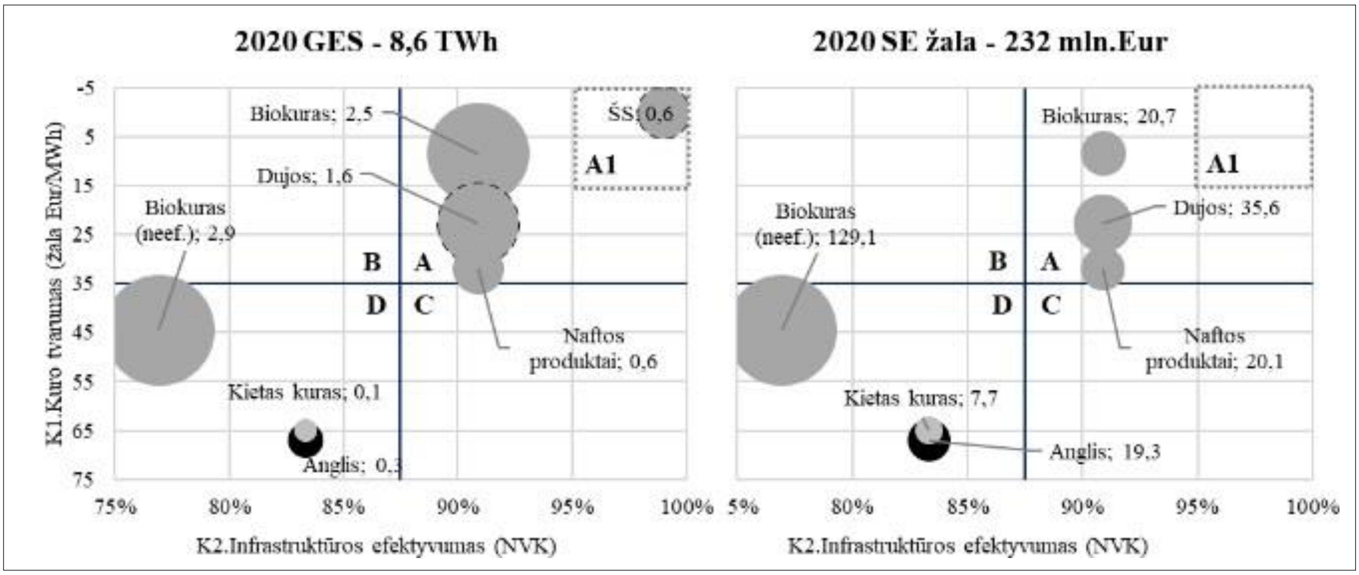
- Inefficient biomass boilers (PM emissions damage: about 46 EUR/MWh).
- Coal and solid fuel boilers (CO_2 and PM emissions damage: about 66 EUR/MWh).

Square A: relatively low-pollution fuel and high-efficiency supply. This segment generates the lowest relative socioeconomic damage (EUR/MWh). The segment includes:

- petroleum product boilers (CO_2 and PM emissions damage: about 32 EUR/MWh).
- natural gas boilers (CO_2 and PM emissions damage: about 23 EUR/MWh).
- Efficient biomass boilers (PM emissions damage: about 8 EUR/MWh).

Square A1: highest-efficiency supply causing no socioeconomic damage in the form of CO_2 and PM emissions. The segment includes heat pumps (socioeconomic damage: 0 EUR/MWh[117]).

Figure 57. Household heat supply indicators (decentralised supply) in 2020



Source: authors of the Study

b. Priorities for enhancing efficiency

Taking into account the results of the evaluation of the analysis of existing efficiency indicators and the long-term objectives set for the sector, the following priorities for enhancing household efficiency are defined:

1. Transform the supply of relatively low-efficiency and high-emission fuels by encouraging the migration of production sources from Square D to Square A (**high priority)**.
2. Promote the transformation of high-efficiency and medium-emission fuel supply for production sources to migrate from Square A to Square A1 (**medium priority)**.

117 Green electricity scenario (see Chapter 8.2.2).

c. Efficiency enhancing tasks

Enhancing demand efficiency

The baseline scenario (LTRS40) estimates that by 2050, taking into account the change in demand due to environmental factors, the development of DH systems and the implementation of demand efficiency enhancement measures (Chapter 8.3), UEC demand for decentralised heat in households would decrease by about 1.4 TWh to 6 TWh per year.

Enhancing supply efficiency

Taking into account the forecasted change in demand, the identified efficiency enhancement priorities and CBA results of technological alternatives (Annex 2.12), the tasks for enhancing supply efficiency described below are formulated.

180 Table. Tasks on enhancing decentralised heat supply efficiency in households

Fuel	UEC 2020	LTRS 40	Efficiency enhancing tasks (EET)					UEC 2050
			1	2	3	4	5	
Coal	239	-44	-195	-	-	-	-	-
Solid fuel	99	-18	-81	-	-	-	-	-
Petroleum products	570	-106	-	-464	-	-	-	-
Natural gas	1.420	-263	-	-	-1,157	-	-	-
Total FF	**2.328**	**-431**	**-276**	**-464**	**-1,157**	**-**	**-**	**-**
RES gas	-	-	-	-	-	-	-	-
Biofuel	2.232	-414	+138	+93	+116	+909	-909	2.165
Biofuel (n.k.)	2.232	-414	-	-	-	-1,818	-	-
Waste	-	-	-	-	-	-	-	-
Electricity (HP)	235	-43	+51	+138	+386	+337	+337	1.439
Ambience (HP)	399	-74	+87	+233	+655	+572	+572	2.446
Total RES	**5.097**	**-945**	**+276**	**+464**	**+1,157**	**-**	**-**	**6.049**
TOTAL (UEC)	**7.425**	**-1,376**	**-**	**-**	**-**	**-**	**-**	**6.049**
TOTAL (PEC)	**8.585**	**-1,591**	**-41**	**-37**	**-104**	**-455**	**-91**	**6.265**

Source: authors of the Study

EET 1-2. Phasing out fossil fuels

Objective: to replace production sources of fossil fuels (coal, other solid fuels and petroleum products) with RES production sources.

Taking into account that consumers heating with solid fossil fuels (SFF) are sensitive to the price of fuel, it is projected that, following the implementation of the policy measures:

- 50% of SFF boilers would be switched to efficient biofuel boilers, i.e. to the lowest-price RES production source with a similar operating mode.
- 50% of SFF boilers would be replaced by heat pumps.

The assessment is based on data from the EPMA boiler programme for 2016-2022, which reveals that about 1/4 of consumers using solid fossil fuels switched to biofuel boilers and 3/4 – to heat pumps. When simulating the scenario that part of the change will take place without state support, it is projected that the majority of consumers replacing SFF boilers without state support would replace them with a cheaper source of production, i.e. efficient biofuel boilers.

The operation of liquid fossil fuel (LFF) boilers differs from SFF boilers, i.e. it is a more automated method of heating. It is estimated that consumers using liquid fuel sources do not have reasonable opportunities to connect to the DSO’s natural gas network. It is projected that following the implementation of the policy measures:

- 20% of LFF boilers would be switched to efficient biofuel boilers, i.e. to the lowest-price RES production source.
- 80% of LFF boilers would be replaced with heat pumps, which are the most similar RES production

sources in terms of their operating mode.

The forecast is confirmed by data of the first semester of EPMA's boiler programme for 2016-2022 showing that about 90% of consumers using liquid fossil oil boilers switched their old boiler to a heat pump. When simulating the scenario that part of the change will take place without state support, it is projected that the majority of consumers replacing SFF boilers without state support would replace them with a cheaper source of production than a heat pump – efficient biofuel boilers.

Policy measures to be implemented	PM10. Removal of the excise duty exemption and introduction of a carbon dioxide component (excluding natural gas consumers) PM11. Replacement of boilers with more efficient technologies PM12. Limiting the use of solid fossil fuels for space heating by location

EET 3. Reducing natural gas consumption

Objective: to reduce the consumption of natural gas for heating in a consistent manner.

This efficiency enhancing task is already being implemented: According to the data of EPMA's boiler replacement programme (see Annex 2.10) for 2016-2022, about 99% of consumers using natural gas boilers switched their boiler to a heat pump.

When forecasting the prospects for NG consumption reduction, it is important to assess to which alternative fuel source existing natural gas consumers would migrate. Taking into account the operational aspect of the installation, the nearest alternative is a heat pump (HP). However, a financial incentive is also necessary for consumers to migrate. One of the key parameters of the baseline scenario is the prediction that electricity will be cheaper than gas in the 2050 perspective (see Chapter 8.2.3).

Accordingly, it is projected that in the household segment:

- 90% of natural gas consumption will migrate to the RES production source that is the closest in terms of the operating mode – heat pumps.
- The remaining 10% would migrate to efficient biofuel boilers, i.e. to the lowest-price RES production source.

Policy measures to be implemented	PM11. Replacement of boilers with more efficient technologies PM13. Removal of the excise duty exemption and introduction of a carbon dioxide component for natural gas PM14. Limiting the expansion of the natural gas network to newly constructed buildings in the DH area PM15. Limiting the expansion of the natural gas network to newly constructed buildings in all areas

EET 4. Phasing out inefficient biofuels

Objective: to reduce particulate matter damage and FEC.

The socioeconomic damage caused by inefficient biofuel boilers (due to particulate emissions) exceeds the damage caused by natural gas boilers. Also, fuel consumption (FEC) of inefficient biofuel boilers is about 20% higher than that of efficient biofuel boilers, producing the same amount of heat (UEC).

This efficiency enhancing task is already being implemented. According to the data of the first semester of EPMA's boiler replacement programme for 2016-2022, about one third of consumers using inefficient biofuel boilers chose 5th-generation biofuel boilers and two thirds – heat pumps.

When simulating the scenario that part of the change will take place without state support, it is projected that as consumer awareness of environmental pollution caused by inefficient biofuel boilers in the form of particulate matter increases and policy implementation measures are applied:

- 50% of inefficient biofuel boilers would be replaced with efficient biofuel boilers, i.e. the lowest-cost, less polluting source of RES production.

- 50% of inefficient biofuel boilers would be replaced with heat pumps.

The replacement of inefficient biofuel boilers is particularly important in densely populated urban areas where the actual particulate matter emission damage is likely to be greater than in sparsely populated areas.

Policy measures to be implemented	PM11. Replacement of inefficient biomass boilers with more efficient RES-based heat production technologies PM19. Limiting the use of solid fuels for space heating in densely populated areas

EET 5. Limiting the use of biofuels

Objective: to reduce the damage caused by particulate matter

Particulate matter emissions from an efficient biofuel boiler are about 2 times lower than from an inefficient biofuel boiler. However, with the increasing awareness of environmental pollution caused by inefficient biofuel boilers, it is projected that some users of efficient biofuel boilers will opt for the least polluting decentralised heating technology – the heat pump.

Limiting the use of solid fuels for space heating in densely populated areas, i.e. where damage caused by particulate matter is the greatest, could be a catalyst for change.

Policy measures to be implemented	PM19. Limiting the use of solid fuels for space heating in densely populated areas

Once the planned efficiency enhancing tasks have been implemented, the household segment decentralised heating supply indicators[118] listed in the table below would be achieved.

181 Table. Decentralised heat supply indicators in households in 2050

Fuel	**UEC**	**FEC**	**GHG**	**PM**	**Emissions**		**SE damage (EUR million)**		
	GWh	GWh	t/MWh	g/MWh	kt CO_2	tPM	CO_2	PM	Total
Coal	-	-	0,38	1.433	-	-	-	-	-
Solid fuel	-	-	0,36	1.433	-	-	-	-	-
Petroleum products	-	-	0,28	7	-	-	-	-	-
Natural gas	-	-	0,20	4	-	-	-	-	-
Total FF	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
RES gas	-	-	-	-	-	-	-	-	-
Biofuel	2.165	2.381	-	504	-	1.200	-	20	20
Biofuel (n.k.)	-	-	-	2.664	-	-	-	-	-
Waste	-	-	-	-	-	-	-	-	-
Electricity (HP)	1.439	1.439	-	-	-	-	-	-	-
Ambience (HP)	2.446	2.446	-	-	-	-	-	-	-
Total RES	**6.049**	**6.265**	**-**	**-**	**-**	**1.200**	**-**	**20**	**20**
TOTAL	**6.049**	**6.265**	**-**	**-**	**-**	**1.200**	**-**	**20**	**20**
Total RES (2020)	5.097	5.990	-	-	-	8.967	-	150	150
TOTAL (2020)	7.425	8.585	-	-	638	9.560	73	160	232

Source: authors of the Study

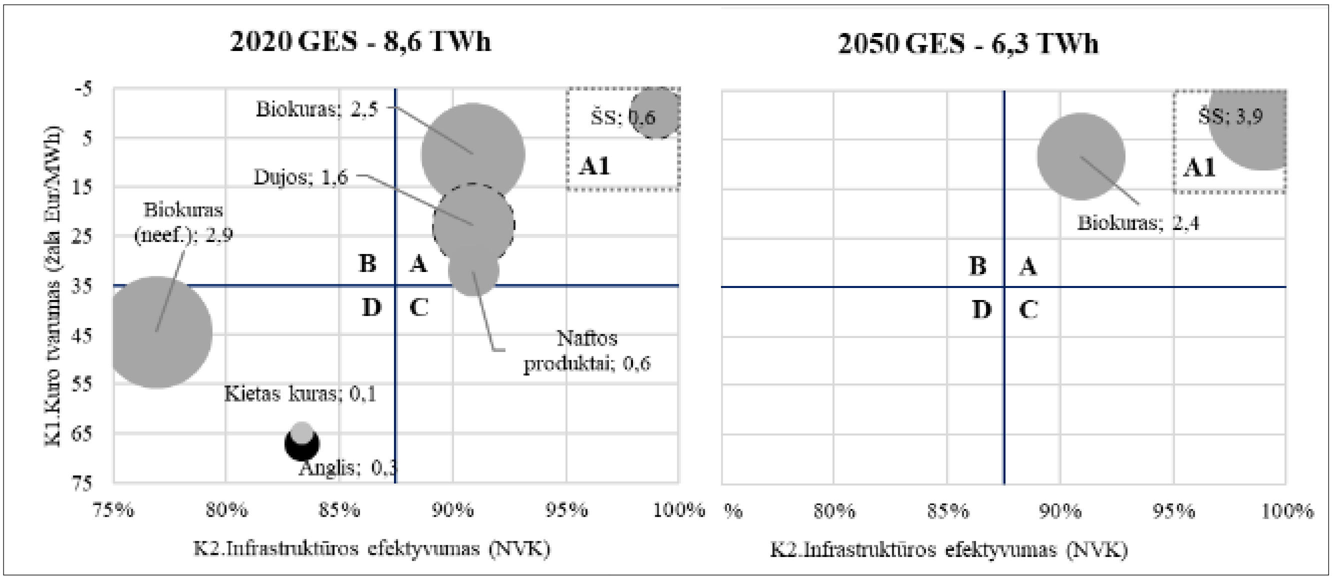
The implementation of the planned efficiency enhancing tasks for 2050 is estimated to lead to the following:

- CO_2 emissions would decrease by 100% (638 kt CO_2).
- PM emissions would decrease by 87% (from 9.6 to 1.2 kt PM).
- Total socioeconomic damage would be reduced by 91% (from EUR 232 million to EUR 20 million).

118 For comparability purposes, for 2050 GHG and PM estimates of socioeconomic damage for 2020 are used.

A graphical illustration of supply indicators for the household segment for 2050 is shown in the figure below.

58 Figure. Decentralised heat supply transformation in households in 2050

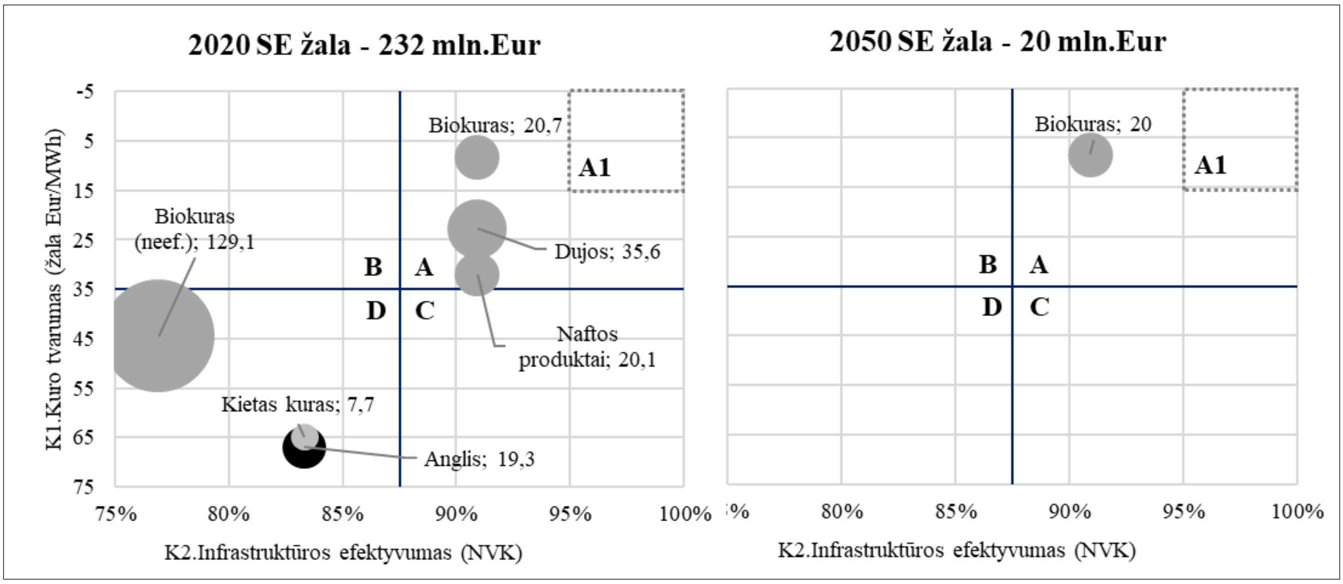


Source: authors of the Study

The analysis of the chart after the implementation of the efficiency enhancing tasks in 2050 shows that the household decentralised heating segment would eliminate the supply of relatively polluting fuels and low efficiency, i.e. the supply would migrate from Square D to Square A.

As a result, socioeconomic damage would decrease from EUR 232 million to EUR 20 million (see figure below).

59 Figure. Change in the socioeconomic damage of decentralised heat supply for households in 2050



Source: authors of the Study

It can be observed that the remaining socioeconomic damage would be related to PM emissions from efficient biofuel boilers. The population density of the area where particulate matter is emitted is not taken into account in the estimate used to calculate the size of damage. Accordingly, it is estimated that the implementation under EET7 of the policy measure “PM19. Limiting the use of solid fuels for space heating in densely populated areas” could lead to a significant reduction in actual damage.

8.5.2. Service sector

The potential for enhancing supply efficiency of the service sector was assessed in 3 stages:

a. Analysis of existing (2020) supply efficiency indicators.

b. Prioritising efficiency enhancement in line with the long-term objectives of the sector.

c. Formulation of efficiency enhancing tasks.

a. Analysis of existing (2020) supply efficiency indicators

Key performance indicators of decentralised supply efficiency in the service sector are summarised below.

Table 182. Decentralised heat supply indicators in the service sector in 2020

Fuel	UEC	FEC	GHG	PM	Emissions		SE damage (EUR million)		
	GWh	GWh	t/MWh	g/MWh	kt CO_2	tPM	CO_2	PM	**Total**
Coal	182	219	0,38	389	83	85	9	1	11
Solid fuel	63	76	0,36	389	27	29	3	0,5	4
Petroleum products	27	30	0,28	11	8	0,3	1	0,01	1
Natural gas	734	807	0,20	3	161	2	18	0,04	18
Total RES	**1.006**	**1.132**	**-**	**-**	**279**	**117**	**32**	**2**	**34**
RES gas	50	55	-	3	-	0,2	-	0,003	0,003
Biofuel	327	359	-	355	-	127	-	2	2
Waste	-	-	-	-	-	-	-	-	-
Electricity (HP)	148	148	-	-	-	-	-	-	-
Ambience (HP)	252	252	-	-	-	-	-	-	-
Total RES	**776**	**814**	**-**	**-**	**-**	**128**	**-**	**2**	**2**
TOTAL	**1.782**	**1.945**	**-**	**-**	**279**	**245**	**32**	**4**	**36**

Source: authors of the Study

The evaluation of existing performance indicators shows that:

- UEC is 9.2% lower than FEC. The indicator is better than in the household segment (14%) due to lower volumes of inefficient sources of production in the FEC structure.
- 94% of total estimated socioeconomic damage (EUR 34 million, Euro) is caused by fossil fuel CO_2 and PM emissions.

The graph below reveals segments of supply efficiency in the service sector based on fuel source efficiency and relative pollution.

Square D: relatively most polluting fuel and low-efficiency supply. This segment generates the highest relative socioeconomic damage (EUR/MWh). The segment includes:

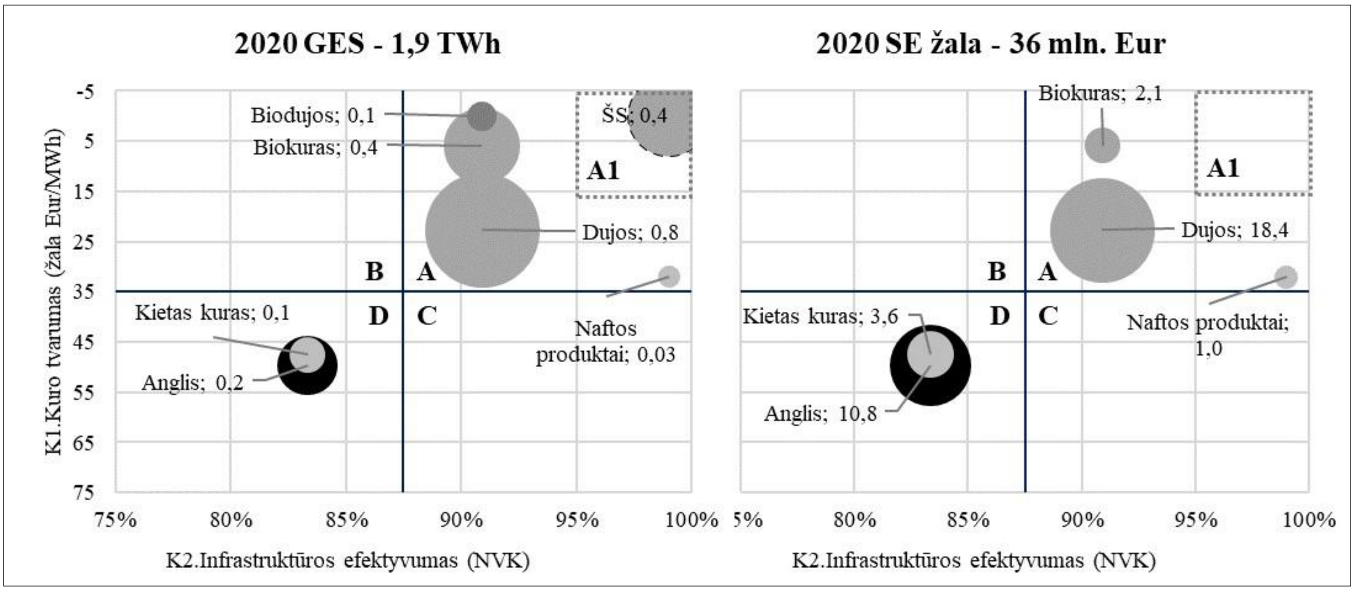
- Coal boilers (CO_2 and PM emissions damage: about 50 EUR/MWh).
- Other solid fossil fuel boilers (CO_2 and PM emissions damage: about 48 EUR/MWh).

Square A: relatively low-pollution fuel and high-efficiency supply. This segment generates the lowest relative socioeconomic damage (EUR/MWh). The segment includes:

- Biomass boilers (PM emissions damage: about 6 EUR/MWh).
- petroleum product boilers (CO_2 and PM emissions damage: about 32 EUR/MWh).
- Natural gas boilers (CO_2 emissions damage: about 23 EUR/MWh).

Square A1: highest-efficiency supply causing no socioeconomic damage in the form of CO_2 and PM emissions. The segment includes heat pumps (socioeconomic damage: 0 EUR/MWh[119]).

Figure 60. Decentralised heat supply indicators in the service sector in 2020



Source: authors of the Study

b. Priorities for enhancing efficiency

Taking into account the results of the evaluation of the analysis of existing efficiency indicators and the long-term objectives set for the sector, the following priorities for enhancing efficiency in the service sector are defined:

1. Transform the supply of relatively low-efficiency and high-emission fuels by encouraging the migration of production sources from Square D to Square A (**high priority)**.
2. Promote the transformation of high-efficiency and medium-emission fuel supply for production sources to migrate from Square A to Square A1 (**medium priority)**.

c. Efficiency enhancing tasks

Enhancing demand efficiency

The baseline scenario (LTRS40) estimates that by 2050, taking into account the change in demand due to environmental factors, the development of DH systems and the implementation of demand efficiency enhancement measures (Chapter 8.4.1), demand in the service sector would decrease by about 0.4 TWh to 1.4 TWh per year.

Enhancing supply efficiency

The tasks for enhancing supply efficiency described below are defined taking into account the projected change in demand and the established priorities for enhancing efficiency.

119 Green electricity scenario (see Chapter 8.2.2).

183 Table. Tasks on enhancing decentralised heat supply efficiency in the service sector

Fuel	UEC 2020	LTRS 40	Efficiency enhancing tasks (EET)				UEC 2050
			1	2	3	4	
Coal	182	-43	-139	-	-	-	-
Solid fuel	63	-15	-48	-	-	-	-
Petroleum products	27	-6	-	-21	-	-	-
Natural gas	734	-172	-	-	-561	-	-
Total FF	**1.006**	**-236**	**-188**	**-21**	**-561**	**-**	**-**
RES gas	50	-12	-	-	-	-	38
Biofuel	327	-77	+150	+4	+56	-125	335
Waste	-	-	-	-	-	-	-
Electricity (HP)	148	-35	+14	+6	+187	+46	367
Ambience (HP)	252	-59	+24	+11	+318	+79	624
Total RES	**776**	**-182**	**+188**	**+21**	**+561**	**-**	**1.364**
TOTAL UEC	**1.782**	**-418**	**-**	**-**	**-**	**-**	**1.364**
TOTAL PEC	**1.945**	**-457**	**-23**	**-2**	**-51**	**-12**	**1.401**

Source: authors of the Study

EET 1-2. Phasing out fossil fuels

Objective: to replace production sources of fossil fuels (coal, other solid fuels and petroleum products) with RES production sources.

The operation of boilers running on solid fossil fuels (SFF) is the most similar to the operation of biofuel boilers, both in terms of the price of equipment or fuel, and in terms of their operating mode. However, in the light of trends in the household sector, it is expected that some companies in the service sector will opt for a more convenient and pollution-friendly heating method. It is therefore projected that following the implementation of the policy measures:

- 80% of SFF boilers would be switched to efficient biofuel boilers, i.e. to the lowest-price RES production source with a similar operating mode.
- 20% of SFF boilers would be replaced by heat pumps.

The operation of liquid fossil fuel (LFF) boilers is a more automated method of heating than SFF, therefore it is more similar to the use of a heat pump or a natural gas boiler. However, since the use of natural gas is more convenient, it is assumed that consumers using LFF do not have reasonable opportunities to connect to the DSO's natural gas network. Taking into account the experience in the household sector (where the population receiving support replaces LFF with heat pump in about 90% of cases), it is projected that in the service sector, following the application of policy implementation measures:

- 20% of LFF boilers would be switched to efficient biofuel boilers, i.e. to the lowest-price RES production source.
- 80% of LFF boilers would be replaced with heat pumps, which are the most similar RES production sources in terms of their operating mode.

Policy measures to be implemented	PP10. Removal of the excise duty exemption and introduction of a carbon dioxide component (excluding natural gas consumers) PM20. Introducing and promoting technological eco-innovations PP12. Limiting the use of solid fossil fuels for space heating by location

EET 3. Reducing natural gas consumption

Objective: to reduce the consumption of natural gas for heating in a consistent manner.

When forecasting the prospects for NG consumption reduction, it is important to assess to which alternative fuel source existing natural gas consumers would migrate.

Taking into account the operational aspect of the installation, the nearest alternative is a heat pump (HP). However, a financial incentive is also necessary for consumers to migrate. One of the key parameters of the baseline scenario is the prediction that electricity will be cheaper than gas in the 2050 perspective (see Chapter 8.2.3).

Accordingly, it is projected that in the services segment:

- 90% of natural gas consumption will migrate to the RES production source that is the closest in terms of the operating mode – heat pumps.
- The remaining 10% would migrate to efficient biofuel boilers, i.e. to the lowest-price RES production source.

Policy measures to be implemented	PM13. Removal of the excise duty exemption and introduction of a carbon dioxide component for natural gas PM14. Limiting the expansion of the natural gas network to newly constructed buildings in the DH area PM15. Limiting the expansion of the natural gas network to newly constructed buildings in all areas PM20. Introducing and promoting technological eco-innovations

EET 4. Limiting the use of biofuels

Objective: to reduce the damage caused by

particulate matter

Combustion of solid fuels, even in an efficient biofuel boiler, produces particulate matter, which has a significant negative impact on health in the surrounding area. Particulate matter damage is the greater, the higher is the concentration of particulate matter and the number of people living in close proximity, therefore the greatest damage is done in urban, densely populated areas where energy consumers in the service sector are most likely to be located.

Limiting the use of solid fuels for space heating in densely populated areas, i.e. where damage caused by particulate matter is the greatest, could be a catalyst for change. Restricting the use of solid fuels in densely populated areas where it is not possible to connect to DH systems leaves the consumer with a single decentralised heating technology – the heat pump option.

It is estimated that 50% of biofuel boilers would be replaced with heat pumps as a result of these incentives.

Policy measures to be implemented	PM19. Limiting the use of solid fuels for space heating by location

Once the above efficiency enhancing tasks have been implemented, the decentralised heating supply indicators[120] in the services sector listed in the table below would be achieved.

120 For comparability purposes, 2020 GHG and PM estimates are used.

184 Table. Decentralised heat supply indicators in the service sector in 2050

Fuel	UEC	FEC	GHG	PM	Emissions		SE damage (EUR million)		
	GWh	GWh	t/MWh	g/MWh	kt CO_2	tPM	CO_2	PM	Total
Coal	-	-	0,38	389	-	-	-	-	-
Solid fuel	-	-	0,36	389	-	-	-	-	-
Petroleum products	-	-	0,28	11	-	-	-	-	-
Natural gas	-	-	0,20	3	-	-	-	-	-
Total FF (2050)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
RES gas	38	42	-	3	-	0,1	-	0,002	0,002
Biofuel	335	369	-	355	-	131	-	2,2	2,2
Waste	-	-	-	-	-	-	-	-	-
Electricity (HP)	367	367	-	-	-	-	-	-	-
Ambience (HP)	624	624	-	-	-	-	-	-	-
Total RES (2050)	**1.364**	**1.401**	**-**	**-**	**-**	**131**	**-**	**2,2**	**2,2**
TOTAL (2050)	**1.364**	**1.401**	**-**	**-**	**-**	**131**	**-**	**2,2**	**2,2**
Total RES (2020)	776	814	-	-	-	128	-	2	2
TOTAL (2020)	1.782	1.945	-	-	279	245	32	4	36

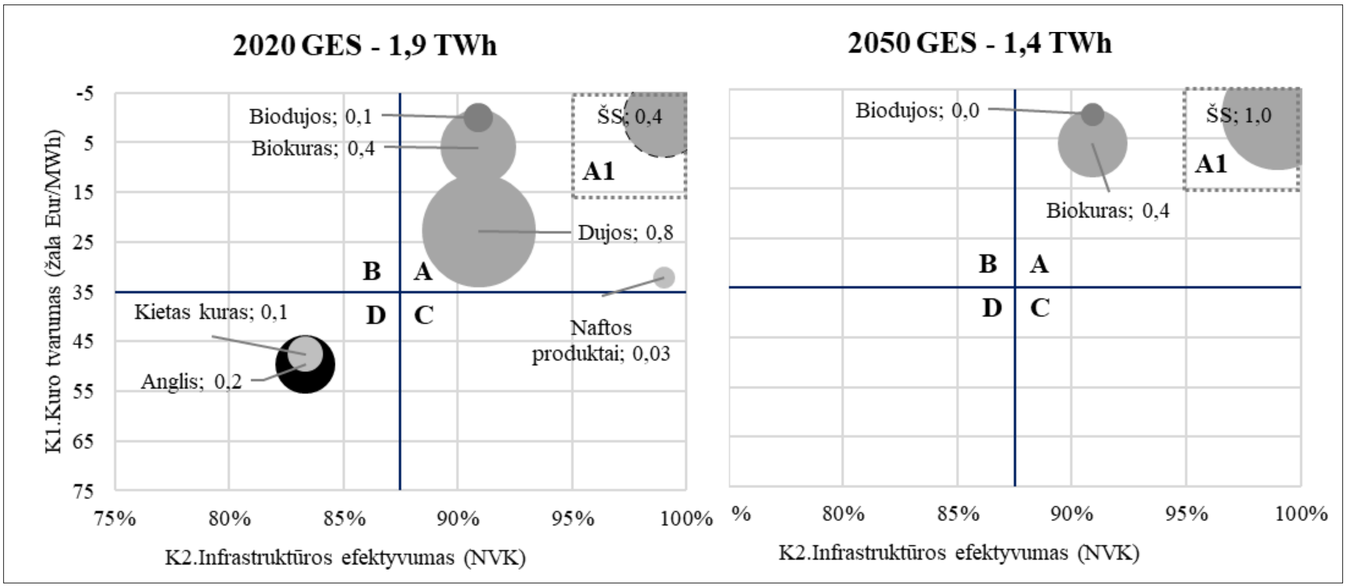
Source: authors of the Study

The implementation of the planned efficiency enhancing tasks for 2050 is estimated to lead to the following:

- CO_2 emissions would decrease by 100% (279 kt CO_2).
- PM emissions would decrease by 46% (from 0.24 to 0.13 kt PM).
- Total socioeconomic damage would be reduced by 94% (from EUR 36 million to EUR 2.2 million).

A graphical illustration of supply indicators for 2050 is shown in the figure below.

61 Figure. Decentralised heat supply transformation in the service sector in 2050

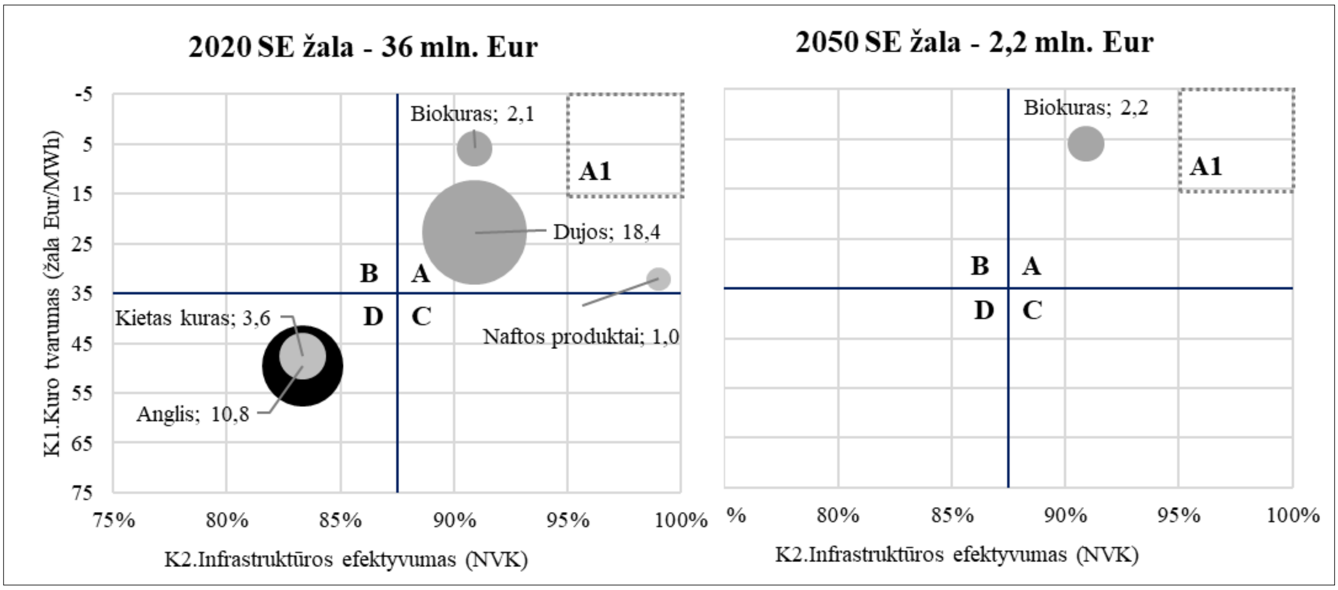


Source: authors of the Study

The analysis of the chart after the implementation of the efficiency enhancing tasks in 2050 shows that the decentralised heating segment in the service sector would eliminate the supply of relatively polluting fuels and low efficiency, i.e. the supply would migrate from Square D to Square A.

As a result, socioeconomic damage would decrease from EUR 36 million to EUR 2.2 million (see figure below).

62 Figure. Change in the socioeconomic damage of decentralised heat supply in the service sector



Source: authors of the Study

Like in the household segment, the remaining socioeconomic damage in the service sector is linked to PM emissions from efficient biofuel boilers. The population density of the area where particulate matter is emitted is not taken into account in the estimate used to calculate the size of damage. Accordingly, it is estimated that the implementation under EET4 of the policy measure “PM19. Limiting the use of solid fuels for space heating in densely populated areas” could lead to a significant reduction in actual damage.

8.5.3. Industry sector

The potential for enhancing supply efficiency in the industry sector was assessed in 3 stages:

a. Analysis of existing (2020) supply efficiency indicators.
b. Prioritising efficiency enhancement in line with the long-term objectives of the sector.
c. Formulation of efficiency enhancing tasks.

a. Analysis of existing (2020) supply efficiency indicators

A summary of key performance indicators for decentralised supply in the industry sector is presented in the table below.

Table 185. Decentralised heat supply indicators in the industry sector in 2020

Fuel	UEC	FEC	GHG	PM	Emissions in 2020		Damage in 2020 (EUR million)		
	GWh	GWh	t/MWh	g/MWh	kt CO_2	tPM	CO_2	PM	**Total**
Coal	800	880	0,38	12	333	11	38	0,1	38
Solid fuel	136	150	0,36	389	54	58	6	0,5	7
Petroleum products	307	337	0,28	43	94	15	11	0,1	11
Natural gas	2.890	3.178	0,20	3	633	9	72	0,1	72
Total FF	**4.133**	**4.546**	**-**	**-**	**1.114**	**93**	**127**	**1**	**128**
RES gas	47	51	-	3	-	0,1	-	0,001	0,001
Biofuel	1.266	1.392	-	252	-	351	-	3	3
Waste	23	26	0,20	-	5	-	1	-	1
Electricity (HP)	36	36	-	-	-	-	-	-	-
Ambience (HP)	61	61	-	-	-	-	-	-	-
Total RES	**1.432**	**1.566**	**-**	**-**	**5**	**351**	**1**	**3**	**3**
TOTAL	**5.565**	**6.112**	**-**	**-**	**1.119**	**444**	**128**	**4**	**131**

Source: authors of the Study

The evaluation of existing performance indicators shows that:

- UEC is 9.1% lower than FEC. The indicator is much better than in households (14%) and a little than in the service sector (9.2%) due to lower volumes of inefficient sources of production in the FEC structure.
- 97% of total estimated socioeconomic damage (EUR 128 million, Euro) is caused by fossil fuel CO_2 and PM emissions.
- Damage caused by the use of natural gas amounts to 55% of total damage caused in the sector in 2020, which is exclusively related to CO_2 emissions.
- Another significant part is damage caused by combustion of coal (29% of total damage in the sector in 2020), which is attributed to damage caused by CO_2 (particulate matter is sufficiently well filtered). Coal consumption in the Lithuanian industry is almost exclusively linked with the cement industry.

The graph below reveals supply efficiency segments in the industry sector based on fuel source efficiency and relative pollution.

Square C: relatively most polluting fuel and high-efficiency supply. This segment generates the largest relative socioeconomic damage of the sector (EUR/MWh). The segment includes:

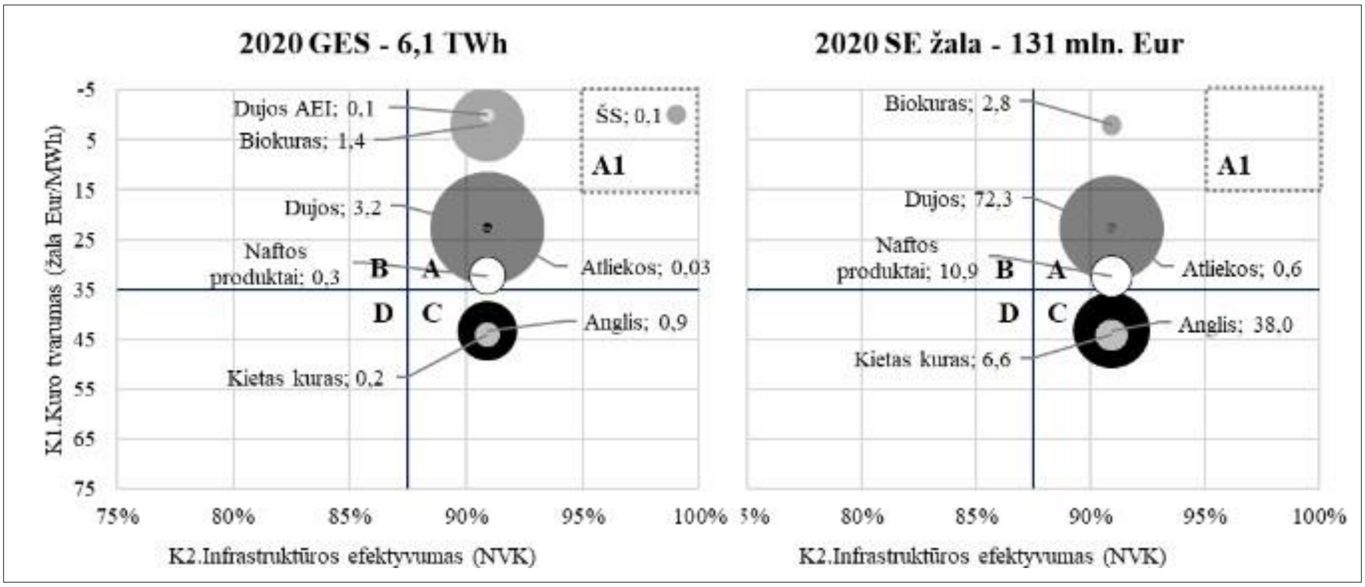
- Coal boilers (CO_2 and PM emissions damage: about 43 EUR/MWh).
- Solid fossil fuel boilers (CO_2 and PM emissions damage: about 44 EUR/MWh).

Square A: relatively low-pollution fuel and high-efficiency supply. This segment generates the lowest relative socioeconomic damage (EUR/MWh). The segment includes:

- Biomass boilers (PM emissions damage: about 2 EUR/MWh).
- Waste incineration boilers (CO_2 and PM emissions damage: about 22 EUR/MWh).
- Natural gas boilers (CO_2 and PM emissions damage: about 23 EUR/MWh).
- Petroleum product boilers (CO_2 and PM emissions damage: about 32 EUR/MWh).

Square A1: highest-efficiency supply causing no socioeconomic damage in the form of CO_2 and PM emissions. The segment includes heat pumps (socioeconomic damage: 0 EUR/MWh[121]).

Figure 63. Decentralised heat supply indicators in the industry sector in 2020



Source: authors of the Study

121 Green electricity scenario (see Chapter 8.2.2).

b. Priorities for enhancing efficiency

Taking into account the results of the evaluation of the analysis of existing efficiency indicators and the long-term objectives set for the sector, the following priorities for enhancing efficiency in the industry sector are defined:

1. Transform the supply of relatively high-pollution fuels by encouraging the migration of production sources from Square C to Square A or to introduce technologies to reduce socioeconomic damage (in cases where the type of fuel is important for the production process) (**high priority)**.
2. Promote the transformation of high-efficiency and medium-emission fuel supply for production sources to migrate from Square A to Square A1 (**medium priority)**.

c. Efficiency enhancing tasks

Enhancing demand efficiency

The baseline scenario (LTRS40) estimates that by 2050, after assessing the change in demand due to industrial growth and implementing demand efficiency enhancing measures (Chapter 8.3), demand in the industry sector will remain at a level similar to 2020, i.e. about 5.6 kWh/year.

Enhancing supply efficiency

The tasks for enhancing supply efficiency described below are defined taking into account the projected change in demand and the established priorities for enhancing efficiency.

186 Table. Tasks on enhancing decentralised heat supply efficiency in the industry sector

Fuel	UEC 2020	LTRS 40	Efficiency enhancing tasks (EET)				UEC 2050
			1	2	3	4	
Coal	800	2	-802	-	-	-	-
Solid fuel	136	0	-	-137	-	-	-
Petroleum products	307	1	-	-307	-	-	-
Natural gas	2.890	6	-	-	-869	-1,612	415
Total FF	**4.133**	**9**	**-802**	**-444**	**-869**	**-1,612**	**415**
RES gas	47	0,1	-	-	-	1.612	1.659
Biofuel	1.266	3	-	355	695	-	2.318
Waste	23	0,1	802	-	-	-	825
Electricity (HP)	36	0,07	-	33	65	-	133
Ambience (HP)	61	0,1	-	56	109	-	227
Total RES	**1.432**	**3**	**802**	**444**	**869**	**1.612**	**5.162**
TOTAL UEC	**5.565**	**12**	**-**	**-**	**-**	**-**	**5.577**
TOTAL PEC	**6.112**	**13**	**-**	**-9**	**-17**	**-**	**6.099**

Source: authors of the Study

<u>EET 1. Coal replacement</u>

Objective: to replace production sources of coal combustion with RES or indigenous production sources.

Coal is used in Lithuania’s industry almost exclusively in cement production where this efficiency enhancing task is already implemented – Akmenė cement plant already has waste incineration capacity (up to 216,220 tons per year), which includes both fuel obtained from waste and an IPPC permit for the incineration of other industrial waste.

It is projected that the rising cost of emission allowances combined with policy measures to encourage the phasing-out and replacement of coal with RES-based sources (such as dry sewage sludge or recovered solid fuels, sorted municipal waste) would lead to a complete transformation of carbon supply into waste incineration.

Policy measures to be implemented	PM22. Promoting the replacement of polluting technologies with less polluting ones for companies involved in the trading of emission allowances PM28. Reducing the use of coal, coke and lignite

EET 2. Phasing out fossil fuels

Objective: to replace production sources of fossil fuels (solid fuels and petroleum products) with RES production sources.

The operation of boilers running on solid fossil fuels (SFF) is the most similar to the operation of biofuel boilers (except where there is a need for industrial processes with very high temperatures), both in terms of the price of equipment or fuel, and in terms of their operating mode. Given the technical availability of alternatives to the use of SFF, the phasing-out of this fuel should be driven by tax and regulatory developments and the growing importance of corporate social responsibility. It is therefore projected that following the implementation of the policy measures:

- 80% of SFF boilers would be switched to efficient biofuel boilers, i.e. to the lowest-price RES production source with a similar operating mode.
- 20% of SFF boilers would be replaced by heat pumps.

At the same time, the use of liquid fossil fuels (LFF) is also to be phased out in the industry sector. Incentives for change include the fiscal and regulatory environment and the growing importance of corporate social responsibility. It is projected that following the implementation of the policy measures:

- 80% of LFF boilers would be switched to efficient biofuel boilers, i.e. to the lowest-price RES production source[122].
- 20% of LFF boilers would be replaced by heat pumps.

Policy measures to be implemented	PM10. Removal of the excise duty exemption and introduction of a carbon dioxide component for fossil fuels (excluding NG) PM28. Reducing the use of coal, coke and lignite PM20. Introducing and promoting technological eco-innovations

EET 3. Reducing natural gas consumption

Objective: to replace sources of fossil fuel production (NG) with RES production sources.

It is projected that policy measures put in place to encourage the transformation of heating into RES-based sources would result in a transformation of 30% of NG supply into RES fuel (in those industries where the replacement is technologically feasible). Incentives for change include the fiscal and regulatory environment and the growing importance of corporate social responsibility. It is projected that following the implementation of the policy measures:

- 80% of heat from NG boilers being replaced would be converted to heat from efficient biofuel boilers, i.e. to the lowest-price RES production source.
- 20% of heat from NG boilers being replaced would be converted to heat from heat pumps, which is the most comparable heat production technology in terms of its operating mode.

Policy measures to be implemented	PM13. Removal of the excise duty exemption and introduction of a carbon dioxide component for natural gas PM22. Promoting the replacement of polluting technologies by less polluting ones for companies involved in the trading of emission allowances PM24. Using renewable energy sources in industry PM26. A single national measurement system to track progress in business, industry and energy use and pollution reduction PM27. Implementing alternative fuel measures (large enterprises) PM21. Decarbonisation of industry

122 It is estimated that consumers using liquid fuel sources do not have reasonable opportunities to connect to the DSO's NG network.

EET 4. Integrating renewable gases

Objective: to reduce the consumption of natural gas for heating in a consistent manner.

Taking into account the EU's and Lithuania's strategic objectives and the projected scenario for the development of the electricity and gas network (Chapter 8.2.2), it is estimated that by 2050 the structure of the gas mixture supplied through Lithuania's gas network will consist of:

- 80% renewable gases (50% – synthetic methane and hydrogen produced using RES electricity, 30% – indigenous or imported biomethane).
- 20% natural gas and liquefied natural gas.

To achieve this gas mixture structure, there is a need:

- to promote the biomethane sector, not only to reduce the use of fossil fuels but also to address waste management issues – biomethane produced from food waste, manure or other agricultural waste is one of the important elements of the circular economy.
- Promoting P2G (Power to Gas) technologies to convert electricity from RES into gaseous fuels.

Policy measures to be implemented	PM16. Promoting the development of biomethane gas production facilities PM17. Promoting research into hydrogen integration PM18. Promoting the development of hydrogen production facilities PM21. Decarbonisation of industry PM22. Promoting the replacement of polluting technologies by less polluting ones for companies involved in the trading of emission allowances PM23. Study to quantify the need for clean, green and renewable energy industry

Once the above efficiency enhancing tasks have been implemented, the decentralised heating supply indicators[123] on the industry sector listed in the table below would be achieved.

187 Table. Decentralised heat supply indicators in the industry sector in 2050

Fuel	UEC	FEC	GHG	PM	Emissions		SE damage (EUR million)		
	GWh	GWh	t/MWh	g/MWh	kt CO_2	tPM	CO_2	PM	Total
Coal	-	-	0,38	12	-	-	-	-	-
Solid fuel	-	-	0,36	389	-	-	-	-	-
Petroleum products	-	-	0,28	43	-	-	-	-	-
Natural gas	415	456	0,20	3	91	1	10	0,01	10
Total FF (2050)	**415**	**456**	**-**	**-**	**91**	**1**	**10**	**0**	**10**
RES gas	1.659	1.825	-	3	-	5	-	0,04	0,04
Biofuel	2.318	2.550	-	252	-	643	-	5	5
Waste	825	908	0,20	-	180	-	20	-	20
Electricity (HP)	133	133	-	-	-	-	-	-	-
Ambience (HP)	227	227	-	-	-	-	-	-	-
Total RES (2050)	**5.163**	**5.643**	**-**	**-**	**180**	**648**	**20**	**5**	**26**
TOTAL (2050)	**5.577**	**6.099**	**-**	**-**	**271**	**649**	**31**	**5**	**36**
Total RES (2020)	1.432	1.566	-	-	5	351	1	3	3
TOTAL (2020)	5.565	6.112	-	-	1.119	444	128	4	131

Source: authors of the Study

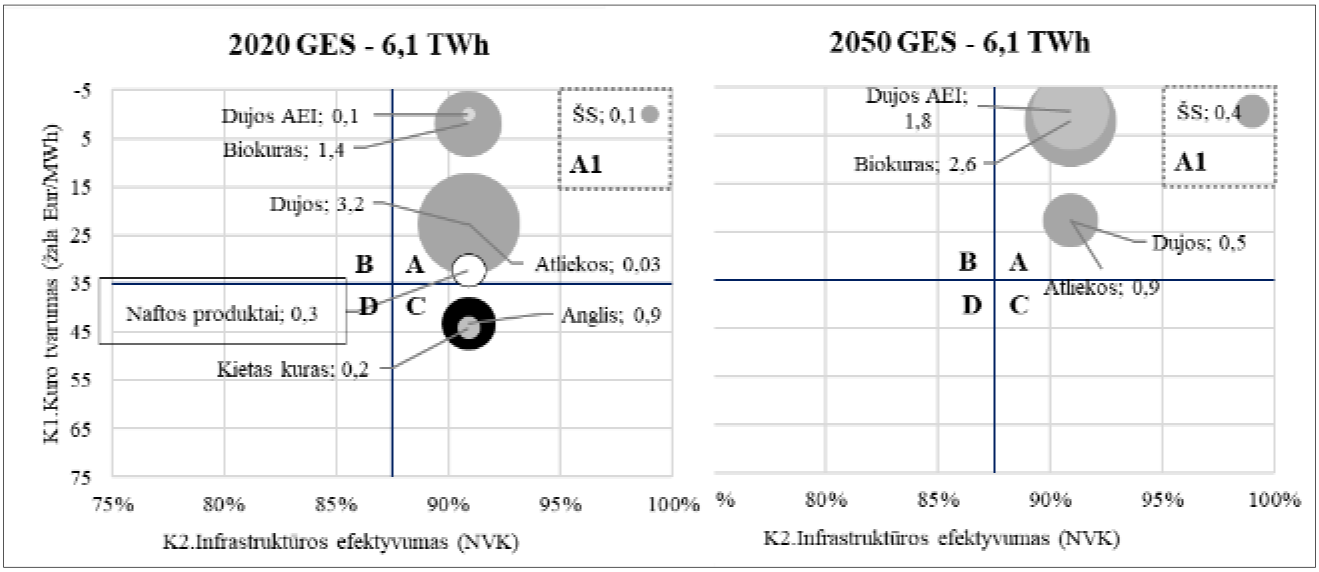
123 For comparability purposes, 2020 GHG and PM estimates are used.

The implementation of the planned efficiency enhancing tasks for 2050 is estimated to lead to the following:

- CO_2 emissions would decrease by 76% (from 1,119 to 271 $ktCO_2$).
- PM emissions would increase by 46% (from 0.4 to 0.6 t PM).
- Total socioeconomic damage would be reduced by 72% (from EUR 131 million to EUR 36 million).

A graphical illustration of supply indicators for the industry sector for 2050 is shown in the figure below.

64 Figure. Decentralised heat supply transformation in the industry sector in 2050



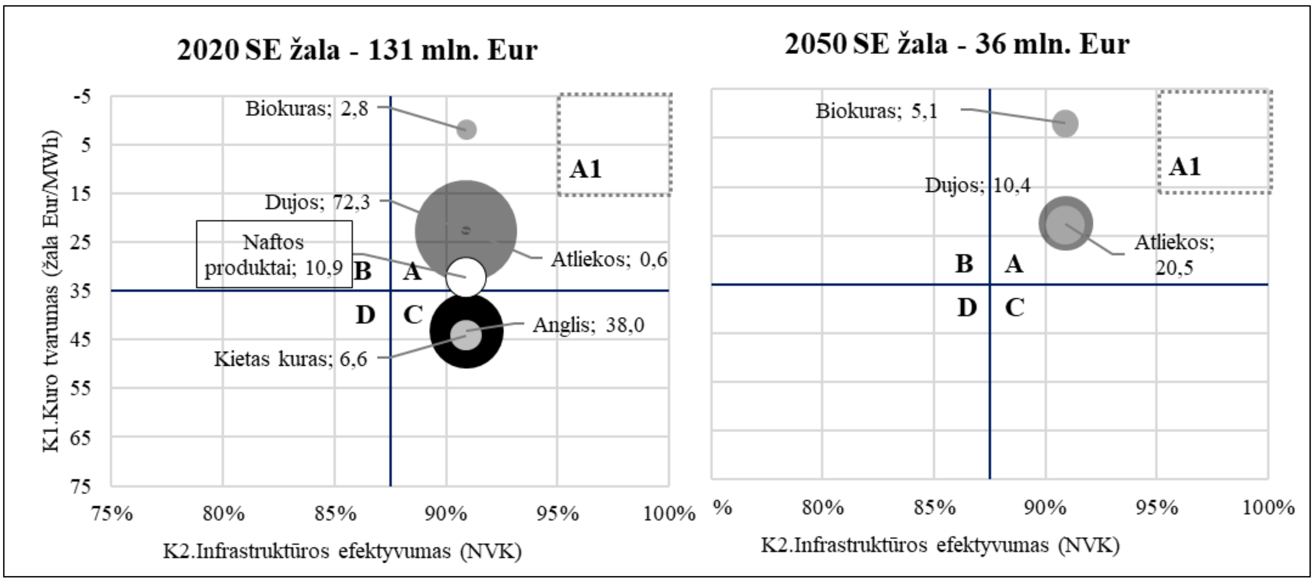
Source: authors of the Study

The analysis of the chart shows that, following the planned efficiency enhancing tasks for 2050:

- In the supply of relatively polluting fuels and high efficiency, fossil fuels would be replaced with waste (0.9 TWh)
- The supply of fossil fuels would decrease to 0.5 TWh (natural gas).
- Renewable gas consumption would increase to 1.8 TWh.

As a result, socioeconomic damage would decrease from EUR 131 million to EUR 36 million (see figure below).

65 Figure. Change in the socioeconomic damage of decentralised heat supply in the industry sector



Source: authors of the Study

It can be observed that in 2050 most of the remaining socioeconomic damage would be linked to the use of natural gas boilers and waste. As thermal energy in the industry sector is mainly used for processes and not for space heating, the possibility to replace the fuel used depends on the specific sector and the thermal energy parameters required for it.

A major part of CO_2 emissions from waste incineration plants is attributed to one specific plant's waste incineration installations. Consumption in the natural gas industry is also associated with a limited number of enterprises requiring certain operating parameters for thermal energy or installations.

Accordingly, it is assessed that, like in the DH sector, the introduction of carbon capture, use and storage (CCUS) technologies can be considered in the industry sector in the context of an enabling regulatory and fiscal environment.

8.6. KEY OBSERVATIONS

Taking into account the long-term strategic objectives of the energy sector, the following objectives and target indicators are set for the heating sector:

Table 188. Objectives for Lithuania's heating sector for 2050

Sector	Objective	Target indicators (2050)
Heating sector	T1. Decrease in FEC intensity	18.8 TWh
	T2. Decrease in PEC intensity	20.6 TWh
	T3. GHG emissions	0 kt CO_2
	T4. RES share in the DH sector	100%
	T5. RES share in the decentralised sector	90%

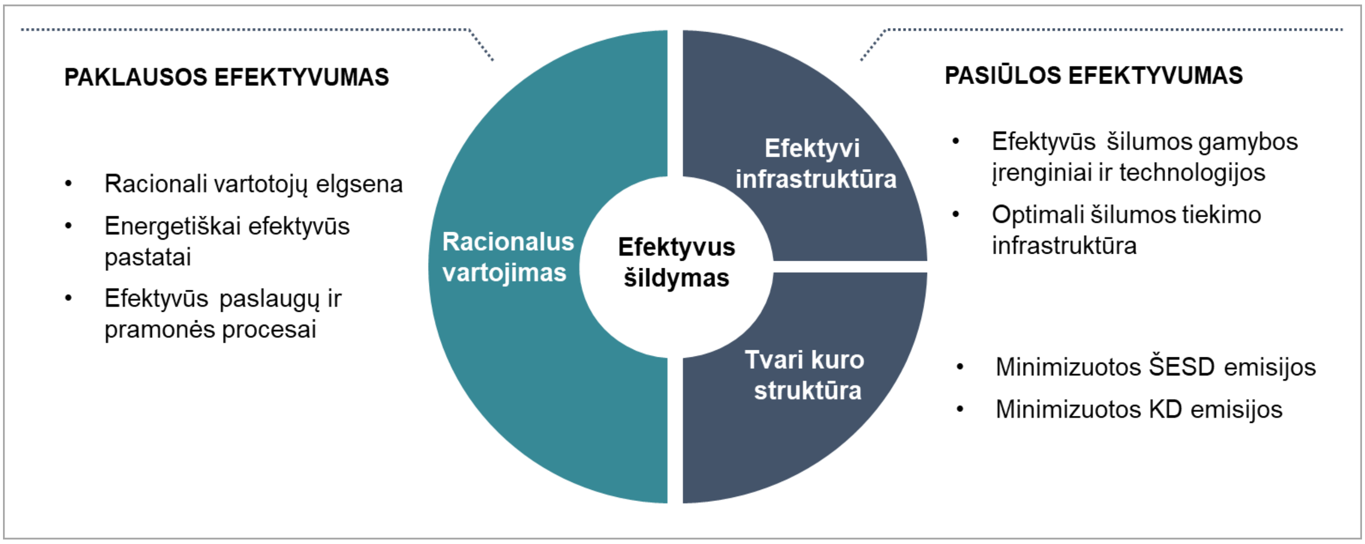
Source: authors of the Study

Taking into account the long-term objectives set for the heating sector, three main expectations are defined for the area of thermal energy efficiency:

- Rational consumption: a key measure to reduce FEC intensity.
- Efficient infrastructure: a key measure to reduce PEC intensity.
- Sustainable fuel mix: a key measure to reduce GHG emissions.

In terms of the energy supply chain, these expectations are divided into two groups: increasing the efficiency of heating demand and increasing the efficiency of heating supply.

66 Figure. Assessment model for the potential for efficient heating



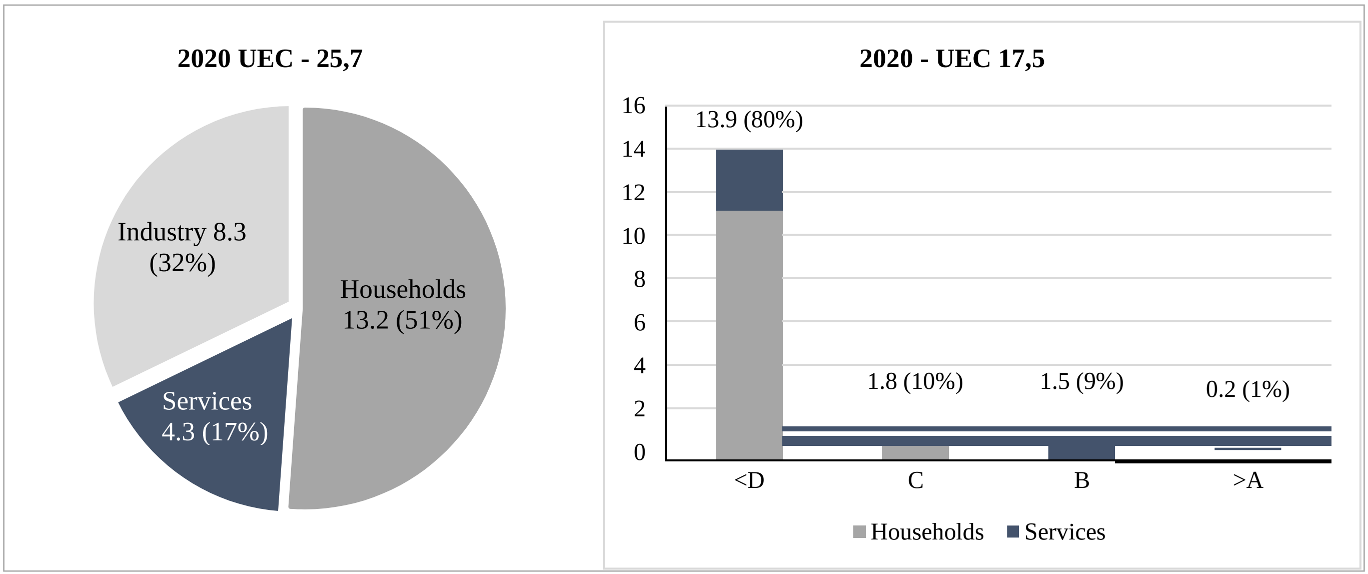
Source: authors of the Study

When assessing the potential for enhancing demand efficiency, solutions are sought to reduce the need for heating energy while maintaining the same quality parameters of the service (e.g. indoor temperature level). When assessing the potential for enhancing supply efficiency, technological solutions are sought to meet efficient heating demand with the lowest financial and economic (social) costs.

1. Potential for enhancing heating demand efficiency

An analysis of the heating demand structure has revealed that a major part of the demand (about 68%) is for heating buildings (households and the service sector) while the majority of buildings (about 79%) are low energy efficiency.

67 Figure. Lithuania's heating UEC in 2020, GWh

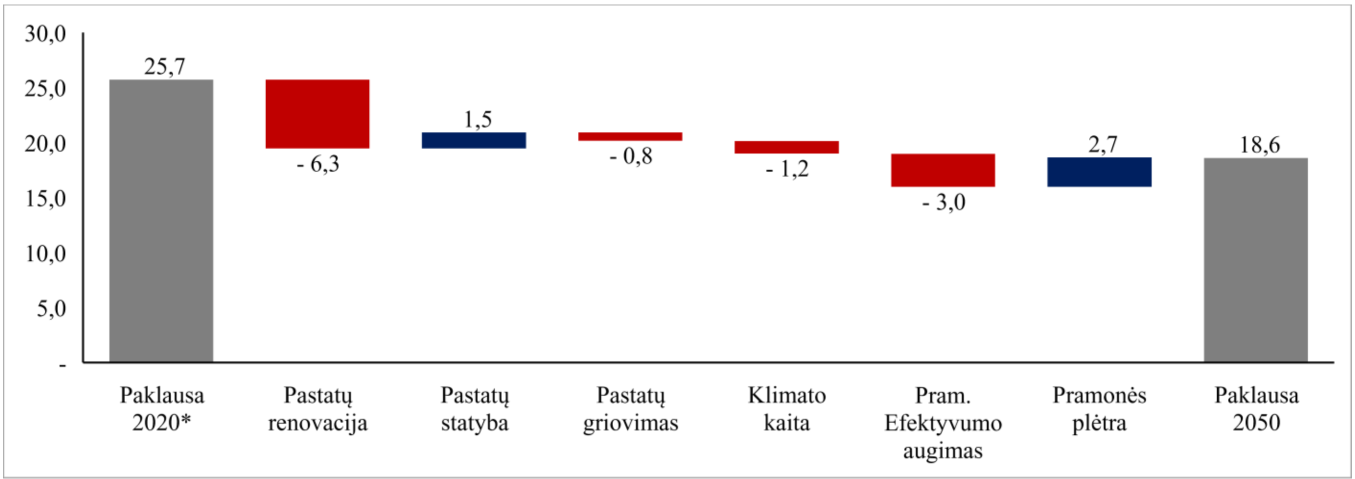


Source: authors of the Study

Accordingly, it can be concluded that the main potential for enhancing heating demand efficiency is in enhancing the energy efficiency of buildings (renovation).

It is estimated that full implementation of the objectives set in the Long-Term Renovation Strategy (LTRS) for 2050 would reduce the level of heat demand by about 6.3 TWh due to renovation measures. Taking into account all the factors influencing heating demand, it is projected that heating demand would decrease by 28% (from 25.7 TWh in 2020[124] to 18.6 TWh in 2050).

68 Figure. Forecast of the change in heating demand in 2020-2050 (LTRS100), UEC, TWh



Source: authors of the Study

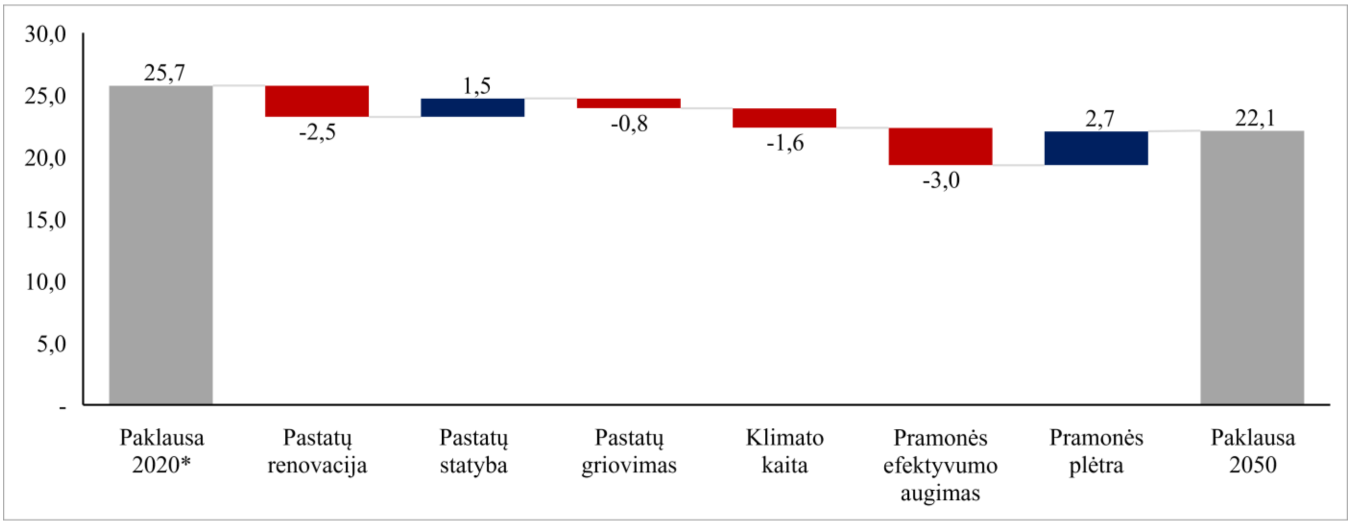
In accordance with the precautionary principle and in order to be prepared for a less optimistic pace of renovation of the building stock, the scope of this Study is modelled on the premise that 40% of the surface area of buildings envisaged in the LTRS will be renovated by 2050. This solution allows for the development of the required policy measures to increase supply efficiency, also in the event that

124 The reference year is calculated as the average for 2018, 2019 and 2021 (more details in Chapter 5.1).

the LTRS renovation targets are not fully met. In this way, even if the sectoral targets for reducing FEC and PEC intensity are not fully met, the GHG emission reduction targets would still be achievable.

Under the baseline scenario offering a forecast of heating demand, taking into account all the factors influencing heating demand, it is projected that heating demand would decrease by 14% (from 25.7 TWh in 2020 to 22.1 TWh in 2050).

69 Figure. Forecast of the change in heating demand in 2020-2050 (baseline scenario), UEC, TWh



Source: authors of the Study

2. Potential for enhancing heating supply efficiency

As described above, long-term strategic objectives for the energy sector shape two main strands of action for enhancing heating supply efficiency:

- Efficient infrastructure: a key measure to reduce PEC intensity.
- Sustainable fuel mix: a key measure to increase the RES share and to reduce GHG emissions.

An analysis of the heating supply structure has revealed that when assessing fuel sustainability (the RES share in the fuel mix):

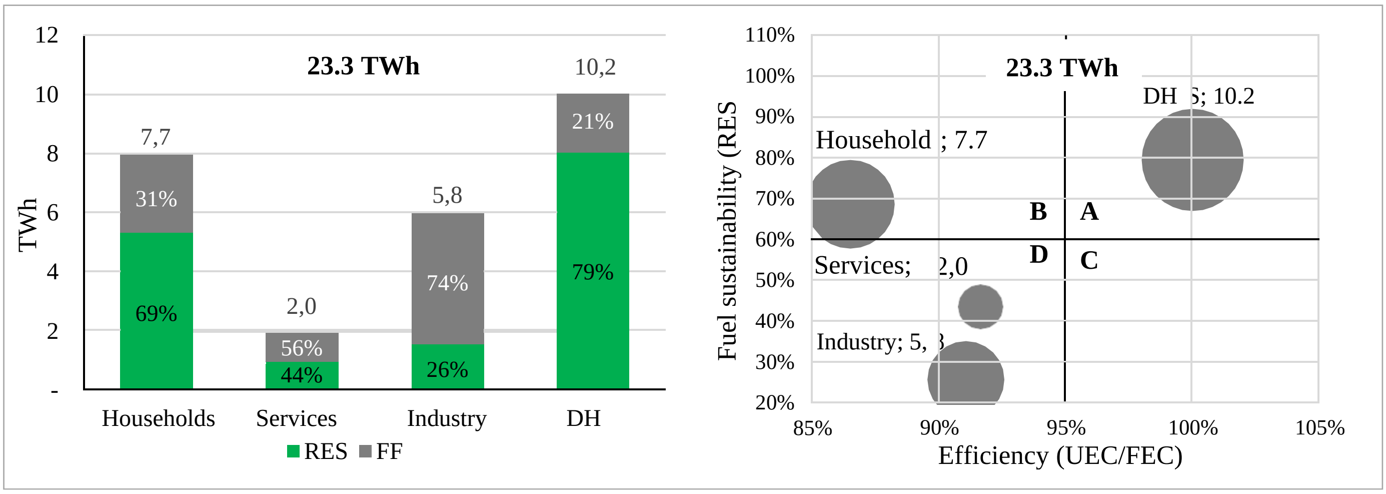
- The best indicators are in the district heating (DH system) segment where the RES share reaches 79%.
- The smallest RES share is in the industry sector: 26%.

In assessing the efficiency of manufacturing infrastructure:

- The best UEC to FEC ratio is also in the district heating segment (100%).
- The lowest efficiency is in the household segment (it is estimated that about 50% of biomass-fuelled boilers are inefficient[125]).

125 Functional operation factor (FOF) of approximately 77%.

70 Figure. Heating supply efficiency indicators (2020)



Source: authors of the Study

As a significant part of the heating sector's fuel mix consists of natural gas (29% in 2020) and there is a steady increase in the share of electricity (5% in 2020), it is important to assess the most probable scenarios for the development of the gas and electricity sectors when setting targets for enhancing the efficiency of the heating sector.

Long-term scenarios for the development of the Lithuanian gas sector are not fully simulated in strategic planning documents. The Roadmap for the development of the gas transmission system published by the European Network of Transmission System Operators for Gas (ENTSOG)[126] offer projections for three fundamental scenarios for the configuration of the gas transmission system:

- Methane scenario (in combination with the CCUS[127] technology).
- Methane and hydrogen mix scenario (in combination with the CCUS technology).
- Hydrogen scenario.

It is estimated that by 2050 the gas sector configuration will be in line with the interim gas sector development scenario, i.e. natural gas will be blended with renewable gas (ratio 20/80) while the CCUS technology will be used to control the remaining GHG emissions.

To sum up the long-term objectives set for Lithuania's electricity sector, it can be concluded that the main goal for 2050 is for Lithuania to consume only domestic electricity produced from RES. The baseline scenario assumes that this strategic objective for the electricity sector will be achieved, i.e. in 2050, 100% of electricity consumed in the heat sector will be produced in Lithuania using RES.

Taking into account the objectives set for the heating sector, the most probable scenarios for the development of the sectors concerned and the analysis of the current situation, the following priority strands of action for enhancing supply efficiency are established.

126 https://www.entsog.eu/entsog-roadmap-2050.

127 Carbon Capture, Utilisation, and Storage.

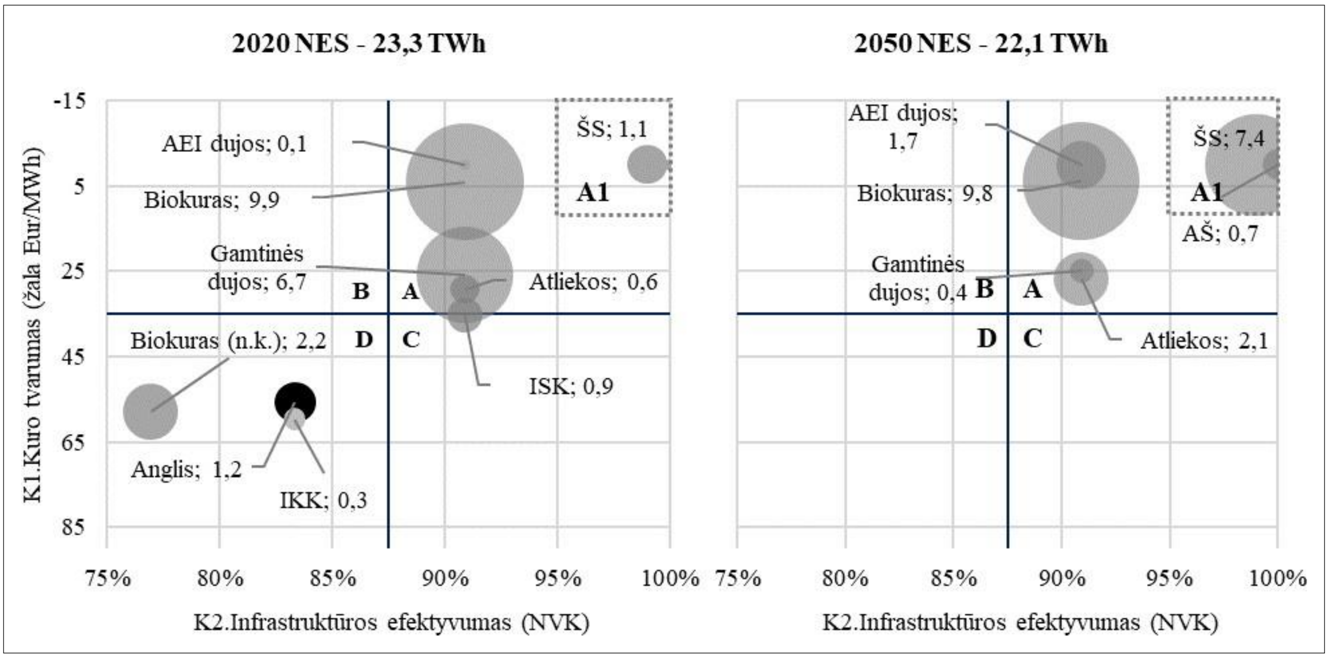
Table 189. Strands of action for enhancing heating supply efficiency (summary)

Sector	Efficiency indicators (2020)		Strands of action for enhancing efficiency (2050)	
	Infrastructure efficiency	**Fuel sustainability**	**Heating sector**	**Sectors concerned**
District heating	high	high	• Rational development • Optimisation of the production structure • Reducing supply losses (4G network transformation) • Waste heat integration	• RES share in the electricity generation structure (100%) • RES share in the gas network (80%)
Decentralised heating – Households	Low	Medium	• Eliminating consumption of solid and liquid fossil fuels • Eliminating natural gas consumption • Eliminating inefficient biofuel production sources • Limiting biofuel consumption	
Decentralised heating –Service sector	Medium	Medium	• Eliminating consumption of solid and liquid fossil fuels • Eliminating natural gas consumption • Limiting biofuel consumption	
Decentralised heating – Industry sector	Medium	Low	• Eliminating consumption of solid and liquid fossil fuels • Reducing natural gas consumption • Implementing the CCUS technology	

Source: authors of the Study

After the implementation of the efficiency enhancing tasks in 2050, the heating sector would eliminate the supply of relatively polluting fuels and low efficiency, i.e. the supply would migrate from Square D to Square A.

Figure 71. Transformation of heat production structure (2050)



Source: authors of the Study

To sum up, under the baseline scenario:

- Consumption of solid and liquid fossil fuels is eliminated (2.5 TWh in 2020).
- Natural gas consumption is reduced significantly (from 6.7 TWh to 0.4 TWh) (both due to reduced gas consumption and gas sector transformation).
- Inefficient sources of biofuel production are eliminated (2.3 TWh in 2020).
- Thanks to the spread of heat pumps and waste heat integration, the share of ambient energy increases almost 7-fold (from 0.8 TWh to 5.9 TWh).

The sectoral change in the production structure under the baseline scenario for 2050 is disclosed in the table below.

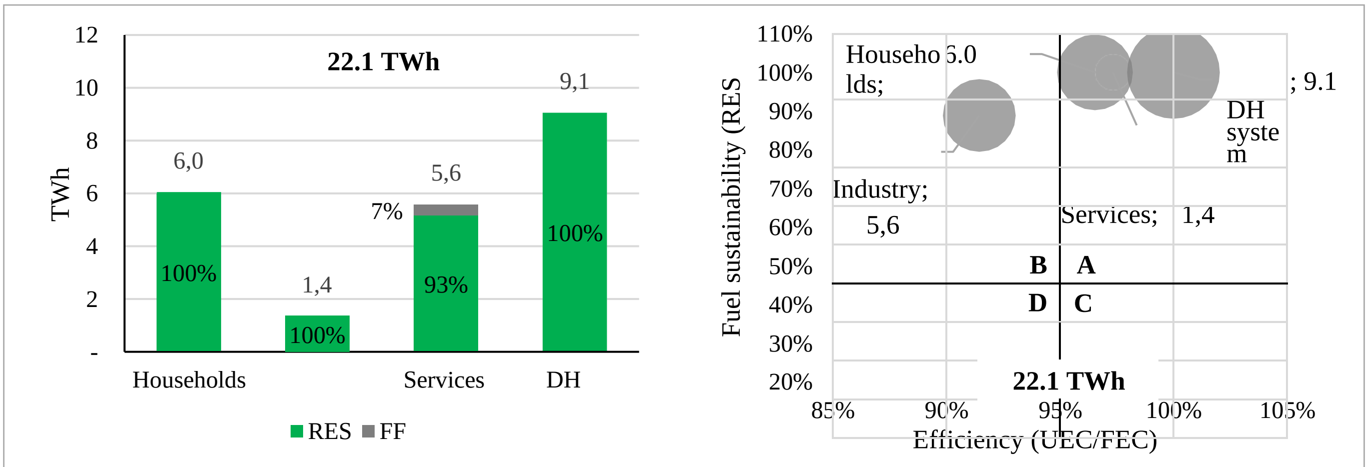
Table 190. Changes in the production structure in 2050 (summary)

Fuel	UEC 2020	Change	UEC 2050				
			Total	Households	Services	Industry	DH system
Coal	1.221	-1,221	-	-	-	-	-
Solid fuel	347	-347	-	-	-	-	-
Petroleum products	904	-904	-	-	-	-	-
Natural gas	6.743	-6,328	415	-	-	415	-
Total FF	**9.214**	**-8,799**	**415**	**-**	**-**	**415**	**-**
RES gas	96	+1,600	1.697	-	38	1.659	-
Biofuel	9.933	-170	9.762	2.164	335	2.318	4.945
Biofuel (n.k.)	2.232	-2,232	-	-	-	-	-
Waste	597	+1,473	2.070	-	-	825	1.245
Waste heat	89	+350	441	-	-	-	441
Solar collectors	-	+251	251				251
Electricity (HP)	419	+2,122	2.541	1.439	367	133	602
Ambience (HP)	712	+4,157	4.869	2.446	624	227	1.572
Total RES	**14.079**	**+7,552**	**21.631**	**6.049**	**1.364**	**5.162**	**9.056**
TOTAL (UEC)	**23.292**	**-1,247**	**22.046**	**6.049**	**1.364**	**5.577**	**9.056**

Source: authors of the Study

A change in the production structure would allow achieving these 2050 heating supply indicators.

72 Figure. Heating supply efficiency indicators (2050)



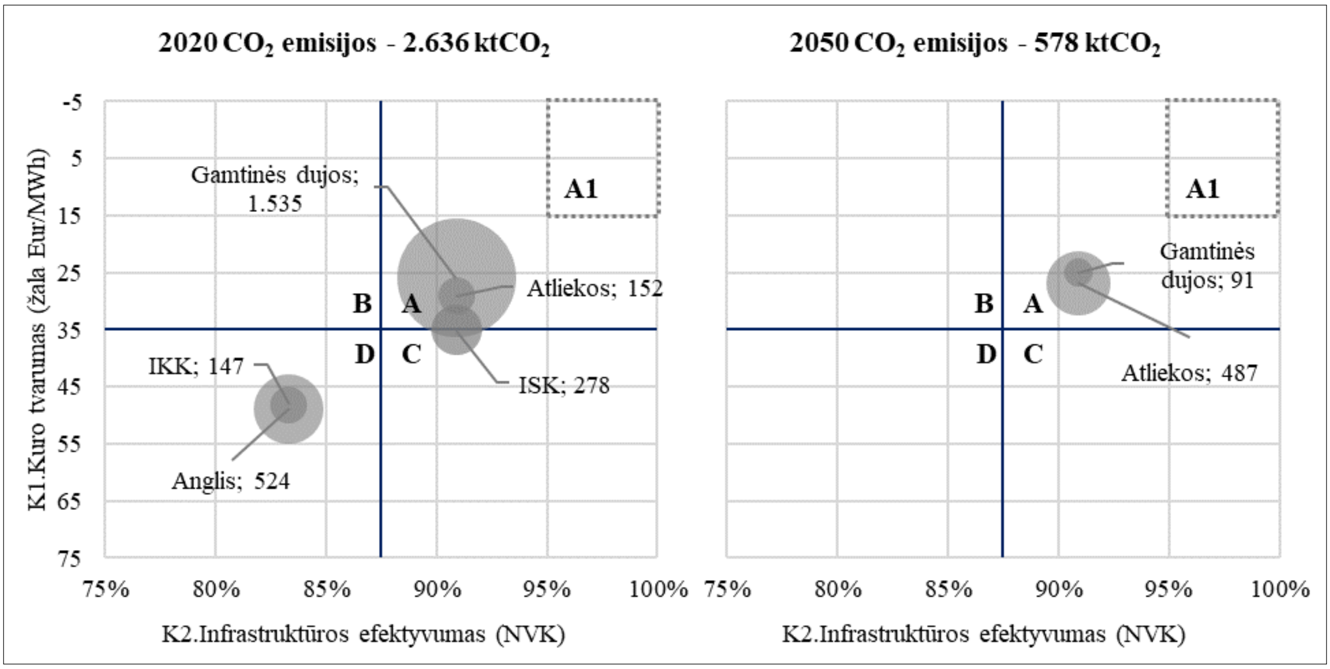
Source: authors of the Study

As one might notice, in 2050:

- The fuel mix in the sectors using heating energy for space heating (households, the service sector and the DH system) is dominated by RES fuel sources and the supply is in a range of relatively high efficiency and fuel sustainability (Square A).
- The industry sector's supply, due to the relatively lower use of the heat pump technology, is within a less efficient range (Square B).
- As most of the heating energy in the industry sector is not used for space heating but rather for production processes[128], it is projected that about 11% of the sector's fuel mix will consist of fossil fuels while the CCUS technology will be used to control the remaining GHG emissions.

This transformation of the heat production structure would reduce CO_2 emissions by more than 4 times.

73 Figure. Change in CO_2 emissions (2020-2050)



Source: authors of the Study

In the baseline scenario, upon taking full advantage of the possibilities for enhancing heating efficiency established in the Study, the following indicators would be achieved.

Projected indicators for the heating sector for 2050

Sector	Objective for 2050	Target indicators	Baseline scenario indicators
Heat sector	T1. Decrease in FEC intensity	18.8 TWh	22.8 TWh
	T2. Decrease in PEC intensity	20.6 TWh	24.5 TWh
	T3. GHG emissions	0 kt CO_2	578 kt CO_2
	T4. RES share in the DH sector	100%	100%
	T5. RES share in the decentralised sector	90%	97%

Source: authors of the Study

As can be seen, under the baseline scenario, the target indicators for Targets T1 and T2 (FEC 18.8 TWh and PEC 20.6 TWh) are not fully met. This indicator is mainly influenced by measures to enhance heating demand efficiency. In order to achieve the target, measures planned in the Long-Term Renovation Strategy (LTRS) to enhance demand efficiency should be implemented to the full extent.

128 A specific fuel type may be important for the production process, e.g. when the process requires a specific heat temperature or a specific chemical element is generated during combustion.

It is also important to note that while the target indicators for Targets T1 and T2 have not been fully met, their structure in 2050 shows a significant increase in the share of ambient energy.

NB: under the baseline scenario, a significant part of primary energy consumption (PEC) and final energy consumption (FEC) in their structure in 2050 (about 7.5 TWh, 30%) is thermal energy generated by heat pumps. The electricity used to produce this amount of thermal energy is about a third (approximately 2.5 TWh).

The target indicator for Target T3 (0 kt CO_2 emissions) is not fully met. The remaining share of the emissions comprises the following:

- Emissions from waste incineration plants (488 kt CO_2/year). The emissions come from three installations of high capacity and economic capacity participating in the ETS. Accordingly, it is assessed that, with appropriate financial incentives (high cost of allowances), the remaining emission damage can be controlled with the CCUS technology. With the growing RES share in the waste composition, the need for the CCUS technology would proportionately decrease.
- Emissions from natural gas (91 kt CO_2/year). The emissions come from the industry sector, which in the baseline scenario is projected to consume about 2 TWh of the gas mixture with low CO_2 footprint, 20% of which will be attributable to natural gas. As in the case of waste incineration plants, it is assessed that, with appropriate financial incentives (high cost of allowances), a major proportion of the remaining emission damage can be controlled with the CCUS technology.

In the baseline scenario, the indicators of the remaining objectives (T4 and T5) are fully met.

8.7. SCENARIO ANALYSIS

As described in Chapter 8.2.3, the baseline scenario is simulated using the following key parameters (2050):

1. in 2050, 100% of electricity consumed in the heat sector is produced in Lithuania using RES.
2. Structure of the gas mixture supplied by gas networks:
    - 80% renewable gas. Of which: 50% – synthetic methane and hydrogen produced using RES electricity, 30% – indigenous or imported biomethane.
    - 20% natural gas and liquefied natural gas.
3. Generating heat from electricity is cheaper than from gas mixture.
4. Biofuels are considered to be climate-neutral.
5. 40% of the building surface area of buildings to be renovated under the LTRS is renovated.

The analysis of alternative scenarios (AS) was carried out in order to assess how possible changes in the key parameters of the baseline scenario would affect the achievement of the long-term objectives in the heat sector. Three main alternative scenarios are considered:

- RES electricity – MAX (AS-1). The scenario is simulated based on the assumption that RES electricity volumes and technological solutions in 2050 bring about a low electricity price and are fully sufficient for a breakthrough in renewable gas production, eliminating the need for natural gas.
- RES electricity – MIN (AS-2). The scenario is simulated based on the assumption that RES electricity volumes and technological solutions in 2050 are not sufficient for a breakthrough in renewable gas production.
- Waste heat – MAX (AS-3). The scenario is simulated based on the assumption that most of the theoretical waste heat potential identified is realised in 2050.

The table below offers a comparison of the heat production structure (FEC) for each scenario.

191 Table. Comparison of the production structure in 2050

Fuel	**Baseline scenario**	**RES electricit y – MAX**	**RES electricity – MIN**	**Waste heat – MAX**
Natural gas	2%	-	8%	2%
RES gas	8%	10%	2%	8%
Biofuel	45%	29%	45%	42%
Heat pumps	32%	48%	32%	32%
Waste	9%	9%	9%	9%
Waste heat, solar collectors	3%	3%	3%	6%

Source: authors of the Study

As one might notice:

- Natural gas is completely replaced with renewable gas (biomethane and synthetic methane and hydrogen) in the production structure under Scenario AS-1. Part of biofuel supply also migrates towards the heat pump technology.
- Synthetic gases (synthetic methane and hydrogen) are eliminated from the production structure under Scenario AS-2, proportionately boosting the amount of natural gas.
- In the production structure under Scenario AS-3, the share of biofuel supply decreases proportionately after the realisation of most of the waste heat potential.

The impact of the scenarios on the achievement of the long-term objectives for the heat sector is summarised in the table below.

192 Table. Comparison of achievement of energy targets in the heat sector in 2050

Target	Unit of measu rement	Target indicators	BS	AS-1	AS-2	AS-3
T1. Decrease in FEC intensity	TWh	18,8	22,8	22,6	22,8	22,8
T2. Decrease in PEC intensity	TWh	20,6	24,5	24,2	24,5	24,4
T3. GHG emissions	kt CO_2	-	578	487	851	578
T4. RES share in the DH sector	per cent	100%	100%	100%	100%	100%
T5. RES share in the decentralised sector	per cent	90%	97%	100%	87%	97%

Source: authors of the Study

AS-1: RES electricity – MAX

The scenario simulates a situation where RES electricity volumes and technological solutions in 2050 bring about a low electricity price and are fully sufficient for a breakthrough in renewable gas production. In this way, a larger proportion of decentralised heat consumers opt for electricity-based heating solutions. In addition, demand for natural gas and related damage are eliminated completely.

In such a situation, it is estimated that:

- The migration of consumers towards heat pump technology is intensifying. Accordingly, the share of biofuels in the production structure is reduced and is as follows: Households and the service sector – 10% each, the industry sector – 30%, DH systems – 44%.
- Renewable gases make up 100% of the gas mix. Natural gas consumption in the industry sector is therefore eliminated.

A comparison of the projected fuel mix under this scenario with the baseline scenario fuel mix is given in the table below.

193 Table. Comparison of the fuel mix between AS-1 and the baseline scenario

Fuel	UEC 2020	UEC 2050		
		BS	AS-1	Change
Coal	1.222	-	-	-
Solid fuel	347	-	-	-
Petroleum products	904	-	-	-
Natural gas	6.742	415	-	-415
Total FF	**9.214**	**415**	**-**	**-415**
RES gas	96	1.697	2.074	+377
Biofuel	9.933	9.762	6.550	-3,493
Biofuels (n/e)	2.232	-	-	-
Waste	597	2.070	2.070	-
Waste heat	89	441	441	-
Solar collectors	-	251	251	+251
Electricity (HP)	419	2.541	3.729	+812
Ambience (HP)	712	4.869	7.211	+2,342
Total RES	**14.079**	**21.631**	**22.046**	**+415**
Total	**23.292**	**22.046**	**22.046**	**-**

Source: authors of the Study

The impact of the scenario on the achievement of energy targets for the heat sector is showed in the table below.

194 Table. Comparison of indicators between AS-1 and the baseline scenario

Objective	Unit of measurement	Target indicators for 2050	Indicator forecasts for 2050		
			BS	AS-1	Change
T1. Decrease in FEC intensity	TWh	18,8	22,8	22,6	-0.3
T2. Decrease in PEC intensity	TWh	20,6	24,5	24,2	-0.4
T3. GHG emissions	kt CO_2	-	578	487	-91
T4. RES share in the DH sector	per cent	100%	100%	100%	-
T5. RES share in the decentralised sector	per cent	90%	97%	100%	+3%

Source: authors of the Study

It can be observed that in the scenario under consideration:

- Increased use of heat pump technology causes Targets T1-T2 and T5 to improve.
- It is also important to note that while the target indicators for Targets T1 and T2 have not been fully met, their structure in 2050 under this scenario shows the most significant increase in the share of ambient energy (AS-1 – 7.5 TWh, BS – about 5 TWh).
- The elimination of natural gas reduces GHG emissions (the rest of emissions are generated by the waste incineration process) and improves the indicators for T3 and T5.

AS-2: RES electricity – MIN

The scenario simulates a situation where RES electricity volumes and technological solutions in 2050 are not sufficient for a breakthrough in renewable gas production. In this way, the heat production structure retains a larger share of natural gas and related damage.

In this situation, it is estimated that renewable gases (biomethane) make up only 20% of the gas mixture, the rest is natural gas.

A comparison of the projected fuel mix under this scenario with the baseline scenario fuel mix is given in the table below.

195 Table. Comparison of the fuel mix between AS-2 and the baseline scenario

Fuel	UEC 2020	UEC 2050		
		BS	AS-2	Change
Coal	1.222	-	-	-
Solid fuel	347	-	-	-
Petroleum products	904	-	-	-
Natural gas	6.742	415	1.659	+1,244
Total FF	**9.214**	**415**	**1.659**	**+1,244**
RES gas	96	1.697	453	-1,244
Biofuel	9.933	10.043	10.043	-
Biofuels (n/e)	2.232	-	-	-
Waste	597	2.070	2.070	-
Waste heat	89	441	441	-
Solar collectors	-	251	251	+251
Electricity (HP)	419	2.541	2.541	-
Ambience (HP)	712	4.869	4.869	-
Total RES	**14.077**	**21.632**	**20.388**	**-1,244**
TOTAL UEC	**23.292**	**22.046**	**22.046**	**-**

Source: authors of the Study

The impact of the scenario on the achievement of energy targets for the heat sector is showed in the table below.

196 Table. Comparison of indicators between AS-2 and the baseline scenario

Objective	Unit of measurement	Target indicators for 2050	Indicator forecasts for 2050		
			BS	AS-2	Change
T1. Decrease in FEC intensity	TWh	18,8	22,8	22,8	-
T2. Decrease in PEC intensity	TWh	20,6	24,5	24,8	-
T3. GHG emissions	kt CO_2	-	578	886	+273
T4. RES share in the DH sector	%	100%	100%	100%	-
T5. RES share in the decentralised sector	%	90%	97%	90%	-7%

Source: authors of the Study

It can be observed that in the scenario under consideration, higher volumes of natural gas cause an increase in GHG emissions and a decrease in RES share in the decentralised sector. At the same time, the indicators for T3 and T5 are deteriorating. The appropriate management of emissions calls for additional measures need to be implemented.

AS-3: Breakthrough scenario for waste heat

The scenario simulates a situation where technological solutions in 2050 allow to realise most of the identified theoretical potential of waste heat.

197 Table. Summary on the potential of waste heat used in Lithuania

Heat generation installations	Thermal power	Waste heat potential		
		Technical	Realised (BS)	Realised (AS-3)
1. Thermal power plants, whether or not capable of being modified so as to be able to supply waste heat, with a total thermal power exceeding 20 MW	> 20 MW	93	78	78
2. Heat and power cogeneration installations of a total thermal power exceeding 20 MW	> 20 MW	55	-	
3. Waste incineration plants	-	71	-	
4. Power installations with a total thermal power exceeding 20 MW using RES energy for heat or cold production other than those referred to in paragraphs 1 and 2	> 20 MW	-	-	
5. Power installations with a total thermal power of less than 20 MW and more than 1 MW in which heat or cooling is produced using RES energy.	1 to 20 MW	-	-	
6. Industrial installations with a total thermal input exceeding 20 MW from which waste heat can be supplied	> 20 MW	70	70	70
7. Other sources of waste heat	Not applicable	1.391	253	1.043
Total		**1.680**	**401**	**1.191**

Source: authors of the Study

In this situation, it is estimated that three quarters of the technical quantity of waste heat from other waste heat sources (data centres, food retail and centralised waste water treatment plants) will be connected to the DH networks.

A comparison of the projected fuel mix under this scenario with the baseline scenario fuel mix is given in the table below.

198 Table. Comparison of the fuel mix between AS-3 and the baseline scenario

Fuel	UEC 2020	UEC 2050		
		BS	AS-3	Change
Coal	1.222	-	-	-
Solid fuel	347	-	-	-
Petroleum products	904	-	-	-
Natural gas	6.742	415	415	-
Total FF	**9.214**	**415**	**415**	**-**
RES gas	96	1.697	1.697	-
Biofuel	9.933	10.043	9.074	-968
Biofuels (n/e)	2.232	-	-	-
Waste	597	2.070	2.070	-
Waste heat	89	412	1.129	+968
Solar collectors	-	251	251	-
Electricity (HP)	419	2.541	2.541	-
Ambience (HP)	712	4.869	4.869	-
Total RES	**14.077**	**21.632**	**21.632**	**-**
TOTAL UEC	**23.292**	**22.046**	**22.046**	**-**

Source: authors of the Study

The impact of the scenario on the achievement of energy targets for the heat sector is showed in the table below.

199 Table. Comparison of indicators between AS-3 and the baseline scenario

Objective	Unit of measurement	Target indicators for 2050	Indicator forecasts for 2050		
			BS	AS-2	Change
T1. Decrease in FEC intensity	TWh	18,8	22,8	22,8	-
T2. Decrease in PEC intensity	TWh	20,6	24,5	24,4	-0.1
T3. GHG emissions	kt CO_2	-	578	578	-
T4. RES share in the DH sector	per cent	100%	100%	100%	-
T5. RES share in the decentralised sector	per cent	90%	97%	97%	-

Source: authors of the Study

It can be observed that in the scenario under consideration:

- A bigger waste heat quantity and efficiency reduces PEC intensity in comparison with other technologies (the indicator for T2 is improving);
- The remaining indicators stay unchanged as waste heat is used in the DH sector where the targets under the baseline scenario have already been achieved.
- If biofuels were not considered climate-neutral, the maximum integration of waste heat would improve the indicator for T2.

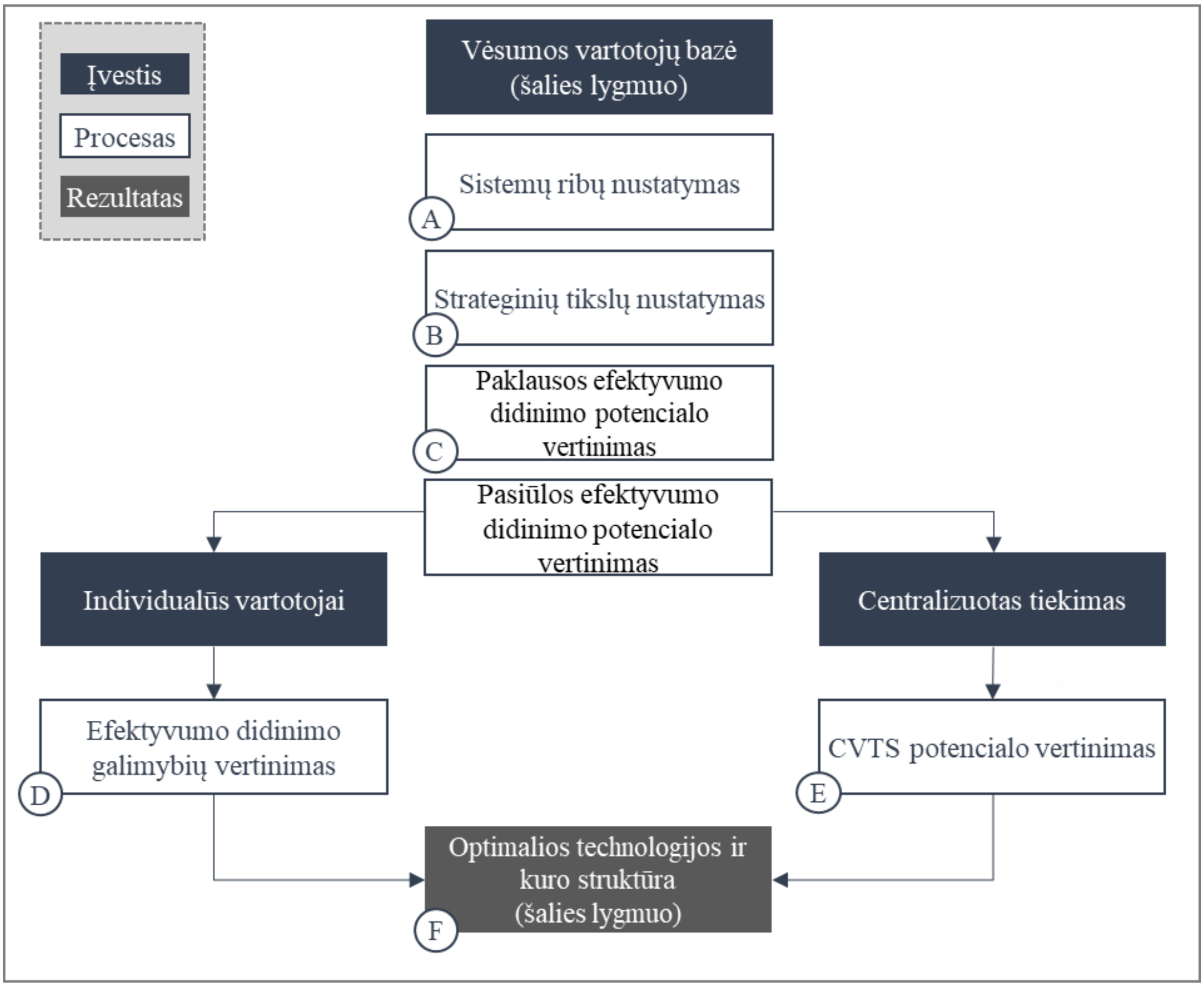
9. ASSESSMENT OF THE POTENTIAL FOR EFFICIENT COOLING

Recommendation 4.1.1. Member States may use various means to analyse the economic potential of heating and cooling technologies but the method must:

- apply throughout the territory of the country;
- be based on a cost-benefit analysis;
- apply when identifying alternative scenarios for more efficient and renewable heating and cooling technologies, including the development of baseline and alternative scenarios for national heating and cooling systems;
- be used to cover a wide range of technologies such as industrial waste heat and cooling, waste incineration, high-efficiency cogeneration, other renewable energy sources, heat pumps and heat loss reduction in existing centralised networks; and
- be applied taking into account socioeconomic and environmental factors

A logic circuit of the model for assessing efficient cooling options is shown in the figure below:

Figure 74. Assessment model for the potential for efficient heating



Source: authors of the Study

Stage A. Geographical and system delimitation

The first stage identifies geographical and system boundaries by defining groups of cooling consumers and suppliers whose energy exchanges are or may be significant. An assessment of efficient cooling options is carried out at the level of each system identified.

The results of Stage A are presented in Chapter 9.1.

Stage B. Analysis of strategic objectives

An analysis of strategic objectives for the entire energy sector and specifically for the cooling sector is carried out as a second stage. The analysis identifies (and, where appropriate, calculates) the cooling sector target indicators and their target values for 2050.

The results of Stage B are presented in Chapter 9.2.

Stage C. Assessment of the potential for enhancing consumption (demand) efficiency

At this stage, the potential for enhancing cooling efficiency is assessed. The

results of Stage C are presented in Chapter 9.3.

Stage D. Assessment of the potential for enhancing cooling supply efficiency

At this stage, the current efficiency of cooling supply and its potential for improvement are assessed in the light of the main strategic objectives:

The results of Stage D are presented in Chapter 9.4.1.

Stage E. Determination of the potential of a district cooling system

At this stage, the development potential of the district cooling system is determined. Within its scope The study identifies areas and buildings that are conducive to the supply of district cooling and can potentially use district cooling but does not assess the financial or economic feasibility of connecting these buildings to the district cooling network.

The results of Stage E are presented in Chapter 9.4.2.

Stage F. Summary of assessment results

A summary of the results of the assessment of efficient heating potential is given in Chapter 9.5.

9.1. ANALYSIS OF STRATEGIC OBJECTIVES

Recommendation 3.1. A specific heating and cooling policy must be consistent with the five dimensions of the Energy Union, in particular in the area of energy efficiency:

1. decarbonisation;
2. energy efficiency;
3. energy security;
4. the internal energy market;
5. research, innovation and competitiveness.

Member States must describe how energy efficiency and GHG emission reductions in the heating and cooling sector are consistent with those five aspects and quantify them where justified and possible.

The cooling supply system is an integral part of the general energy sector, technically and energy flow-wise closely connected to the power grid, fuel supply and other systems. Accordingly, the objectives of the cooling sector are examined in the context of the overall objectives of the energy sector at national level.

Objectives for the energy sector for 2050

To sum up the analysis of the strategic objectives of the Lithuanian energy sector (see Chapter 8.2.1), the following key objectives for 2050 can be identified:

200 Table. Objectives for Lithuania's energy sector for 2050

Sector	Objective	Target indicators (2050)
Lithuania, total	Decrease in PEC and FEC intensity (compared to 2017)	2.4-fold
	GHG emissions reduction (compared to 1990)	95%
	RES share in FEC	80%

Source: authors of the Study

Objectives for the cooling sector for 2050

The above objectives for the energy sector as a whole are not specifically broken down at sectoral level. Values[129] of the cooling sector targets for 2050 distinguished (calculated) from the country's overall targets applicable to the cooling sector for the purposes of the Study are presented in the table below.

201 Table. Energy targets for the cooling sector for 2050

Sector	Objective	Target indicators (2050)		
		Set	Calculated	
Cooling sector	T1. Decrease in FEC intensity	-	2.4-fold	-
	T2. Decrease in PEC intensity	-	2.4-fold	-
	T3. GHG emissions	0%	0%	0 kt CO_2
	T4. RES share in the DH sector	100%	100%	100%
	T5. RES share in the decentralised sector	-	100%	100%

Source: authors of the Study

NB: since the cooling sector is still developing and constitutes a negligible part of the overall heating and cooling sector as well as the entire energy sector, it does not have a specific FEC and PEC indicator (compared to the 2017 level) within the scope of the Study but generic goals for efficient consumption and production of cooling are defined.

129 Detailed information is provided in Annex 2.3.

To sum up these objectives, three main expectations can be formulated for the area of cooling energy efficiency:

1. Rational consumption: a key measure to reduce (or stall) FEC intensity (Target T1).
2. Efficient infrastructure: a key measure to reduce (or stall) PEC intensity (Target T2).
3. Sustainable fuel mix: a key measure to reduce GHG emissions (Targets T3 to T5).

As far as the energy supply chain is concerned, these expectations are grouped into two groups (see Chapter 8.2.1 for details):

- Increasing cooling demand efficiency and
- Increasing cooling supply efficiency.

Link between the heating sector and other energy sectors

The cooling supply system is closely related to the power sector. Virtually all cold is generated by electricity. Accordingly, it is important to take into account the most likely scenario for the development of the electricity sector when defining the objectives for improving the efficiency of the cooling sector (for details see Chapter 8.2.2).

9.2. GEOGRAPHICAL AND SYSTEM BOUNDARIES

Recommendation 4.1.1.

A geographically defined area must be fully representative of the area under assessment, i.e. the administrative territory of the Member State concerned. In an area delimited by geographical boundaries, Member States should identify synergies of heat and cooling demand with heat and cooling from waste and renewable energy sources.

Geographical boundaries

Although the area defined within common geographical boundaries must fully correspond to the administrative territory of the Member State concerned, for large Member States it is recommended to subdivide their territory into regions (e.g., NUTS-1) to facilitate the drawing up of maps and plans and to take account of different climate zones.

The entire territory of the Republic of Lithuania (about 65,000 km^2) is classified as NUTS-1 level. The entire territory of Lithuania falls within the cool temperate climate zone. Although the climate impact of the Baltic Sea is felt in the western part of the country, energy consumption of buildings differs from the rest of the country by only 2%[130]. Since climate-related differences in energy consumption between the western part and the rest of the country are not significant, the entire territory of the Republic of Lithuania within the scope of this Study is considered as one geographical area.

System boundaries

System boundaries define a group of cooling consumers and suppliers whose energy exchanges are or may be significant. Unlike the heating sector, there are currently no developed district cooling systems. Accordingly, the entire territory of the Republic of Lithuania within the scope of this Study is assessed as a single system.

130 Study on drawing up the long-term strategy for channelling investments to the renovation of the national stock of residential and commercial buildings owned both publicly and privately.

9.3. POTENTIAL FOR ENHANCING CONSUMPTION/DEMAND EFFICIENCY

Enhancing the efficiency of the cooling sector comprises two principal strands: enhancing the efficiency of cooling consumption (demand) and enhancing the efficiency of cooling supply (for details see Chapter 9.4).

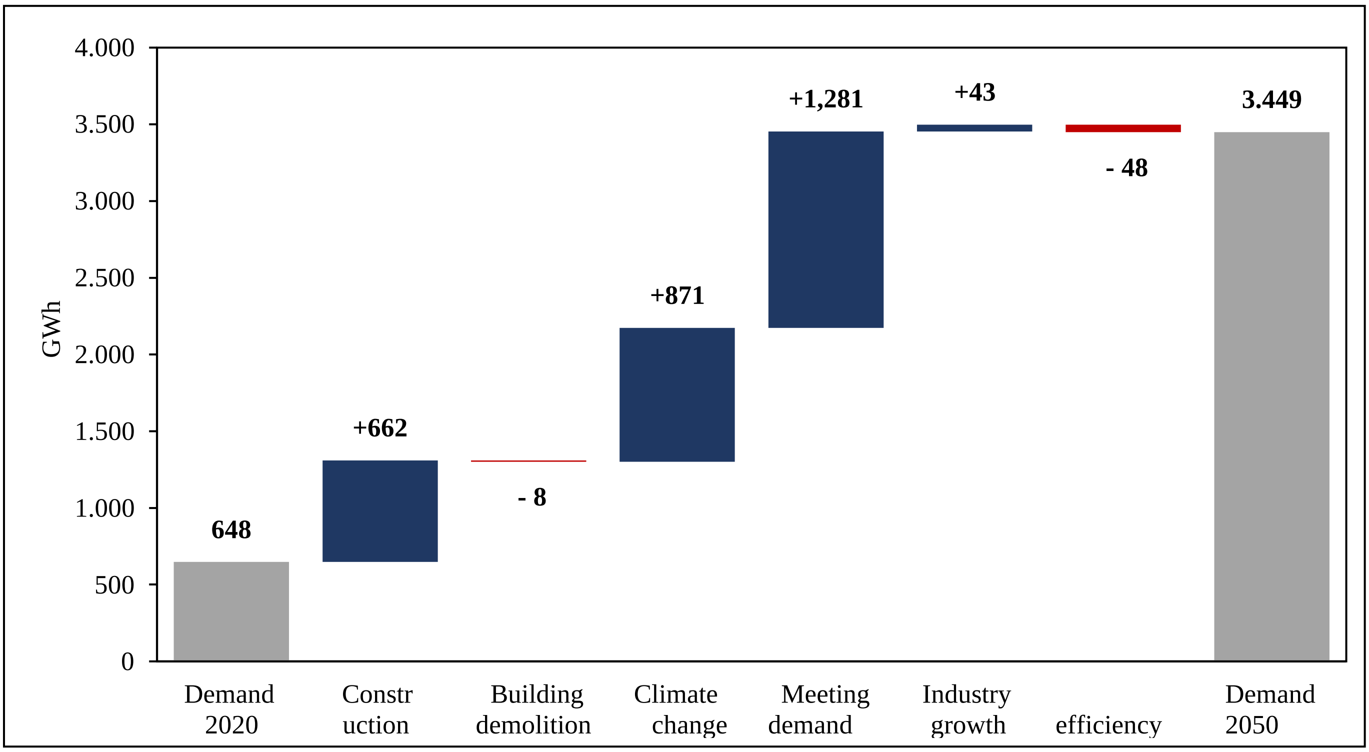
The first step in assessing the potential for enhancing the efficiency of the cooling sector is the analysis of the potential for enhancing cooling efficiency.

To sum up the results of our forecast of cooling demand (for details see Chapter 6.2), the baseline scenario foresees that cooling demand will increase about 4 times in 2050 (from 0.6 TWh in 2020 to 3.4 TWh in 2050). The main drivers of change in demand will be the following:

- An increasing level of meeting the need for cooling;
- Climate change.

At the same time, the demand for cooling will also be influenced by other factors – changes in the building stock and the development of the industry sector. Detailed information on the cooling demand forecast is provided in Chapter 6. Changes in demand in the baseline scenario according to the factors influencing demand are presented in the figure below.

Figure 75. Evolution of cooling demand UEC in 2020-2050, GWh



Source: authors of the Study

It can be observed that the baseline scenario does not result in significant measures to enhance the efficiency of efficient use of cooling (with the exception of efficiency gains in the industry sector). It is important to note that unlike the heating sector where heating is a necessity and heat is used mainly in inefficient buildings, the cooling sector is still emerging, i.e. cooling technologies are only just beginning to be deployed and are generally implemented using the most efficient solutions available. Accordingly, no efficiency enhancing tasks are defined for existing cooling consumption but it is planned that effective solutions for meeting future cooling consumption will be promoted.

9.4. POTENTIAL FOR ENHANCING SUPPLY EFFICIENCY

The second step in assessing the potential for enhancing the efficiency of the cooling sector is analysing the potential for enhancing cooling supply efficiency, which is done in the light of the main strategic objectives (Chapter 9.1):

- To increase the share of RES in cold production.
- To reduce GHG emissions.

9.4.1. Assessment of the potential for enhancing cooling efficiency

The potential for enhancing cooling supply efficiency was assessed in 3 stages:

a. Analysis of existing (2020) supply efficiency indicators.
b. Prioritising efficiency enhancement in line with the long-term objectives of the sector.
c. Formulation of efficiency enhancing tasks.

a. Analysis of existing (2020) supply efficiency indicators

A summary of the key performance indicators of cooling supply efficiency can be found below.

202 Table. Decentralised heat supply indicators in households in 2020

Fuel	UEC	FEC	GHG	PM	Emissions in 2020		Damage in 2020 (EUR million)		
	GWh	GWh	t/MWh	g/MWh	ktCO2	tPM	CO2	PM	Total
Heat pumps	648	648	-	-	-	-	-	-	-
Total RES	**648**	**648**	-	-	-	-	-	-	-
TOTAL	**648**	**648**	-	-	-	-	-	-	-

Source: authors of the Study

The evaluation of existing performance indicators shows that:

- Currently, all cooling is produced using HP technology.
- In the case of HP, UEC is equal to FEC but in the FEC structure about one third is made up of electricity while approximately two thirds are attributable to ambient energy.
- HP technology is linked with highest-efficiency supply causing no socioeconomic damage in the form of CO_2 and PM emissions (socioeconomic damage: 0 EUR/MWh[131]).

In conclusion, HP technology is already efficient in the production of cooling (the average FOF is 270%) and is significantly more efficient than other sources of production (e.g. natural gas boilers). By analysing possible HP variations, 3 main groups of HPs can be identified.

203 Table. Options for HP cooling generation technologies

	Aerothermal	Hydrothermal	Geothermal
Ambient heat source	Air	Water	Soil
Installation cost	Lowest	Moderate	Highest
Efficiency	Medium	High	High
Change in efficiency	With ambient temperature increasing, cooling production efficiency is dropping	With a sufficient amount /flow of water, remains stable throughout the year	Remains stable throughout the year
Noise	High	Low	Low
Heat/cold accumulation	Not possible	Not possible	In winter, the soil is cooled during the production of heat

Source: authors of the Study

131 Green electricity scenario (see Chapter 8.2.2).

These technologies are fundamentally different in terms of their deployment cost and the environment from which energy is taken, consequently their respective efficiency fluctuates. However, from the perspective of the objectives pursued, they are all in line with the target indicators, i.e. they do not generate GHG emissions and contribute to the RES share in the production structure (the green electricity scenario).

b. Priorities for enhancing efficiency

While existing cooling technologies should be assessed as efficient in achieving the overall primary energy reduction targets set in the NECAP, it is appropriate to analyse the additional potential for efficiency enhancement, i.e. the possibility of developing a district cooling network. HP technology is currently also used to provide district cooling but its centralisation essentially gives rise to two strands for efficiency enhancement:

- Enhances energy efficiency as higher power installations achieve higher energy efficiency;
- Allows to balance waste heat supply and demand during the warm season.

HP effectiveness increases with an increase in size (power). For example[132], the efficiency of a 10 MW heat pump is about 28% higher than 1 MW, so even for relatively large objects, energy efficiency can be enhanced and primary energy demand reduced.

In order to enhance energy supply efficiency, compressor or absorption heat pumps may be installed where cooling supply can be centralised. The table below provides a comparison of the typical parameters of individual and district HP types to deliver 1,000 MWh of cold.

204 Table. Efficiency comparison of heat pumps, MWh

Indicator	**Type of HP**				**Comments**
	Individual	**Compressor**	**Compressor+**	**Absorption**	
Cold generated (UEC)	**1.000**	**1.000**	**1.000**	**1.000**	**1**
Energy consumed (FEC)	1.370	1.200	1.465	1.010	2 = 3 + 4 + 5
FEC (electricity)	370	200	465	10	(3)
FEC (ambient)	1.000	1.000	1.000	-	(4)
FEC (waste heat)	-	-	-	1.000	(5)
Heat produced	1.370	1.200	1.465	-	(6) = 7 + 8
Non-useful waste heat	1.370	1.200	-	-	(7)
Useful waste heat	-	-	1.465	-	(8)
Useful energy (UEC)	**1.000**	**1.000**	**2.465**	**1.000**	(9) = 2 + 8
Efficiency (electricity)	270%	500%	530%	10000%	(10) = 9 ÷ 4

Source: authors of the Study

The heat pump of the Compressor+ type uses identical cooling production technology as compressor technology but additionally raises released waste heat temperatures to deliver it to the third generation heat networks. This makes it possible to use the heat generated during the cooling process.

Below is a summary of two basic types of district cooling technologies (HP types). 1. Air-

cooled compressor heat pumps

Air-cooled compressor heat pumps are the most common type of heat pump for large buildings. In terms of operation basically similar to a conventional air-to-water heat pump.

- **Power:** over 300 kW
- **Advantages**: less investment, simple and fast installation in virtually any place, heat generated during cooling can be inputinto the district heating network
- **Disadvantages:** more expensive operation, high noise level, high power input required
- **Efficiency of the installation:** high, and RES share in cooling UEC demand at least 80%
- **Power source used:** electricity

132 Based on https://ens.dk/en/our-services/projections-and-models/technology-data/technology-data-industrial-process-heat.

- **Sustainability of the fuel mix:** no emissions are generated during electricity consumption. Considering that in 2021 42% of electricity was renewable, and in 2030 it is planned that 100% of electricity will be renewable, fuel is seen as efficient.
- **Pilot projects:** In 2020, no building was supplied with district cooling. When the Study was being drawn up, AB Kauno energija installed two compressor heat pumps in Kaunas City: one in a commercial building of 2,000 m^2 (320 kW power) and one in a multi-apartment building of 7,195 m^2 (344 kW power). More pilot projects are needed in the future to assess the potential for developing a district cooling system.

<u>2. Absorbing cooling unit</u>

An absorption cooling unit generates cold by using thermal energy from a nearby heat generating unit or heat supplied by district heating networks. It makes sense to install absorption cooling units if there is waste heat surplus of medium and high temperatures, which would allow cold to be produced using virtually no primary energy. In the absence of excess waste heat of medium and high temperatures, the range of preferred options should include compressor cooling units that recover waste heat and those that do not.

It makes sense to install waste heat recovery facilities when it is possible to use this heat in low-temperature heat networks.

- **Power:** between 500 and 1,000 kW
- **Advantages**: cheaper operation, especially in DH systems where there is a lot of thermal energy from cogeneration, waste incineration or processes, boosts the use of heat-generating facilities, low noise level, no need for high power input
- **Disadvantages:** Higher investment required for medium- or high- temperature heat sources (incompatible with low-temperature heat networks, i.e. in the case of developing low-temperature networks, they should be installed near the mains)
- **Efficiency of the installation:** medium, converts thermal energy to cold without additional emissions while the RES share is about 100% (depending on the HP)
- **Power source used:** medium- and high-temperature heat
- **Sustainability of the fuel mix:** depends on a specific heat source but in Lithuania's case this would mostly be waste heat from industrial processes, heat from biofuel cogeneration and waste incineration and biofuel installations
- **Pilot projects:** Lithuania does not have any absorption cooling unit within its district heating or cooling systems and there are only plans to install one in the public building Mokslo sala of 11,523 m^2 in Kaunas. The unveiling of the building is planned for mid-2023, so the installation and the commissioning will happen no earlier than that

To sum up, the following priorities for enhancing efficiency in the cooling sector are defined:

1. Maintain 100% of RES-based technologies in cooling production (**high priority).**
2. Where it is appropriate to develop a district cooling network (**medium priority)**.

c. Efficiency enhancing tasks

Enhancing demand efficiency

The baseline scenario estimates that by 2050, taking into account the change in demand due to environmental factors (Chapter 7.2), cooling demand will increase to 3.4 TWh.

Enhancing supply efficiency

Tasks for enhancing cooling supply efficiency are defined depending on the priorities identified.

EET 1. Promoting efficient sources of cooling production Objective: to maintain 100% RES share RES in cold production.

Cold is currently generated by heat pumps in small and medium-sized buildings and by compressor heat pumps in large-scale (power) buildings. Due to the fact that the cooling sector is still developing, cooling production units are installed using the most technologically and economically practical solutions. This means that decentralised cooling production is inherently efficient and does not cause GHG emissions under the green electricity scenario.

It is projected that with further technological advancement cold will continue to be produced using efficient RES-based heat generating facilities.

Policy measures proposed	-

EET 2. Assessment of district cooling development

Objective: to enhance the efficiency of cooling energy production by promoting the development of DC systems.

Although current cooling supply efficiency is considered to be high, there is some potential for efficiency gains when implementing DC systems. Currently there are individual pilot DC projects in Lithuania where a cooling production facility is installed at the end are not representative or sufficient for the assessment of DC development. This means that for the assessment of the DC potential it is appropriate to continue implementing pilot projects and develop a more elaborate assessment of the potential based on these data covering actual demand for cooling and the actual costs and benefits of demand for cooling when using DC systems.

Policy measures proposed	PM30. Feasibility assessment of the development of district cooling networks

Once the planned efficiency enhancing tasks have been implemented, the decentralised heating supply indicators listed in the table below would be achieved.

205 Table. Decentralised heat supply indicators in households in 2050

Fuel	**UEC**	**FEC**	**GHG**	**PM**	**Emissions**		**SE damage (EUR million)**		
	GWh	GWh	t/MWh	g/MWh	ktCO2	ktPM	CO_2	PM	Total
HP	3.449	3.449	-	-	-	-	-	-	-
Total RES (2050)	3.449	3.449	-	-	-	-	-	-	-
TOTAL (2050)	3.449	3.449	-	-	-	-	-	-	-
Total RES (2020)	648	648	-	-	-	-	-	-	-
TOTAL (2020)	648	648	-	-	-	-	-	-	-

Source: authors of the Study

The evaluation of the indicators presented above shows that, following the planned efficiency enhancing tasks for 2050:

- Energy demand for cooling would increase fivefold.
- There would be no CO_2 emissions and no socioeconomic damage[133].

133 Green electricity scenario (see Chapter 8.2.2).

9.4.2. Assessment of the development potential of district cooling

Further in this Chapter is an illustration of the assessment of DC development potential in Vilnius and Kaunas

Cities. Factors required for an accurate assessment of the development of district cooling:

- Demand for cooling at the level of a specific building;
- District cooling system costs;
- Difference between the weighted prices of the district cooling system and of an individual solution;
- The cost of developing a district cooling network.

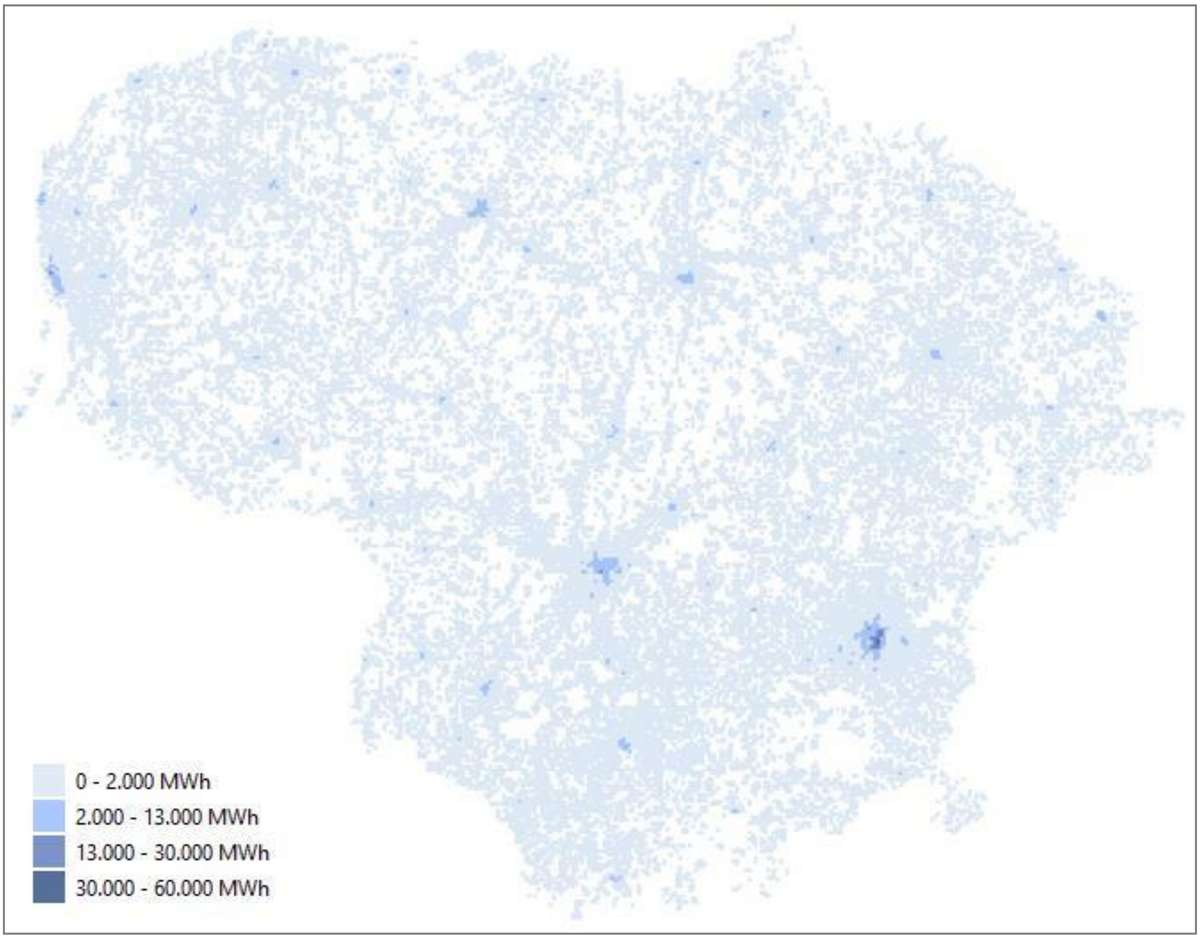
These factors define the distance at which each building could be connected by district cooling networks. Since none of these factors has been assessed in Lithuania, it is not possible to assess the scale of potential hydraulically seamless cooling networks in Lithuania.

So maps were drawn up for the cities of Vilnius and Kaunas detailing the cooling demand compaction areas and identifying buildings that could potentially be connected to DC systems.

Two types of buildings that can use district cooling were identified:

- Buildings in the service sector with an area of over 2,000 m^2
- Residential buildings with an area of over 2,000 m^2 and centralised air-conditioning solutions deployed

76 Figure. Map of the need for cooling in Lithuania, MWh/km^2, 2020



Source: authors of the Study

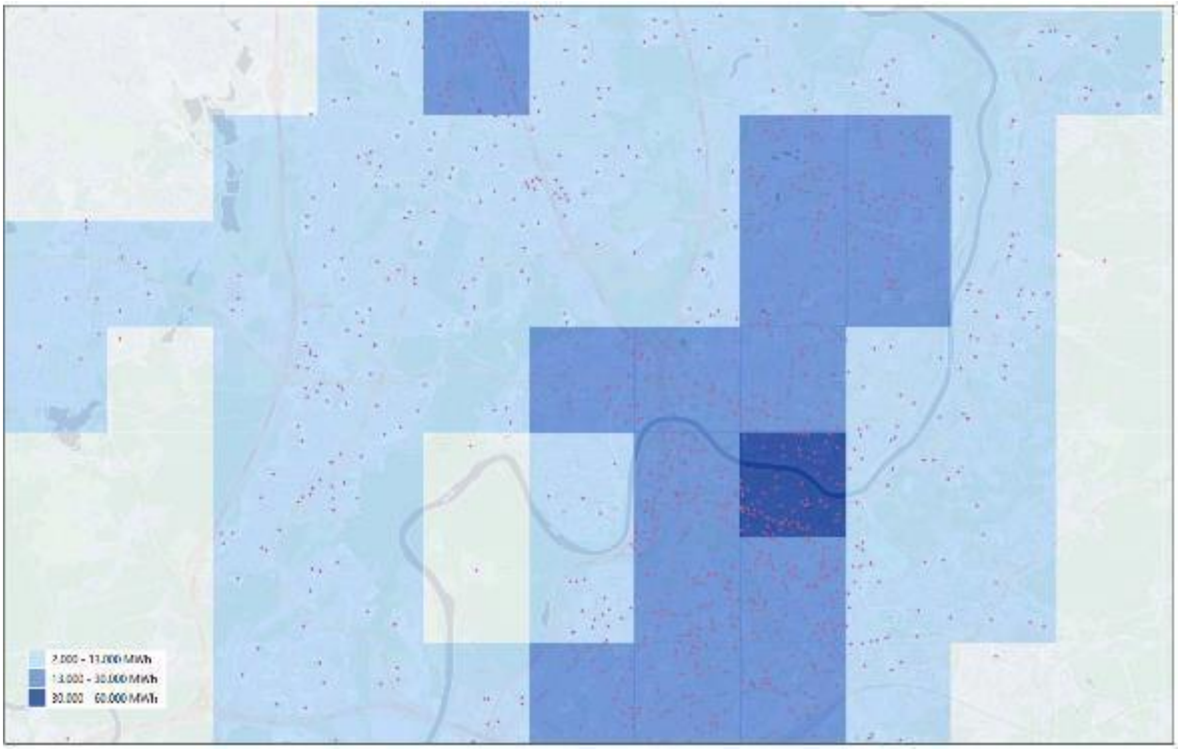
The map identifies the following cooling demand compaction areas where it might be possible to develop district cooling:

- 1 km^2 where annual cooling demand is 30,000 to 60,000 MWh (Vilnius)
- 16 km^2 where annual cooling demand is 13,000-30,000 MWh (of which 14 km^2 in Vilnius and 1 km^2 in Kaunas and Klaipėda each)

District cooling potential in Vilnius City

Below is a map of cooling demand compaction in Vilnius City, with potential clusters in need of district cooling. The greatest potential for the development of a district cooling network exists in the square of the highest need for cooling (see map below). However, the situation of each building must be assessed on a case-by-case basis, taking into account cooling demand (realised demand) of each consumer and technical possibilities to use district cooling.

77 Figure. Clusters in need of cooling and potential clusters in need of district cooling in Vilnius



Source: authors of the Study

Below is a table offering a detailed view on buildings that can potentially be connected to district cooling networks in Vilnius City. For more information on the need for cooling and cooling demand, see Chapter 4.

Table 206. Composition of the need for potential district cooling in Vilnius in 2020

Sector	Number of buildings	Surface area of buildings, M m^2	Need for cooling, GWh	Cooling demand, GWh
Households	53	0,2	4,6	0,05
Service sector	1.257	8,0	439	43,9

Source: authors of the Study

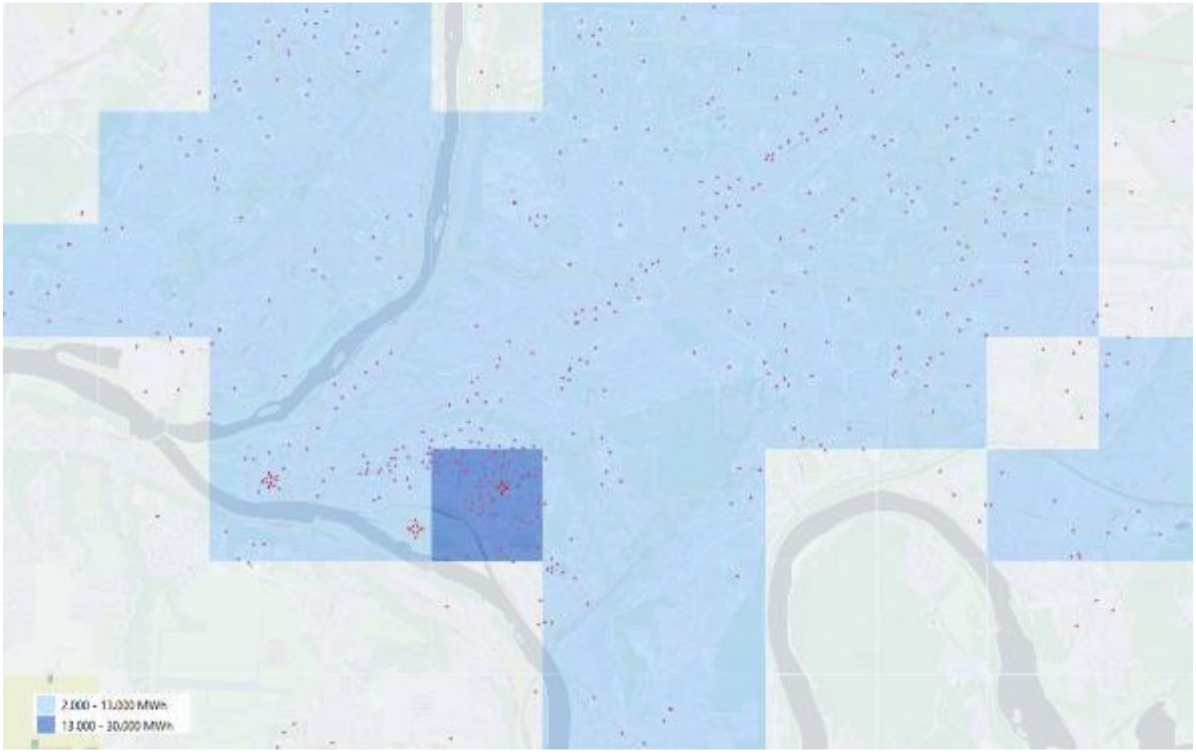
The greatest cooling demand potential exists within an area of 1 km^2 where the annual need for cooling is 30 to 60 GWh. An important factor is that this area is crossed by a river, which can have a significant impact on the development of district cooling supply due larger investments required for the interconnection of potential clusters of district cooling demand.

Vilnius also has an area of 14 km^2 where the need for cooling is between 13 and 30 GWh. Part of this area is also crossed by a river and a railway and is located in the Old Town of Vilnius. All of these factors can have a significant impact both on possibilities to connect buildings with district cooling networks and on technical possibilities to use district cooling in buildings. It is estimated that the potential for connecting individual buildings or groups of buildings to district cooling networks may exist in areas with a lower density in terms of the need for cooling.

District cooling potential in Kaunas City

Below is a map of cooling demand compaction in Kaunas City, with potential clusters in need of district cooling. The greatest potential for the development of a district cooling network exists in the square of the highest need for cooling (see map below). However, the situation of each building must be assessed on a case-by-case basis, taking into account cooling demand (realised demand) of each consumer and technical possibilities to use district cooling.

Figure 78. Clusters in need of cooling and potential clusters in need of district cooling in Kaunas



Source: authors of the Study

AB Kauno energija has implemented two pilot projects for compressor heat pumps in Kaunas City and is currently implementing a pilot project for an absorption cooling unit. The latter are marked with red asterisks on the map above. These pilot projects could potentially be a starting point for developing district cooling networks.

Below is a table offering a detailed view on buildings that can potentially be connected to district cooling networks in Kaunas City. For more information on the need for cooling and cooling demand, see Chapter 4.

207 Table. Composition of the need for potential district cooling in Kaunas in 2020

Sector	Number of buildings	Surface area of buildings, M m^2	Need for cooling, GWh	Cooling demand, GWh
Households	24	0,1	1,8	0,02
Service sector	593	3	167	16,7

Source: authors of the Study

In Kaunas City there is only 1 km^2 where the need for cooling is between 13 and 30 GWh and it is adjacent to the absorption heat pump pilot project
Mokslo sala implemented by AB Kauno energija. It is estimated that the for connecting individual buildings or groups of buildings to district cooling networks may exist in areas with a lower density in terms of the need for cooling.

9.5. KEY OBSERVATIONS

To summarise the analysis of the strategic objectives for the energy sector, the following key objectives for Lithuania's energy sector for 2050 can be highlighted:

208 Table. Objectives for Lithuania's energy sector for 2050

Sector	Objective	Target indicators (2050)
Lithuania, total	Decrease in PEC and FEC intensity (compared to 2017)	2.4-fold
	GHG emissions reduction (compared to 1990)	95%
	RES share in FEC	80%

Taking into account the long-term strategic objectives of the energy sector, the following objectives and target indicators are set for the heating sector:

209 Table. Objectives for the cooling sector for 2050

Sector	Objective	Target indicators (2050)
Cooling sector	T1. Decrease in FEC intensity	*Not set*
	T2. Decrease in PEC intensity	*Not set*
	T3. GHG emissions	0 kt CO_2
	T4. RES share in the DH sector	100%
	T5. RES share in the decentralised sector	100%

Source: authors of the Study

The cooling sector is an emerging sector and constitutes an insignificant part of the energy sector. Accordingly, no targets are set to reduce FEC and PEC indicators as compared to 2017 levels.

Like in the case of the heating sector, three main expectations are defined for the area of cooling energy efficiency:

- Rational consumption: a key measure to reduce (or stall) FEC intensity.
- Efficient infrastructure: a key measure to reduce (or stall) PEC intensity.
- Sustainable fuel mix: a key measure to reduce GHG emissions.

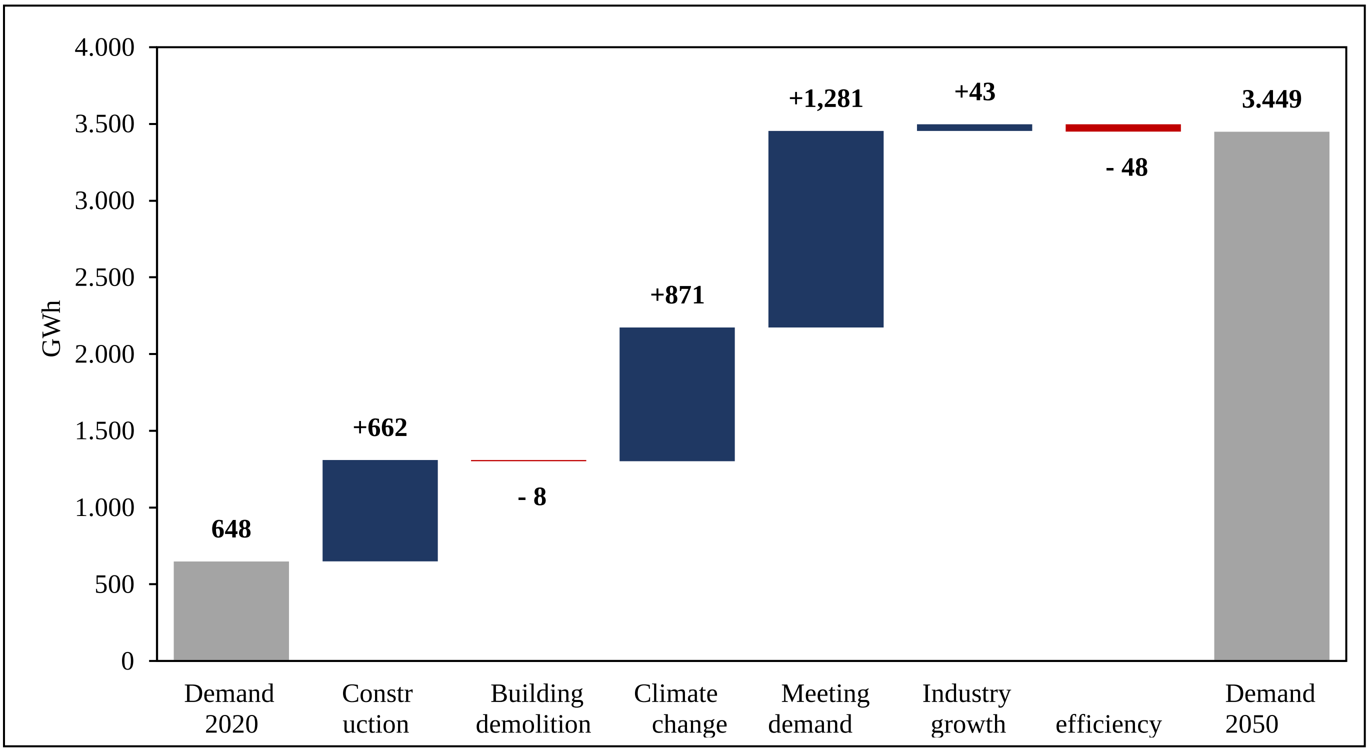
Like in the assessment of heating, in terms of the energy supply chain, these expectations are divided into two groups: increasing the efficiency of cooling demand and enhancing the efficiency of cooling supply.

Potential for enhancing cooling demand efficiency

Cooling demand (UEC) in 2020 is estimated at 0.6 TWh. Unlike the heating sector, while heat during the cold season is an indispensable service to meet basic human needs, cooling in the climate zone concerned is still not an indispensable service. This is also confirmed by the assessment that a significant part of the need for cooling is unmet. Actual cooling consumption in the service sector is estimated at 10% while the need for cooling in households is estimated at only 1%.

It is the change in the level of meeting the need for cooling that constitutes the most significant part of the change in the projected cooling demand. The baseline scenario for projected cooling demand estimates that cooling demand will increase about 4-fold in 2050 (from 0.6 TWh in 2020 to 3.4 TWh in 2050).

Figure 79. Evolution of cooling demand UEC in 2020-2050, GWh



Source: authors of the Study

It is important to note that the baseline scenario does not result in significant measures to enhance the efficiency of efficient use of cooling (with the exception of efficiency gains in the industry sector). As the cooling sector is still developing and cooling technologies are only beginning to be deployed, their deployment is generally based on the most efficient solutions available. Accordingly, no efficiency enhancing tasks are defined for existing cooling consumption but it is planned that effective solutions for meeting future cooling consumption will be promoted.

Potential for enhancing cooling supply efficiency

As described above, long-term strategic objectives for the energy sector shape two main strands of action for enhancing heating supply efficiency:

- Efficient infrastructure: a key measure to reduce PEC intensity.
- Sustainable fuel mix: a key measure to increase the RES share and to reduce GHG emissions.

The analysis of the cooling supply structure shows that when assessing these strands of action:

- All cooling is produced in a decentralised manner using high-efficiency HP technology.
- The technologies used will not generate GHG emissions and will have the RES share of 100% in the production structure (the green electricity scenario).

Taking into account the objectives set for the cooling sector, the most probable scenarios for the development of the sectors concerned and the analysis of the current situation, the following priority strands of action for enhancing supply efficiency are established.

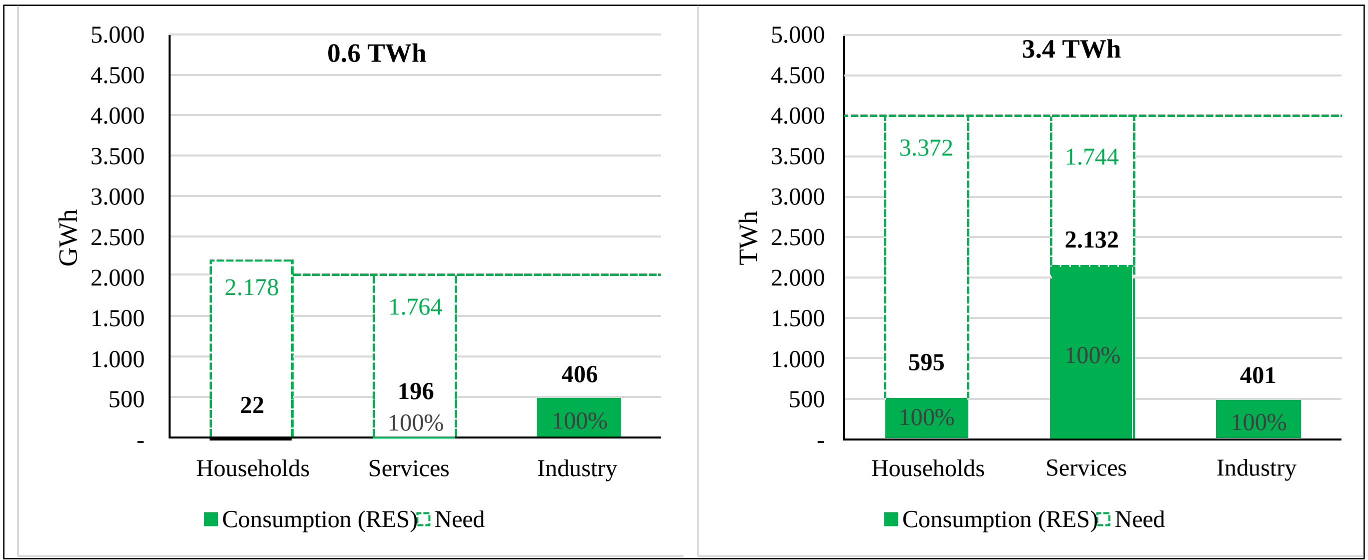
Table 210. Summary of supply efficiency targets

Sector	Efficiency indicators in 2020		Strands of action for enhancing efficiency (2050)	
	Infrastructure efficiency	**Fuel sustainability**	**Cooling sector**	**Sectors concerned**
Centralised cooling	-	-	• Rational development by increasing production efficiency	• RES share in the electricity generation structure (100%)
Decentralised cooling	High	High[134]	• Maintaining the RES share in the production structure	

Source: authors of the Study

Once the planned EETs are implemented, the following cooling demand and supply indicators can be projected for 2050.

Figure 80. Cooling demand and supply UEC in 2050



Source: authors of the Study

As can be seen, in the baseline scenario:

- The need for cooling energy is increasing (from 5.1 to 9.1 TWh);
- There is a significant increase in the level of meeting the need (from 13 to 38%) and, accordingly, in the demand for cooling (from 0.6 to 3.4 TWh);
- The RES share of 100% is maintained in the production structure.

In addition, an assessment of the potential of district cooling supply was carried out (for more information see Chapter 9.4.2), during which the preliminary potential of district cooling supply in Vilnius and Kaunas cities was established at up to 1 TWh.

Forecasts for the cooling sector in the baseline scenario for 2050 are presented below.

[134] The most probable scenario for the development of the electricity sector

211 Table. Objectives for the cooling sector for 2050

Sector	Objective (2050)	Target indicators	Baseline scenario indicators
Cooling sector	T1. Decrease in FEC intensity	*Not set*	3.4 TWh
	T2. Decrease in PEC intensity	*Not set*	3.4 TWh
	T3. GHG emissions	0 kt CO_2	0 kt CO_2
	T4. RES share in the DH sector	100%	100%
	T5. RES share in the decentralised sector	100%	100%

Source: authors of the Study

As one might notice, in the baseline scenario all target indicators set for the targets (T3-T5) are fully met.

10. ANALYSIS OF POLICY MEASURES

Recommendation 5.1. Member States should review additional policy measures ensuring a logical link between the measures, their effects and the data collected on heating and cooling.

Achieving the objectives set for the heating and cooling sector requires the implementation of efficiency enhancing tasks defined for individual sectors. The table below provides information on existing and planned policy measures needed to implement efficiency enhancing tasks.

212 Table. Summary of policy measures

Sector	Efficiency enhancing tasks (EET)	Policy measures
District heating	Measures to enhance demand efficiency	Policy measures listed in the long-term renovation strategy
	EET 1. Enhancing heat supply efficiency (heat transfer agent)	PM3. Upgrade and/or replace worn-out biofuel boilers with other RES technologies
		PM4. Promote the use of biofuels for the production of heat energy in district heating systems
		PM5. Promote the use of RES for DH heat production by assessing the options for using solar technologies, heat pumps and heat storage facilities in DH systems
		PM6. New biofuel combustion plants in the district heating supply sector
		PM7. Promote the use in the district heating sector of waste heat generated in industry, in the waste sector or due to cooling energy
		PM30. Feasibility assessment of the development of district cooling networks
	EET 2. Enhancing heat supply efficiency (steam)	PM1. Renovate and/or modernise the heat transmission network and its installations/elements
		PM2. Modernisation of the heat metering system
	EET 3. Reduction of supply losses	PM1. Renovate and/or modernise the heat transmission network and its installations/elements
		PM2. Modernisation of the heat metering system
	EET 4. Use of waste heat capacity	PM7. Promote the use in the district heating sector of waste heat generated in industry, in the waste sector or due to cooling energy
		PM29. Changes in the regulatory environment for waste heat

Table 218. Summary of policy measures

Sector	Efficiency enhancing tasks (EET)	Policy measures
Households	Measures to enhance demand efficiency	Policy measures listed in the long-term renovation strategy
	EET 1-2. Phasing out fossil fuels	PM10. Removal of the excise duty exemption and introduction of a carbon dioxide component (excluding NG)
		PM11. Replacement of boilers with more efficient technologies
		PM12. Prohibiting the use of solid fossil fuels for space heating
	EET 3. Reducing natural gas consumption	PM11. Replacement of boilers with more efficient technologies
		PM13. Removal of the excise duty exemption and introduction of a carbon dioxide component for natural gas
		PM14. Restriction of the expansion of the natural gas network to newly constructed buildings in the DH area
		PM15. Restriction of the expansion of the natural gas network to newly constructed buildings in all areas
	EET 4. Phasing out inefficient biofuels	PM11. Replacement of inefficient biomass boilers with more efficient RES-based heat production technologies
		PM19. Limiting the use of solid fuels for space heating by location
	EET 5. Limiting the use of biofuel	PM19. Limiting the use of solid fuels for space heating by location
Service sector	Measures to enhance demand efficiency	Policy measures listed in the long-term renovation strategy
	EET 1-2. Phasing out fossil fuels	PM10. Removal of the excise duty exemption and introduction of a carbon dioxide component for fossil fuels (excluding NG)
		PM12. Limiting the use of solid fossil fuels for space heating by location
		PM20. Introducing and promoting technological eco-innovations
	EET 3. Reducing natural gas consumption	PM13. Removal of the excise duty exemption and introduction of a carbon dioxide component for natural gas
		PM14. Limiting the expansion of the natural gas network to newly constructed buildings in the DH area
		PM15. Limiting the expansion of the natural gas network to newly constructed buildings in all areas
		PM20. Introducing and promoting technological eco-innovations
	EET 4. Limiting the use of biofuel	PM19. Limiting the use of solid fuels for space heating by location

Table 219. Summary of policy measures

Sector	Efficiency enhancing tasks (EET)	Policy measures
Industry sector	Measures to enhance demand efficiency	Policy measures referred to in the long-term renovation strategy and the National Energy Independence Strategy
	EET 1. Coal replacement	PM22. Promoting the replacement of polluting technologies with less polluting ones for companies involved in the trading of emission allowances
		PM28. Reducing the use of coal, coke and lignite
	EET 2. Phasing out fossil fuels	PM10. Removal of the excise duty exemption and introduction of a carbon dioxide component for fossil fuels (excluding NG)
		PM20. Introducing and promoting technological eco-innovations
		PM28. Reducing the use of coal, coke and lignite
	EET 3. Reducing natural gas consumption	PM13. Removal of the excise duty exemption and introduction of a carbon dioxide component for natural gas
		PM20. Introducing and promoting technological eco-innovations
		PM21. Decarbonisation of industry
		PM22. Promoting the replacement of polluting technologies with less polluting ones for companies involved in the trading of emission allowances
		PM24. Using renewable energy sources in industry
		PM25. Industry 4.0 LAB Net-Zero Plan: promoting innovation to combat climate change
		PM26. A single national measurement system to track progress in business, industry and energy use and pollution reduction
		PM27. Implementing alternative fuel measures (large enterprises)
	EET 4. Biomethane integration	PM16. Promoting the development of biomethane gas production facilities
	EET 5. Hydrogen integration	PM17. Promoting research into hydrogen integration
		PM18. Promoting the development of hydrogen production facilities
		PM21. Decarbonisation of industry
		PM22. Promoting the replacement of polluting technologies with less polluting ones for companies involved in the trading of emission allowances
		PM23. Study to quantify the need for clean, green and renewable energy industry

10.1. POLICY MEASURES TAKEN

This Chapter offers a description of the policy measures taken. The measures taken include policy measures currently being implemented and policy measures for which there is a decision on their future implementation.

PM1. Renovate and/or modernise the heat transmission network and its installations/elements

A measure curated by the Ministry of Energy of the Republic of Lithuania aimed at renovating and modernising the depreciated heat transmission networks. The renovation of district heating networks aims at reducing heat network losses to 120 GWh from 2023.

Objective of the measure	To enhance the efficiency of the district heating network
EET being implemented (sector)	EET 2-3 (DH)
Impact of the measure:	
T1. Decrease in FEC intensity	Yes
T2. Decrease in PEC intensity	Yes
T3. GHG emissions reduction	-
T4. Increased RES share (DH)	-
T5. Increased RES share	-
Source and measure No.	NECAP: RES23, ERK13
Implementation period	2015-2023

PM2. Modernisation of the heat metering system

The EU Internal Market Directive (2009/72/EC) and its amending act (2016/0380(COD)) stipulate that in the case of a positive cost-benefit analysis all heat meters must be replaced by ones with a remote reading function by 2027. Replacing heat meters makes heat metering more accurate and encourages final consumers to use heat more efficiently.

Objective of the measure	To enhance the efficiency of the district heating network
EET being implemented (sector)	EET 2-3 (DH)
Impact of the measure:	
T1. Decrease in FEC intensity	Yes
T2. Decrease in PEC intensity	Yes
T3. GHG emissions reduction	-
T4. Increased RES share (DH)	-
T5. Increased RES share	-
Source and measure No.	NECAP: RES29.
Implementation period	2021-2027

PM3. Upgrade and/or replace worn-out biofuel boilers with other RES technologies

Improvement of incentivising regulation enabling heat supply companies to accumulate assets necessary for an upgrade for additional RES production capacity with a thermal input of 600 MW. This would ensure long-term maintenance of RES share in the district heating sector and would create preconditions for enhancing fuel use efficiency.

Objective of the measure	To enhance the efficiency of the district heating network
EET being implemented (sector)	EET-1 (DH)
Impact of the measure:	
T1. Decrease in FEC intensity	Yes
T2. Decrease in PEC intensity	Yes
T3. GHG emissions reduction	-
T4. Increased RES share (DH)	-
T5. Increased RES share	-
Source and measure No.	NECAP: RES17.
Implementation period	2018-2030

PM4. Promote the use of biofuels for the production of heat energy in district heating systems

Improvement of incentivising regulation enabling heat supply companies to accumulate assets necessary for an upgrade with a thermal input of 70 MW.

A regulatory adjustment would allow achieving a higher share of RES in the district heating network without additional public finance investments.

Objective of the measure	To increase RES share in DH systems
EET being implemented (sector)	EET-1 (DH)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	-
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	Yes
T5. Increased RES share	-
Source and measure No.	NECAP: RES18.
Implementation period	2018-2023

PM5. Promote the use of RES for the production of DH heat energy

Heat pumps have already been used in other countries and have proved their worth in terms of energy efficiency. Since the period is 2021 to 2030, no specific technology is chosen as the basis. Support will be given to the deployment of the most cost-effective solution with the aim of deploying up to 200 MW of RES capacity.

The measure aims to promote the use of solar technologies, heat pumps and heat storage facilities in DH systems and to deploy installations of rated capacity of 200 MW 2030.

Objective of the measure	To increase RES share in DH systems
EET being implemented (sector)	EET-1 (DH)
Impact of the measure:	
T1. Decrease in FEC intensity	Yes
T2. Decrease in PEC intensity	Yes
T3. GHG emissions reduction	-
T4. Increased RES share (DH)	-
T5. Increased RES share	-
Source and measure No.	NECAP: RES19, RES27
Implementation period	2021-2030

PM6. New biofuel combustion plants in the district heating supply sector

In Lithuania, biofuels are already used in most municipalities. In 2017, the RES share in the district heating sector was already 68.7% while in the heating and cooling sector as a whole it was over 46%. Coal and gas oils are still used in some municipalities. The measure is aimed at converting their heating facilities to RES. Additional production capacity of new biofuel combustion facilities in the district heating sector is 70 MW.

The deployment of biofuel installations replacing fossil fuels significantly reduces GHG emissions and increases RES share but does not have a significant impact on enhancing primary energy efficiency. Also, as fossil fuel sources are more often used to meet heat demand only in the cold season, the potential to reduce GHG emissions is lower.

Objective of the measure	To increase RES share in DH systems
EET being implemented (sector)	EET-1 (DH)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	-
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	Yes
T5. Increased RES share	-
Source and measure No.	NECAP: RES26.
Implementation period	2021-2030

PM7. Promote the use in the district heating sector of waste heat generated in industry, in the waste sector or due to cooling energy

This heat is generated during chemical processes at manufacturing plants in any case, so considering that theoretically in Lithuania its annual potential is about 3 TWh, it is planned to use part of it in the district heating sector. Using the entire quantity is not possible because some industrial sites are located in areas too remote from heat consumers. A priority strand in the heat sector is the collection, storage and efficient use of ambient energy and waste energy emitted into the air by power plants, industrial facilities and buildings. Waste heat from thermal power plants can be used to heat buildings. It is planned that waste heat in the district heating sector will amount to 0.45 TWh.

The use of waste heat may with high probability lead to a greater overlap of primary energy as the use of primary energy requires little waste energy but the potential to reduce GHG emissions and increase the share of RES depends on a specific situation, i.e. if biofuel is replaced, the share of GHG and RES remains unchanged.

Objective of the measure	To increase RES share in DH systems
EET being implemented (sector)	EET-1, 4 (DH)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	Yes
T3. GHG emissions reduction	-
T4. Increased RES share (DH)	-
T5. Increased RES share	-
Source and measure No.	NECAP: RES28.
Implementation period	2021-2030

PM8. Implementation of local and RES-based cogeneration power plant projects prioritising Vilnius and Kaunas

The implementation of the measure, which will result in the construction of two cogeneration plants in Vilnius and Kaunas, is being completed. The rated thermal input of newly installed high-efficiency cogeneration units is 317 MW; the installed electrical capacity of newly installed high-efficiency cogeneration units is 127 MW.

Objective of the measure	To increase RES share in DH systems
EET being implemented (sector)	-
Impact of the measure:	
T1. Decrease in FEC intensity	Yes
T2. Decrease in PEC intensity	Yes
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	Yes
T5. Increased RES share	-
Source and measure No.	NECAP: RES3.
Implementation period	2018-2023

PM10. Removal of the excise duty exemption for fossil fuels (excluding NG)

It is planned, as of 2023, to phase out heating-destined fossil fuel subsidies for coal, coke, lignite, red diesel, liquefied petroleum gas in cylinders and peat intended for heating.

At the same time, these amendments to the Law on Excise Duties, as of 2025, introduce a carbon dioxide component for the most polluting fossil fuels, which will gradually increase every year. The exemption applies to natural gas as a transitional fuel which will not be covered by the CO_2 component. Increasing the carbon dioxide component over time could lead to a levy on the centralised procurement of the CO_2 capture service, offsetting CO_2 emissions from FF.

The removal of tax incentives would mean the withdrawal of the financial incentive to choose polluting fossil fuels instead of less polluting or RES-based heat sources.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 1-2. (households) EET 1-2. (service sector) EET-2. (industry)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	-
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	NECAP: Alternative policy measures
Implementation period	From 2023

PM11. Replacement of fossil fuel boilers

It is planned to continue fossil fuel boiler replacement programmes for more efficient RES-based heat production technologies for households by providing a subsidy for the replacement of fossil fuel boilers with efficient RES-based (5G) biofuel boilers and heat pumps in residential houses not connected to DH systems throughout Lithuania.

It is envisaged that when replacing fossil fuel boilers, consumers receiving support will replace equipment with heat pumps and Class 5 biofuel boilers.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 1-3. (households)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	-
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	NECAP: EE7.; DPPM NO 03-001-06-05-01: Measures 9 and 10
Implementation period	From 2023

PM11. Replacement of inefficient biomass boilers with more efficient RES-based heat production technologies

It is planned to continue inefficient biofuel boiler replacement programmes for more efficient RES-based heat production technologies for households by providing a subsidy for boiler replacement with efficient RES-based (5G) biofuel boilers and heat pumps in residential houses not connected to DH systems throughout Lithuania.

It is envisaged that when replacing fossil fuel boilers, consumers receiving support will replace equipment with heat pumps and Class 5 biofuel boilers.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 4. (households)
Impact of the measure:	
T1. Decrease in FEC intensity	Yes
T2. Decrease in PEC intensity	Yes
T3. GHG emissions reduction	-
T4. Increased RES share (DH)	-
T5. Increased RES share	-
Source and measure No.	DPPM NO 03-001-06-05-01: Measures 7 and 8
Implementation period	From 2023

PM16. Development of biomethane gas production facilities

Biomethane production plays an important role not only in reducing the use of fossil fuels but also in the management of organic anthropogenic waste from food and agricultural industries, wastewater treatment and other sectors where organic waste is generated. The promotion of the construction of biomethane facilities requires financial support. Increasing biomethane production and delivering the latter to the natural gas transmission and distribution network would increase the share of RES.

To meet the demand for biomethane simulated under the baseline scenario, 1 TWh of biomethane will be needed by 2050. Based on 2022 data, Amber Grid has issued connection conditions for 8 persons to produce biomethane with a total annual capacity of about 0.7 TWh. According to a study conducted by the Lithuanian Biogas Association, this potential amounts to at least 1.4 TWh. However, biomethane production is a capital-intensive activity, so it is necessary to provide for support measures for the development of biomethane production.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET-4. (industry)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	-
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	NECAP: A4.
Implementation period	-

PM20. Introducing and promoting technological eco-innovations

The objective of the measure is to encourage micro-enterprises and SMEs to introduce technological eco-innovations in order to reduce the negative effects of climate change and the greenhouse effect. Funding is given to investments in tangible assets (installations, technologies) which reduce the negative impact of economic activities on the environment, promote industrial symbiosis and ensure a continuous environmental protection effect, i.e. investments in cleaner production innovations (their deployment).

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 1-3 (service sector) EET 2-3 (industry)
Impact of the measure:	
T1. Decrease in FEC intensity	Yes
T2. Decrease in PEC intensity	Yes
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	NECAP: P10. Preliminary measures in the industry sector: P11.1-E
Implementation period	2022-2024

PM21. Decarbonisation of industry

Interventions relating to the restructuring of the three largest industrial emitters to reduce GHG emissions and the necessary preparatory actions to be taken at national level: financing projects for the decarbonisation of the most polluting industries, feasibility studies, research, etc.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 3 and 5 (industry)
Impact of the measure:	
T1. Decrease in FEC intensity	Yes
T2. Decrease in PEC intensity	Yes
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	Preliminary measures in the industry sector: P17.2
Implementation period	-

PM22. Promoting the replacement of polluting technologies with less polluting ones for companies involved in the trading of emission allowances

The measure is aimed at companies participating in the EU Emissions Trading System. It is intended to co-finance projects that replace polluting production technologies with less polluting ones. Supported activities: investments in tangible assets (installations, technologies) which reduce the negative environmental impact of economic activities and ensure a continuous environmental protection effect.

The measure does not define precise areas of investment, so the precise effect of the measure on the change in GHG, primary energy and RES share is not known.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 1, 3 and 5 (industry)
Impact of the measure:	
T1. Decrease in FEC intensity	Yes
T2. Decrease in PEC intensity	Yes
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	NECAP: P9. Preliminary measures in the industry sector: P10.1-E.
Implementation period	-

PM24. Using renewable energy sources in industry

The aim of the measure is to encourage the installation of RES-based energy production capacities, the development and deployment of new technologies for more efficient use of RES in industrial enterprises in order to use energy to meet the internal needs of enterprises themselves and to enable the supply of excess energy to other industrial enterprises or the transfer of it to district energy grids.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 3 (industry)
Impact of the measure:	
T1. Decrease in FEC intensity	Yes
T2. Decrease in PEC intensity	Yes
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	NECAP: RES6. Preliminary measures in the industry sector: P6.2-E.
Implementation period	-

PM25. Industry 4.0 LAB Net-Zero Plan: promoting innovation to combat climate change. Boosting demand

The measure aims to promote the development of innovative green products and services, support the circular economy and the green transition of the industry. The measure aims to: Establish Hubs for Circularity promoting green and digital transformation. The objective of the measure is not to fund infrastructure solutions but to address information asymmetry and improve the ability of decision-makers to assess and compare the potential and financial attractiveness of circular and green technologies. The measure aims to save 149 GWh of energy and 30 kt CO_2.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 3 (industry)
Impact of the measure:	
T1. Decrease in FEC intensity	Yes
T2. Decrease in PEC intensity	Yes
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	Preliminary measures in the industry sector: P18
Implementation period	2022-2026

PM26. Implementing a single national measurement system to track progress in business, industry and energy use and pollution reduction

The objective of the measure is to establish a benchmarking mechanism to identify progress in energy use in business, industry and services (energy intensity, GHG emissions) and to rank progress by monitoring:

- Quantity and changes in final energy consumption.
- Energy intensity indicator: energy consumed per 1 output/service unit.
- GHG emissions.
- The origin and proportion of energy consumed as compared to total consumption.
- Quantities of energy efficiency measures and savings implemented, etc.

The result of the system is an aggregated amount of business energy efficiency and sustainability with assessment intervals and 38 kt CO_2 savings.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 3 (industry)
Impact of the measure:	
T1. Decrease in FEC intensity	Yes
T2. Decrease in PEC intensity	Yes
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	Preliminary measures in the industry sector: P24
Implementation period	2022-2024

PM27. Implementing alternative fuel measures in large enterprises

The objective of the measure is to encourage the deployment of alternative fuels measures in large industrial enterprises. This measure would help to address the slow pace of development of this type of infrastructure in large enterprises more quickly. As emissions volumes in the market decrease and prices increase intensively, companies are looking for other possible energy production solutions that would contribute to the reduction of GHG emissions.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 3 (industry)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	-
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	NECAP: P1. Preliminary measures in the industry sector: P1-E.
Implementation period	-

PM28. Reducing the use of coal, coke and lignite

The measure is aimed at non-ETS industry. Since coal is the most polluting fossil fuel in terms of GHG emissions, the draft Law on Excise Duties provides that from 1 January 2023 the excise duty rate on coal, coke and lignite used for business purposes will be equal to the excise duty rate on these products used for non-business purposes (for coal – EUR 7.53/t, for coke and lignite – EUR 8.98/t). In 2024 and 2025 respectively, excise duties on these products will consistently increase.

The measure removes tax preferences, the need for public finances does not increase, and in the short term the budget revenue from the taxation of these fuels may increase. In the long run, consumers are expected to replace solid fossil fuels they use with biofuels or heat pumps.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 1-2 (industry)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	-
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	NECAP: P7.; Preliminary measures in the industry sector: P8-E.
Implementation period	-

10.2. POLICY MEASURES PLANNED

This Chapter describes planned policy measures, i.e. measures that are planned to be implemented but no final decision has been taken.

PM14. Limiting the expansion of the natural gas network to newly constructed buildings in the DH area

Based on the analysis of the results of energy performance certificates for buildings, more than 90% of individual buildings with energy performance of Class A++ will be heated with heat pumps while multi-apartment buildings with energy performance of Class A++ will be heated with district heating or heat from heat pumps.

A policy measure is planned that would limit the connection of buildings newly constructed in the DH area to the natural gas network. As the use of other fossil fuels would not be allowed either, the latter would be connected to district heating networks or RES-based heat solutions would be implemented. This would allow for more efficient use of public and private finances to achieve the objective of a climate-neutral economy.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 3 (households, the service sector)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	-
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	NECAP: Alternative policy measures
Implementation period	-

PM23. Study to quantify the need for clean, green and renewable energy industry

The measure will finance an exploratory quantitative study addressing clean, green and renewable energy consumption needs of the Lithuanian industry by 2030. The study would help identify the potential consumption of green electricity by individual industries and the industry sector as a whole and would include an assessment of the potential demand for green hydrogen by individual industries by 2030.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 5 (industry)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	-
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	Preliminary measures in the industry sector: P1.
Implementation period	-

PM29. Promotion of waste heat procurement

In general, the integration of waste heat into the district heating network requires investments: either investments of heat suppliers in transmission networks or investments of waste heat generating enterprises in heat pumps with additional electricity costs. In order to boost the viability of the waste heat integration model, the model should optimally divide the risks and economic benefits between the heat supplier and the waste heat generating enterprises.

Objective of the measure	Enhancing heat supply efficiency by integrating RES production sources
EET being implemented (sector)	EET 4 (DH system)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	Yes
T3. GHG emissions reduction	-
T4. Increased RES share (DH)	Yes
T5. Increased RES share	-
Source and measure No.	-
Implementation period	-

10.3. ADDITIONAL POLICY MEASURES PROPOSED

This Chapter describes policy measures needed to implement the efficiency enhancing objectives defined.

PM12. Limiting the use of solid fossil fuels for space heating by location

A policy measure is planned to allow municipalities to restrict the use of solid fossil fuels by location. The draft policy measure is now open to public consultation. The measure aims primarily at reducing particulate matter and other pollutants in densely populated areas where pollution damage is the greatest.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 1-2 (households, the service sector)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	-
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	Ministry of the Environment of the Republic of Lithuania
Implementation period	From 2025

PM13. Removal of the excise duty exemption and introduction of a carbon dioxide component for natural gas

It is proposed to remove the excise duty exemption for gas and introduce a carbon dioxide component for natural gas, which would encourage consumers to choose RES heat sources or compensate for the environmental damage caused.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 3 (households, the service sector, industry)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	-
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	NECAP: Alternative policy measures
Implementation period	From 2025

PM15. Restriction of the expansion of the natural gas network to newly constructed buildings in all areas

It is proposed to restrict the connection of new buildings to the natural gas network throughout Lithuania. Investments in the development of the natural gas network in parallel with the objective of reducing the use of fossil fuels are inappropriate and create additional barriers to the future conversion of fossil fuels to renewable energy sources and increase the consumption of biomethane which has limited supply.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 3 (households, the service sector)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	-
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	-
Implementation period	From 2025

PM17. Promoting research into hydrogen integration

In order to maximise the effect of switching from fossil fuels, i.e. natural gas to RES but using the existing infrastructure, it is appropriate to promote the blending of green hydrogen into natural gas in the transmission and distribution network. Since this is essentially a new and untested technology, research is needed to assess the network capabilities and optimal solutions for the efficient addition of hydrogen to natural gas in Lithuania.

Currently, there are no established technologies on the market for the incorporation of green hydrogen into the gas supply system but, according to the Joint Research Centre's (JRC) study on blending hydrogen from electrolysis into the European gas grid, 5-10% of green hydrogen can be injected into the existing gas grid without significant investment in the gas grid or equipment used by consumers. Moreover, research by the Technical Association of the European Gas Industry shows that up to 10% of the volume of gas can be blended into existing infrastructure without significant infrastructure investment. Accordingly, within its scope the Study estimates that up to 10% of green hydrogen will be added to the gas grid by 2050.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 5 (industry)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	-
T3. GHG emissions reduction	Yes-
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	-
Implementation period	-

PM18. Promoting the development of hydrogen production facilities

In order to maximise the effect of switching from fossil fuels, i.e. natural gas to RES but using the existing infrastructure and based on relevant research it is appropriate to promote the blending of green hydrogen into natural gas in the transmission and distribution network. It is likely that the production and incorporation of green hydrogen into the gas grid may not be financially viable at the start of operations and financial support will be required. The need for support should be detailed following the implementation of Measure PM17.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 5 (households, the service sector, industry)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	-
T3. GHG emissions reduction	Yes
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	-
Implementation period	-

PM19. Limiting the use of solid fuels for space heating by residential location

A policy measure is proposed to allow municipalities to restrict the use of renewable solid fuels (biofuels) by location for those facilities that do not have particulate matter filters. The restriction is relevant in densely populated areas where there is an accumulation of higher quantities of particulate matter pollution from boilers in buildings and transport.

The measure would make it possible to reduce emissions of particulate matter from all fuels including RES. While maintaining the same principle of increased financing for the replacement of these boilers by banning the use of the fuel type in these areas, the expected effect on public finances due to the change in infrastructure would be important.

Objective of the measure	To reduce the use of fossil fuels for heat generation
EET being implemented (sector)	EET 4-5 (households) EET-4 (service sector)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	-
T3. GHG emissions reduction	Yes-
T4. Increased RES share (DH)	-
T5. Increased RES share	Yes
Source and measure No.	-
Implementation period	-

PM30. Feasibility assessment of the development of district cooling networks

To develop cooling networks, it is necessary to carry out a study and evaluate both the need for cooling networks, technical possibilities and possible benefits for the existing DH system.

For the sake of clarity there is a need for more data to be collected from pilot data, actual cooling demand in various buildings and cooling consumption characteristics.

Objective of the measure	Enhancing heat supply efficiency by integrating RES production sources
EET being implemented (sector)	EET 2 (DH system)
Impact of the measure:	
T1. Decrease in FEC intensity	-
T2. Decrease in PEC intensity	Yes
T3. GHG emissions reduction	-
T4. Increased RES share (DH)	-
T5. Increased RES share	-
Source and measure No.	-
Implementation period	-

ANNEXES

1 ANNEX. MANDATORY DATASET

1.1 Annex. Data structure of useful energy content and final heating and cooling energy consumption

1.2 Annex. Data on existing heating and cooling supply infrastructure

1.3 Annex. Data on existing waste heat and cold supply infrastructure

1.4 Annex. Data on existing and planned (separately) heat production installations that are or will be connected to the district heating network

1.5 Annex. Data on all existing national heat production installations not connected to the district heating network

1.6.1. Annex. Data on all existing national sources of power generation from renewable energy sources

1.6.2. Annex. Data on planned power generation from renewable energy sources

1.7 Annex. National efficient RES-based heating and cooling potential established in the cost-benefit analysis

1.8 Annex. Analysis of current policy measures

1.9 Annex. Overview of new strategies and policies

1.10 Annex. Data on existing heat mains of the district heating network

1.11 Annex. Identification of existing installations generating waste heat and waste cold

2 ANNEX. KEY CALCULATIONS AND ASSUMPTIONS

2.1 Annex. Energy and fuel balance calculations

The fuel balance publishes data on all energy needs of the country without any breakdown of heat or cold (except district heating). In the table below is an extract from the 2020 fuel balance converted to GWh.

215 Table. Extract of 2020 fuel balance converted to GWh

Indicator	Coal	Peat	Biofuel	Biomethane	Solid fuel	Waste	Crude oil	Gas	RES and	Final oil	Ambience	Electricity	Thermal energy	TOTAL
Final consumption	**1.401**	**12**	**7.334**	**1.303**	**335**	**26**	**-**	**6.780**	**-**	**25.624**	**351**	**10.355**	**8.575**	**62.096**
Industry	880	-	1.392	51	150	26	-	3.178	-	337	10	3.594	1.793	**11.413**
Construction	1	-	26	0	0	-	-	198	-	116	0	147	16	**504**
Transport	0	-	0	1.197	0	-	-	333	-	23.872	0	72	0	**25.473**
Agriculture	14	-	200	0	2	-	-	236	-	634	1	195	40	**1.322**
Fisheries	0	-	0	0	0	-	-	0	-	8	0	2	0	**10**
Services and other activity	219	8	359	55	67	-	-	807	-	30	16	3.301	1.836	**6.699**
Households	287	3	5.357	0	115	-	-	2.028	-	627	323	3.045	4.889	**16.675**

Source: Statistics Lithuania

Only the part of energy that is consumed as heat (for heating, hot water, cooling, heat or cold for processes) is relevant for the Study. Since the fuel balance does not provide data with this level of detail, assumptions are made in the form of an expert assessment of the energy used to produce heat. The assumptions are presented in the table below.

216 Table. Share of fuel consumed for thermal energy in 2020 (%)

Indicator	Coal	Peat	Biofuel	Biomethane	Solid fuel	Waste	Crude oil	Gas	RES and other	Final oil	Ambience	Electricity	Thermal energy
Industry	100	100	100	100	100	100	-	100	100	100	100	5	100
Construction	100	100	100	100	100	100	-	100	100	100	100	5	100
Transport	-	-	-	-	-	-	-	-	-	-	-	5	-
Agriculture	100	100	100	100	100	100	-	100	100	100	100	5	100
Fisheries	-	-	-	-	-	-	-	-	-	-	-	5	-
Services and other activity	100	100	100	100	100	100	-	100	100	100	100	7	100
Households	100	100	100	100	100	100	-	77	100	100	100	10	100

Source: authors of the Study

The industry sector's heat demand for the purposes of the Study was calculated based on the fuel balance and final energy demand as defined in the fuel balance where all final energy consumed by the industry is reported at 13.2 TWh. The consumption of this energy by type of fuel is detailed in the table below.

217 Table. Total final energy demand in the industry sector by fuel type, GWh

	DH	Gas	Electricity	RES (biofuels)	HP	Other FF	Total
Industry	1.793	3.178	3.594	1.469	10	1.368	11.413
Construction	16	198	147	26	0	117	504
Agriculture	40	236	195	200	1	650	1.322
Total	**1.849**	**3.612**	**3.936**	**1.694**	**12**	**2.135**	**13.238**
Total, %	14%	27%	30%	13%	0%	16%	100%

Source: authors of the Study

In order to calculate the industry sector's demand for heat energy based on statistical data, two main steps need to be taken:

- single out non-thermal energy (for transport, lighting, and other equipment)
- single out cold

The table below shows the assumptions used to single out the energy used for non-heat purposes, i.e. the share of energy used by relevant sectors by energy source for heating and cooling energy.

218 Table. Heat and cooling share of the total final energy demand in the industry sector, %

Sector	DH	Gas	Electricity	RES (biofuels)	HP	Other FF
Industry	100%	100%	5%	100%	100%	100%
Construction	100%	100%	5%	100%	100%	100%
Agriculture	100%	100%	5%	100%	100%	100%

Source: authors of the Study

This way final energy demand for heat and cold is obtained as detailed in the table below.

219 Table. Total final energy demand for heat and cooling in the industry sector, GWh

Sector	DH	Gas	Electricity	RES (biofuels)	HP	Other FF	Total
Industry	1.793	3.178	186	1.469	10	1.368	7.969
Construction	16	198	7	26	0	24	270
Agriculture	40	236	10	200	1	143	624
Total	**1.849**	**3.612**	**203**	**1.694**	**12**	**1.535**	**8.905**
Total, %	21%	41%	2%	19%	0%	17%	100%

Source: authors of the Study

As a second step, the industry's final energy demand for heat and cold (see table above) is subtracted from the demand for cold. This way the result of the industry's heat demand is obtained as shown in in the table below.

220 Table. Fuel consumed in the industry sector and final energy for heat, GWh

Sector	DH	Gas	Electricity	RES (biofuels)	HP	Other FF	Total
Industry	1.793	3.178	36	1.469	10	1.368	7.855
Construction	16	198	3	26	0	24	267
Agriculture	40	236	4	200	1	143	624
Total	**1.849**	**3.612**	**43**	**1.694**	**12**	**1.535**	**8.746**
Total, %	21%	41%	0%	19%	0%	18%	100%

Source: authors of the Study

As data on fuel and final energy (DH and electricity) are reported separately in the energy and fuel balance, adjustments are needed to obtain data on final and useful energy.

221 Table. Fuel and final energy for heat consumed in the industry sector, GWh

Indicator	DH	Gas	Electricity	RES	HP	Other FF	Total
Energy and fuel balance	1.849	3.612	43	1.694	12	1.535	8.746
Final energy	2.422	3.612	43	1.694	12	1.535	9.318
Useful energy	1.849	3.284	43	1.540	12	1.328	8.056

Source: authors of the Study

The industry sector's demand for useful energy for heat is thus detailed in the table below.

222 Table. Useful energy demand for heat in the industry sector, GWh

	DH	Gas	Electricity	RES (biofuels)	HP	Other FF	Total
Industry	1.793	2.890	36	1.312	61	1.267	7.359
Construction	16	180	3	23	5	22	249
Agriculture	40	215	4	182	7	129	577
Total	**1.849**	**3.285**	**43**	**1.517**	**73**	**1.418**	**8.185**
Total, %	23%	40%	1%	19%	1%	17%	100%

Source: authors of the Study

The industry sector's demand for primary energy for heat is detailed in the table below.

223 Table. Final energy demand for heat in the industry sector, GWh

	DH	Gas	Electricity	RES (biofuels)	HP	Other FF	Total
Industry	1.793	3.178	36	1.443	10	1.393	7.853
Construction	16	198	3	25	1	24	267
Agriculture	40	236	4	200	1	142	624
Total	**1.849**	**3.612**	**43**	**1.668**	**12**	**1.559**	**8.744**
Total, %	21%	41%	0%	19%	0%	18%	100%

Source: authors of the Study

2.2 Annex. Calculation of heating for buildings

Household sector

Data were obtained from heat suppliers on energy consumption of 15,300 household buildings.

224 Table. Data from heat suppliers: number of household buildings connected to DH systems, number

Group, subgroup	EPC						Total
	<D	C	B	A	A+	A++	
1. Residential	12.052	1.903	1.215	92	59	15	**15.336**
1.1. Single-family	1.327	86	56	2	-	-	1.471
1.2. MAB (S)	481	37	38	1	1	-	558
1.3. MAB (M)	9.753	1.690	1.035	75	50	13	12.616
1.4. MAB (L)	491	90	86	14	8	2	691

Source: heat suppliers, authors of the Study

Average (arithmetic mean) heating demand data for these buildings are presented below.

225 Table. Data from heat suppliers: average thermal energy consumption by households (kWh/m^2/year)

Group, subgroup	EPC					
	<D	C	B	A	A+	A++
1. Residential	**147**	**101**	**91**	**59**	**49**	**32**
1.1. Single-family	140	112	78	89	-	-
1.2. MAB (S)	204	120	155	658	19	-
1.3. MAB (M)	148	102	95	58	50	38
1.4. MAB (L)	141	95	79	60	48	24

Source: heat suppliers, authors of the Study

In order to ensure that average actual consumption data are representative and suitable for application to buildings for which no actual data have been obtained, we eliminated the following from the above data:

- Insufficiently accurate data, i.e. consumption data that cannot be assigned to a specific building (addresses where more than one building is registered);
- Atypical deviations, i.e. atypical minimum and maximum consumption values;
- Data samples that are insufficient to reflect heat demand of a specific benchmark building.

<u>Elimination of insufficiently accurate data</u>

Some of the data above also include addresses where more than one building is registered. Since various buildings may have different purposes and/or different EPCs, consumption assigned to an address cannot be exactly allocated to a specific building. It is therefore considered that these data are not reliable enough to be used for the calculation of the standard benchmark consumption of a building.

The table below shows actual average heat demand data and building numbers for addresses where one building is registered.

226 Table. Data from heat suppliers: average thermal energy consumption by households (kWh/m^2/year)

Group, subgroup	EPC					
	<D	C	B	A	A+	A++
1. Residential	**147**	**101**	**91**	**58**	**46**	**33**
1.1. Single-family	126	105	68	90	-	-
1.2. MAB (S)	206	121	165	660	19	-
1.3. MAB (M)	148	101	95	57	46	38
1.4. MAB (L)	142	95	80	59	45	24

Source: heat suppliers, authors of the Study

227 Table. Data from heat suppliers: number of household buildings, number

Group, subgroup	EPC						Total
	<D	C	B	A	A+	A++	
1. Residential	**11.179**	**1.845**	**1.166**	**93**	**69**	**16**	**14.368**
1.1. Single-family	1.343	93	63	2	0	0	1.501
1.2. MAB (S)	442	37	29	1	1	0	510
1.3. MAB (M)	8.938	1.631	994	77	59	14	11.713
1.4. MAB (L)	456	84	80	13	9	2	644

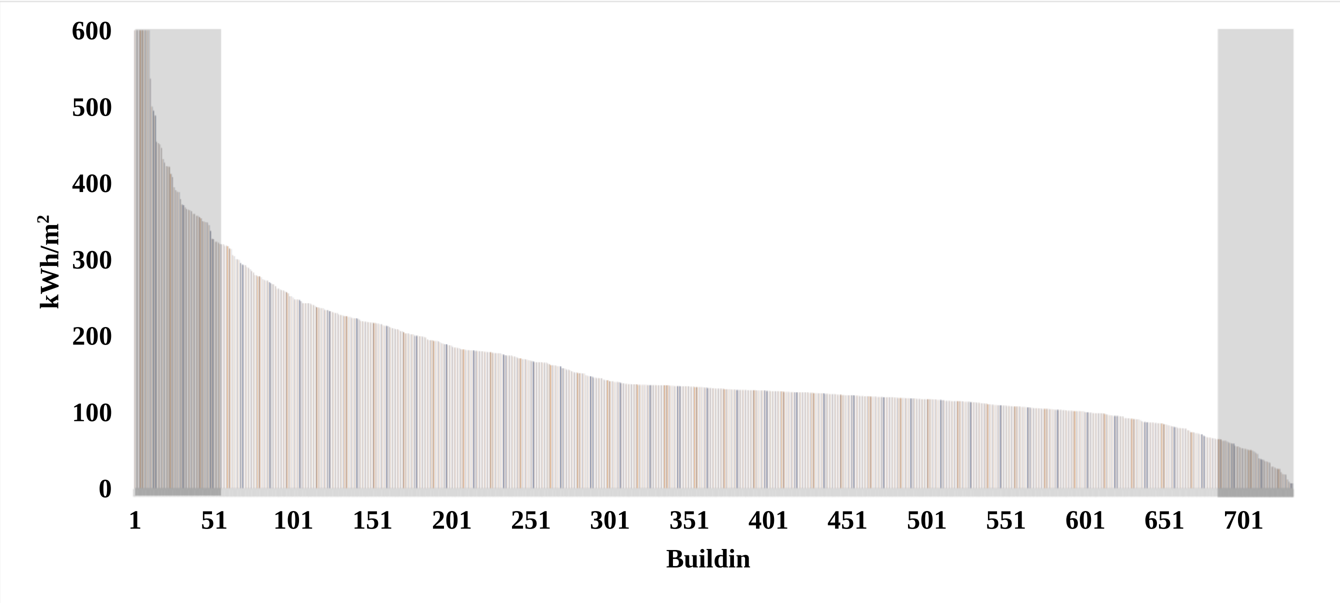
Source: heat suppliers, authors of the Study

<u>Elimination of atypical deviations</u>

When analysing the above data, it can be noted that actual average heat consumption of some benchmark buildings was calculated using data from a relatively small sample of buildings (e.g. the calculated average is therefore potentially unrepresentative).

In order to make proper use of these data for the assessment of the heating demand of buildings with no actual consumption data available, non-representative samples and atypical consumption deviations have to be eliminated. Data are eliminated proportionately, 7.5% of the maximum and of the minimum values as shown in the figure below. The grey parts of the sample are not included in subsequent calculations.

Figure 81. Consumption of heat supplied by the DH system to small multi-apartment buildings (EPC <D) per m²



Source: heat suppliers, authors of the Study

Having analysed and processed their consumption data, we obtain the following actual consumption by benchmark building.

228 Table. Data from heat suppliers: average consumption in benchmark buildings, kWh/m²/year

Group, subgroup	EPC					
	<D	C	B	A	A+	A++
1. Residential	147	101	95	59	46	34
1.1. Single-family	104	97	81	90	-	-
1.2. MAB (S)	194	124	142	660	19	-
1.3. MAB (M)	150	101	96	58	47	35
1.4. MAB (L)	144	95	79	61	44	33

Source: heat suppliers, authors of the Study

229 Table. Data from heat suppliers: number of buildings (excluding non-representative ones), number

Group, subgroup	EPC					
	<D	C	B	A	A+	A++
1. Residential	9.503	1.569	992	81	59	14
1.1. Single-family	1.143	81	55	2	0	0
1.2. MAB (S)	376	33	25	1	1	0
1.3. MAB (M)	7.598	1.387	846	67	51	12
1.4. MAB (L)	388	72	68	13	9	2

Source: heat suppliers, authors of the Study

Inadequate sample solution

For benchmarks for which actual average heat consumption was obtained for fewer than 15 buildings in all (see table above), it is not sufficient to take a sample to calculate the benchmark, therefore these data are removed from the subsequent analysis and the result is obtained as shown below.

230 Table. Data from heat suppliers: average consumption in benchmark buildings, kWh/m²/year

Group, subgroup	EPC					
	<D	C	B	A	A+	A++
1. Residential	147	101	95	59	46	34
1.1. Single-family	104	97	81	-	-	-
1.2. MAB (S)	194	124	142	-	-	-
1.3. MAB (M)	150	101	96	58	47	-
1.4. MAB (L)	144	95	79	-	-	

Source: heat suppliers, authors of the Study

As can be seen from the above data, actual average heat consumption of some of benchmark buildings could not be calculated as there were insufficient data for them to be representative of the benchmark building. Where actual data are insufficient, consumption was calculated based on average consumption of the entire household sector. This way we obtain estimated standardised consumption for all benchmark buildings.

231 Table. Estimated consumption in benchmark buildings, kWh/m²/year [234]

Group, subgroup	EPC					
	<D	C	B	A	A+	A++
1. Residential	147	101	95	59	46	34
1.1. Single-family	104	97	81	50	39	29
1.2. MAB (S)	194	124	117	73	57	42
1.3. MAB (M)	150	101	96	58	47	35
1.4. MAB (L)	144	95	79	49	39	29

Source: authors of the Study

We use estimated standardised consumption as shown above to calculate heat consumption of 366,000 buildings for which no actual data are available.

232 Table. Number of buildings for which actual data are available, thou

Group, subgroup	EPC						
	<D	**C**	**B**	**A**	**A+**	**A++**	**Total**
1. Residential							
1.1. Single-family	290.952	27.837	23.439	2.460	1.974	40	346.702
1.2. MAB (S)	8.721	84	73	3	4	0	8.885
1.3. MAB (M)	9.193	376	443	45	65	0	10.122
1.4. MAB (L)	129	-4	17	0	1	0	143
Total	308.995	28.293	23.972	2.508	2.044	40	**365.852**

Source: authors of the Study

As a result, we obtain estimated, statistically adjusted consumption for all household consumers (buildings).

233 Table. Annual UEC for heating buildings – actual data, GWh

Group, subgroup	EPC						
	<D	**C**	**B**	**A**	**A+**	**A++**	**Total**
1. Residential							
1.1. Single-family	3.044	393	272	15	9	0	3.733
1.2. MAB (S)	322	2	2	0	0	-	326
1.3. MAB (M)	1.505	165	91	3	3	0	1.768
1.4. MAB (L)	142	23	15	1	0	0	181
Total	5.013	583	380	18	13	1	6.008

Source: authors of the Study

Service sector

Data were obtained from heat suppliers on energy consumption of about 5,700 buildings in the service sector.

234 Table. Data from heat suppliers: number of service sector buildings connected to DH systems, number

Group, subgroup	EPC						
	<D	**C**	**B**	**A**	**A+**	**A++**	**Total**
2. Service sector							
2.1. Services	599	111	172	11	15	1	909
2.2. Administrative	1.406	174	136	33	16	-	1.765
2.3. Trade	486	83	208	15	13	-	805
2.4. Other	1.538	378	245	17	4	-	2.182
Total	**4.029**	**746**	**761**	**76**	**48**	**1**	**5.661**

Source: heat suppliers, authors of the Study

Average (arithmetic mean) heating demand data for these buildings are presented below.

235 Table. Data from heat suppliers: average thermal energy consumption in the service sector (kWh/m^2/year)

Group, subgroup	EPC					
	<D	**C**	**B**	**A**	**A+**	**A++**
2. Service sector	**80**	**61**	**60**	**37**	**24**	**58**
2.1. Services	77	63	58	33	23	58
2.2. Administrative	77	63	58	33	23	58
2.3. Trade	77	63	58	33	23	58
2.4. Other	83	60	65	105	49	-

Source: heat suppliers, authors of the Study

In order to ensure that average actual consumption data are representative and suitable for application to buildings for which no actual data have been obtained, we eliminated the following from the above data:

- Insufficiently accurate data, i.e. consumption data that cannot be assigned to a specific building (addresses where more than one building is registered);
- Atypical deviations, i.e. atypical minimum and maximum consumption values;
- Data samples that are insufficient to reflect heat demand of a specific benchmark building.

Elimination of insufficiently accurate data

Some of the data above also include addresses where more than one building is registered. Since various buildings may have different purposes and/or different EPCs, consumption assigned to an address cannot be exactly allocated to a specific building. It is therefore considered that these data are not reliable enough to be used for the calculation of the standard benchmark consumption of a building.

The table below shows actual average heat demand data and building numbers for addresses where one building is registered.

236 Table. Data from heat suppliers: average thermal energy consumption in the service sector (kWh/m²/year)

Group, subgroup	EPC					
	<D	**C**	**B**	**A**	**A+**	**A++**
2. Service sector	**77**	**57**	**57**	**36**	**19**	**58**
2.1. Services	72	57	51	31	19	58
2.2. Administrative	72	57	51	31	19	58
2.3. Trade	72	57	51	31	19	58
2.4. Other	84	57	68	108	26	-

Source: heat suppliers, authors of the Study

237 Table. Data from heat suppliers: number of service sector buildings, number

Group, subgroup	EPC						Total
	<D	**C**	**B**	**A**	**A+**	**A++**	
2. Service sector	**2.003**	**426**	**449**	**62**	**48**	**1**	**2.989**
2.1. Services	228	43	73	6	14	1	365
2.2. Administrative	772	111	86	32	16	0	1.017
2.3. Trade	304	62	150	11	15	0	542
2.4. Other	699	210	140	13	3	0	1.065

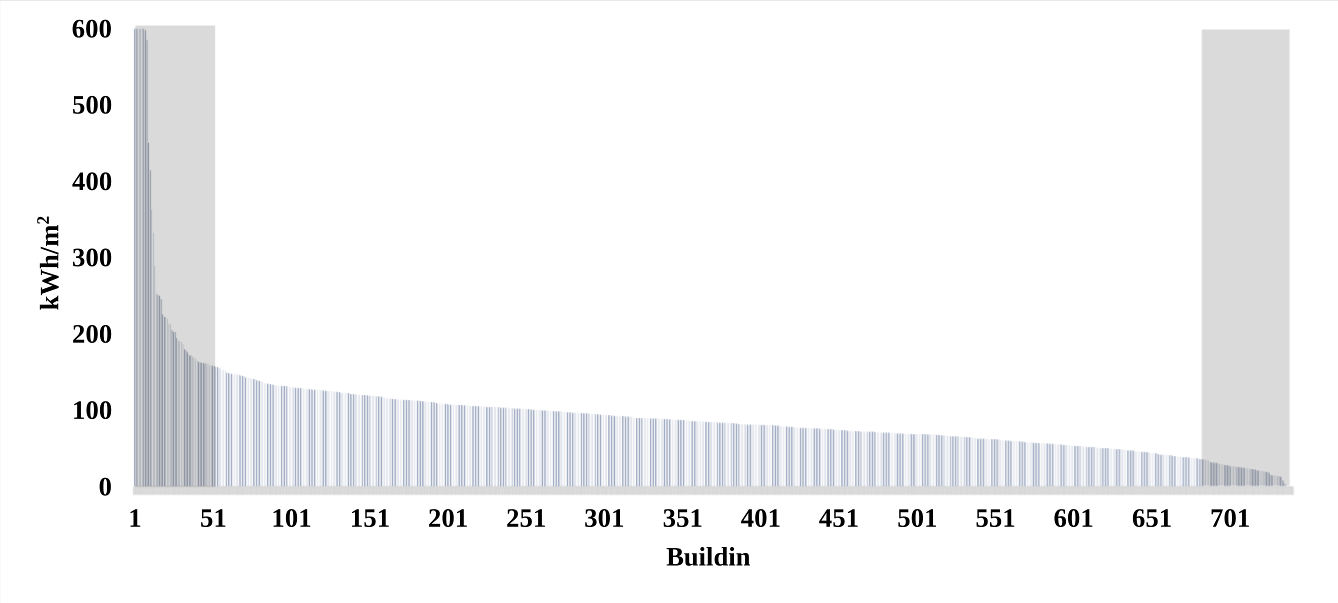
Source: heat suppliers, authors of the Study

Elimination of atypical deviations

When analysing the above data, it can be noted that actual average heat consumption of some benchmark buildings was calculated using data from a relatively small sample of buildings (e.g. the calculated average is therefore potentially unrepresentative).

In order to make proper use of these data for the assessment of the heating demand of buildings with no actual consumption data available, non-representative samples and atypical consumption deviations have to be eliminated. Data are eliminated proportionately, 7.5% of the maximum and of the minimum values as shown in the figure below. The greyed-out sections of the sample are not included in subsequent calculations.

Figure 82. Consumption of heat supplied by the DH system to administrative buildings (EPC <D) per m²



Source: heat suppliers, authors of the Study

Having analysed and processed their consumption data, we obtain the following actual consumption by benchmark building.

238 Table. Data from heat suppliers: average consumption in benchmark buildings, kWh/m²/year

Group, subgroup	**EPC**					
	<D	**C**	**B**	**A**	**A+**	**A++**
2. Service sector	**87**	**69**	**61**	**47**	**26**	**58**
2.1. Services	85	85	72	64	42	58
2.2. Administrative	87	74	64	32	17	-
2.3. Trade	55	65	50	35	23	-
2.4. Other	101	65	68	108	26	-

Source: heat suppliers, authors of the Study

239 Table. Data from heat suppliers: number of buildings for calculating benchmark consumption, number

Group, subgroup	**EPC**					
	<D	**C**	**B**	**A**	**A+**	**A++**
2. Service sector	1.703	364	383	54	42	*1*
2.1. Services	194	37	63	*6*	*12*	*1*
2.2. Administrative	658	95	74	28	*14*	-
2.3. Trade	260	54	128	*11*	*13*	-
2.4. Other	595	180	120	*13*	*3*	-

Source: heat suppliers, authors of the Study

<u>Inadequate sample solution</u>

For benchmarks for which actual average heat consumption was obtained for less than 15 buildings inclusive (see table above), it is not sufficient to take a sample to calculate the benchmark, therefore these data are removed from the subsequent analysis and the result is obtained as shown below.

240 Table. Data from heat suppliers: average consumption in benchmark buildings, kWh/m²/year

Group, subgroup	EPC					
	<D	C	B	A	A+	A++
2. Service sector	**87**	**69**	**61**	**47**	**26**	**-**
2.1. Services	79	74	58	35	26	-
2.2. Administrative	79	74	58	35	26	-
2.3. Trade	79	74	58	35	26	-
2.4. Other	101	65	68	-	-	-

Source: heat suppliers, authors of the Study

As can be seen from the above data, actual average heat consumption of some of benchmark buildings could not be calculated due to the lack of sufficient data for them to be representative of the benchmark building. Where actual data are insufficient, their consumption is estimated using average consumption of the entire service sector while average consumption of Class A++ service sector is estimated based on the residential sector. This way we obtain estimated average consumption for all benchmark buildings.

241 Table. Estimated consumption in benchmark buildings, kWh/m²/year

Group, subgroup	EPC					
	<D	C	B	A	A+	A++
2. Service sector	**87**	**69**	**61**	**47**	**26**	**19**
2.1. Services	79	74	58	35	26	19
2.2. Administrative	79	74	58	35	26	19
2.3. Trade	79	74	58	35	26	19
2.4. Other	101	65	68	52	29	22

Source: authors of the Study

We use estimated average consumption as shown above to calculate heat consumption of 34,300 buildings for which no actual data are available.

242 Table. Number of buildings for which no actual data are available, thou

Group, subgroup	EPC						
	<D	C	B	A	A+	A++	Total
2. Service sector							
2.1. Services	8.018	1.420	1.491	173	63	2	11.167
2.2. Administrative	6.935	497	415	45	21	0	7.913
2.3. Trade	5.865	514	678	86	76	2	7.221
2.4. Other	6.736	702	476	31	21	1	7.967
Total	**27.554**	**3.133**	**3.060**	**335**	**181**	**5**	**34.268**

Source: authors of the Study

As a result, we obtain estimated consumption for all household consumers (buildings).

243 Table. Annual useful energy consumption for heating buildings – actual data, GWh

Group, subgroup	EPC						
	<D	C	B	A	A+	A++	Total
2. Service sector							
2.1. Services	404	72	98	2	1	0	577
2.2. Administrative	1.419	102	69	38	9	-	1.637
2.3. Trade	69	39	90	-7	-1	0	191
2.4. Other	575	109	50	1	2	0	738
Total	**2.468**	**322**	**307**	**34**	**11**	**0**	**3.142**

Source: authors of the Study

2.3 Annex. Calculation of the heat sector's 2050 targets

244 Table. Calculation of PEC and FEC indicators planned for 2050

Indicator	Unit of measurement	Actual data		Calculated indicators	
		2017	2020	2030	2050
GDP growth (compared to 2020)	%	-	0	30%	65%
Annual GDP growth (compared to 2020)	%	-	0	3.0%	2.2%
GDP	million EUR	-	49.744	64.908	81.966
GDP (2010 prices)	million EUR	36.099	39.268	51.239	64.705
Intensity of energy consumption	kg_{ne}/kEur	217,97	199,32	145,31	90,82
Decrease in energy consumption intensity	times	1,00	1,09	1,50	2,40
Gross inland energy consumption	TWh	91,5	91,0	86,6	68,3
FEC Lithuania	TWh	62,2	62,1	59,1	46,6
FEC within the scope of the Study	TWh	26,9	25,1	23,9	18,8
PEC within the scope of the Study	TWh	31,3	27,4	26,1	20,6

Source: authors of the Study

2.4 Annex. Comparison of district heating with decentralised heating solutions

The National Energy Independence Strategy (NEIS) as one of the strengths of Lithuania's energy highlights the fact that well-developed district heating systems operate in all cities [135] and vice versa, due to over-regulation, an insufficiently attractive connection to district heating systems is seen as a disadvantage.

Competitiveness of district heating systems

Financial competitiveness of district heating networks compared to individual heating systems is based on three aspects:

a. Lower installed heat production capacity.
b. Lower unit price of installed heat output.
c. Lower operating and fuel costs.

Next, these three aspects are examined using a practical example – 10 multi-apartment buildings of 30 apartments each.

a. Reduced installed heat production capacity

When installing individual heat sources for each consumer, the power of the installations must be selected in such a way that it meets the maximum power need of each individual consumer. Thermal energy is used for space heating and hot water preparation. During the day, the need for energy for space heating is steady while that for hot water preparation fluctuates significantly. It is these fluctuations that create the preconditions for the centralisation of heat production.

When installing a heat source for one 30-apartment building, a heat source with a capacity of about 94 kW must be provided for hot water preparation. If there are 10 such buildings and each is equipped with individual hot water preparation, total capacity of the installations will be 940 kW. Meanwhile, in the case of district heating, the effect of estimating imbalances in hot water consumption is achieved. By installing one centralised heat source that will provide for 300 apartments (10 buildings of 30 apartments each), only 394 kW of power will be enough, i.e. 2.4 times less power is needed for heat production equipment. Therefore, the application of district heating technology reduces the required total capacity of heat production installations.

b. Lower unit price of installed heat output

Installing heat production capacity as a single large heat source significantly reduces relative investment (EUR/kW) compared to distributed (individual) production of the same capacity. In general, the following economies of scale formula is used during the technical-financial assessment:

$$\frac{C_1}{C_2} = \left(\frac{P_1}{P_2}\right)^a$$

Where: C_1 means costs of the installation
C_2 means costs due to changes in equipment efficiency P_1 means current efficiency of the equipment
P_2 means changed efficiency of the equipment
a means the proportion coefficient (generally set within the range of 0.6 to 0.7)

In the example here, replacing 10 separate production sources with one centralised one would result in a 2.2-fold decrease in the price of the initial investment. However, in the case of DH systems, the price of heat supply infrastructure must be additionally taken into account.

135 https://enmin.lrv.lt/uploads/enmin/documents/files/Nacionaline%20energetines%20nepriklausomybes%20strategija_2018_LT.pdf.

In Vilnius, the average distance of the heat mains between consumers connected to district heating networks is about 80[136] meters. Currently, it costs about EUR 374 EUR/m[137] to build a meter of heat mains, i.e. in the simulated case it would cost about EUR 30,000 to connect one multi-apartment building to the DH network, and an average of EUR 300,000 to connect 10 multi-apartment buildings.

The table below shows a comparison of district heating and three individual heating methods (natural gas, biofuel and heat pump), simulating an example of 10 multi-apartment buildings (30 apartments each). The installed pipeline of the district heating network is expected to last about 50 years while the individual heating system on average lasts about 22 to 25 years, so the investment in the district heating network is halved.

245 Table. Comparison between district and decentralised heating system investments

	Units of measurement	District	Individual	Difference	Difference, %
Installed capacity	kW	2.745	3.290	545	-17%
For heating the building	kW	2.350	2.350	0	0%
For hot water	kW	395	940	545	-58%
Price of heat in the gas system	EUR	471.117	1.242.238	771.121	-62%
Price of the HP system	EUR	1.001.688	2.641.245	1.639.557	-62%
Price of the biofuel system	EUR	496.683	1.309.650	812.968	-62%
Price of a typical pipeline	EUR	149.896			

Source: authors of the Study

It should be noted that, with the widespread development of the use of heat pumps for individual heating, it is necessary to include the installation of the power grid in the investment. In cold conditions, i.e. with temperatures dropping below -25°C, efficiency of most aerothermal heat pumps drops to 1, i.e. they generate as much heat as they consume electricity. The power input capacity of many buildings would therefore need to be increased by 3-4 times, which would mean additional investments not only in the power distribution network but also in the transmission network, power generation and power interconnections with EU countries.

c. Lower operating and fuel costs

District heat generation costs experience similar economies of scale as production equipment, i.e. operating costs (excluding fuel) are about 2.2 times lower (for the simulated scenario of 10 multi-apartment buildings, each with 30 apartments). Operating costs account for up to 30% of the total cost of heat production, and economies of scale, depending on the fuel used, can help to ensure up to 12% lower operating costs.

As far as fuel combustion efficiency is concerned, two aspects are analysed: lower purchasing price of fuel and fuel efficiency, for example:

- The comparative price of firewood for an individual multi-apartment building is about EUR 18/MWh while district heat producers buy wood chips for EUR 12-14 /MWh, or 27% cheaper. Thanks to better maintained heat production equipment, condensing smoke economisers already used and condensing smoke economisers currently being installed, district heat producers can generate 20-25% more heat compared to individual solutions.
- The comparative price of gas for an individual multi-apartment building is about EUR 55 /MWh while district heating producers buy gas at a price lower by about 10% (due to lower transmission and distribution fees and the possibility to purchase gas as a commercial customer). That said, equipment efficiency between individual multi-apartment buildings and district production varies only slightly. Both low-power and high-power systems are equipped with condensing smoke economisers, and maintenance is relatively simple and only in the long term, due to better maintenance of district heating boilers, the efficiency gap is expected to grow.
- By installing high-performance heat pumps, a district heating installer could purchase electricity up to 10% cheaper[138]. District heat producers could reduce electricity prices even further by exploiting price

136 https://chc.lt/lt/musu-veikla/apie-ab-vilniaus-silumos-tinklus/26.

137 Sistela.

138 Based on 2017-2020 electricity price gap between natural and legal persons.

fluctuations when installing on-site wind turbines and storage tanks and taking other measures. The efficiency of heat pumps depends on their size, for example, a 10 MW aerothermal heat pump with the same amount of electricity will produce about 27% more heat than a 1 MW aerothermal heat pump.

The variable cost of centrally produced heat is 25-54% lower than heat production using the same fuel for each building individually. Cost savings result from relatively lower operating costs, greater efficiency of more powerful systems and a better bargaining position when purchasing fuel. Given that losses of the district heating network amount to about 14% and variable costs of district heating are at least 25% lower than those of individual heat production in each multi-apartment building, district heating networks where it is financially feasible to build them (or they already exist) are the cheapest way to supply heat.

246 Table. Comparison between variable costs of district and decentralised heating systems

	Unit of measurement	District	Individual	Difference	Difference, %
Heat content	MWh	2,403	2,403	-	-
Gas operating costs	EUR	18,566	48,955	30,389	-62%
HP operating costs	EUR	21,286	56,127	34,841	-62%
Biofuel operating costs	EUR	33,439	88,172	54,733	-62%
Gas efficiency	Coeff.	0,94	0,90	-0.04	4%
HP efficiency	Coeff.	4,95	3,9	-1.053	27%
Biofuel efficiency	Coeff.	1,06	0,88	-0.176	20%
Gas purchasing price	EUR/MWh	50	55	5	-9%
Purchasing price of HP electricity	EUR/MWh	136	150	14	-9%
Biofuel purchasing price	EUR/MWh	13	18	5	-28%
Gas fuel costs	EUR	148,627	146,850	-1,777	1%
HP fuel costs	EUR	76,928	92,423	15,495	-17%
Biofuel fuel costs	EUR	34,398	49,152	14,754	-30%
Variable gas costs	EUR	167,193	195,805	28,612	-15%
Variable HP costs	EUR	98,214	148,550	50,336	-34%
Variable biofuel costs	EUR	67,837	137,324	69,487	-51%
Average energy losses of district heating networks		14%	-		

Source: authors of the Study

To sum up, an optimally functioning DH system is in many cases (with sufficient demand density) a cheaper alternative both in terms of investment and variable costs.

Other positive aspects of district heating

District heating technology has many positive aspects:

1. Less air pollution (both locally and city-wide)
2. High reliability of heat supply and energy mix diversification
3. Other aspects: Extremely low noise level, small area occupied by a heat substation in a heated building

Below is a detailed description of essential positive aspects.

Less air pollution

Large district heating boiler houses are subject to much more stringent monitoring of environmental parameters and relatively cheaper combustion product cleaning facilities. Even when technically sound solid fuel combustion plants are installed in individual houses, their particulate matter emissions are on average between 28.8 and 72 g/MWh of fuel whereas in district heating boiler houses this indicator is only between 0.4 and 7.2 g/MWh of fuel. In other words, producing the same amount of heat results in at least 10 times more pollution from individual heating than from district heating. The same is true for other sources of pollution.

While individual emission indicators for district heating may be higher than for typical individual heating, major pollutants such as particulate matter and nitrogen oxides in individual heating significantly exceed the same values for district heating.

Energy mix diversification

The last but perhaps the most important argument when opting for district heating technology is its reliability and the possibility of diversifying the energy mix involved.

A well-developed district heating network usually has its mains connected in circles and several heat sources installed in different parts of the network. In addition, district network boiler houses may use different types of fuel. Therefore, this type of heating is much more reliable than individual heating. In the event of any malfunction or failure of one of the kinds of power supply, sources can switch between the main and alternative fuels rapidly and imperceptibly for the final consumer or launch standby boiler houses.

It is also important to understand that some technologies or energy can only be used in district heating. In this way, for example, when choosing an individual heating method, one may not opt for cogeneration plant technologies and waste incineration while using waste heat becomes much more difficult. The technologies listed are not only important for the production of thermal energy but also have an impact on the entire country addressing socioeconomic issues, reducing the country’s energy dependence and allowing the country to deal with greenhouse gas emissions more effectively.

Negative aspects of district heating

One of the main arguments against district heating is heat supply systems (pipelines) themselves, which imply a large initial investment. Only large construction companies are able to carry out the laying of heat supply pipelines, and the very process of laying heating mains requires expensive and complex equipment. In addition, pipelines suffer heat energy losses, which reduces the efficiency of primary energy use and boosts variable costs of heat production.

Specific cost of capital increases as the density of heat consumption decreases, which may become an obstacle to the development of heat supply networks to urban areas with lower population density.

One downside might be the fact that some heat consumers want to have greater control over their heat consumption, which is not always possible with district heating. Apart from needing heat, some commercial consumers also need cold for their ventilation systems while district cooling technologies in Lithuania are not yet developed and heat supply companies cannot provide such a service.

2.5 Annex. Algorithm for assessing the potential of connecting to the DH systems

Calculation of the maximum capacity for the need for heat

The maximum need for heat of a given decentralised consumer is calculated in accordance with the procedure set out in Annex 2.8.

Calculation of the connection area

The connection area is calculated according to the following formula:

$$Connection\ area = \frac{Heat\ selling\ price \times Heat\ content}{Additional\ costs \times Pipeline\ length\ factor}$$

Where:

Heat selling price: heat price (excluding VAT) for the newly connected site based on the weighted sold heat price in the municipality concerned in 2020[139] (including heat production and supply components).

Heat content: the site's need for heat (actual or estimated)

Additional costs: additional costs of heat supply per meter of distance from the site based on the weighted heat supply component in the municipality concerned in 2020;

Pipeline length factor: the average ratio of the pipeline length between the sites and the geographical distance between them, which in the Study is set at 1.1697.

Data on the prices set by heat suppliers are collected centrally by the NERC[140]. The weighted price is calculated by estimating that the average need for heat varies month-on-month, i.e. during the heating season (November to March) a monthly leverage of 0.132 is used while during the transitional season (April and October) it is 0.085 and during the warm season (May to September) it is 0.034.

Additional costs are calculated on the basis of the comparative economic indicators of estimated construction prices of the buildings based on estimated construction prices of the buildings in April 2022. Prices are VAT exclusive. The resulting table is below:

247 Table. Installation costs of the DH system pipeline and by diameter

Diameter – DN	Transmission capacity, kW	Installation price, EUR/m	Heat loss kWh/m/year
40	160	374,74	202
50	290	374,74	228
65	560	374,74	271
80	870	374,74	282
100	1700	651,59	297
125	3000	651,59	354
150	5000	651,59	428
200	10000	1.031,69	479
250	18000	1.031,69	460
300	29000	1.629,73	569
350	38000	1.629,73	579
400	53000	2.335,63	790

Source: comparative economic indicators of estimated construction prices of the buildings based on estimated construction prices of the buildings in April 2022

139 https://www.vert.lt/SiteAssets/teises-aktai/siluma/C%C5%A0T%20%C5%A1ilumos%20kainos%202022-07.pdf.
140 https://www.vert.lt/SiteAssets/teises-aktai/siluma/C%C5%A0T%20%C5%A1ilumos%20kainos%202022-07.pdf.

To assess the connection area, the following calculations are performed:

- Amortisation deductions – the cost of installing the pipeline is divided by 30 years
- Return on investment – 5% of the investment amount
- Heat loss coverage – buffer length multiplied by loss per meter of the mains (see table above) and heat production price
- Coverage of the wage fund – calculated based on heat suppliers' benchmark indicators published by the NERC – 4.729 EUR/1 km of 100 mm diameter connecting pipe, calculated proportionately to the pipe diameter
- Repair costs – calculated based on heat suppliers' benchmark indicators published by the NERC – 750 EUR/1 km of 100 mm diameter connecting pipe, calculated proportionately to the pipe diameter
- Other additional costs – calculated based on heat suppliers' benchmark indicators published by the NERC – 536 EUR/1 km of 100 mm diameter connecting pipe, calculated proportionately to the pipe diameter

Accordingly, buffers are calculated for all sites that are not connected to the DH system and it is checked whether within the site's buffer there is another site that is connected to the DH system:

- If there is a site connected to the DH system found within the buffer, the site whose buffer is being defined becomes connectable to the DH system.

This exercise is performed in cycles so as to identify not only the sites to be directly connected to the DH system but also the sites that could be connected through connectable sites.

It is also checked whether it is not possible to start developing new local DH networks, i.e.:

- Calculate the average number of overlapping connection areas in the DH system area only for buildings connected to the DH system
- Intersections of connection areas not connected to the DH system where more connection areas overlap at the intersection point than within the existing DH system are identified
- Buildings whose connection areas intersect more times than the average number of intersections within the DH system area constitute a new local DH system
- It is checked whether it is possible to connect other sites directly to the newly formed local DH system or through other sites using the algorithm described above.

2.6 Annex. Assessment of the potential for enhancing efficiency in DH systems

The optimal set of production technologies for district heating is assessed individually for each system in accordance with the following procedure:

a) Calculation of the system's need for heat
b) Identifying existing heat generating installations
c) Identifying sources of waste heat
d) Identifying heat demand characteristics limiting the use of waste heat
e) Calculating the optimal distribution of sources and the required heat capacity to for the development
f) System's need for heat

a) Calculation of the system's need for heat

The need for heat in an existing or newly formed DH system is calculated by summing the need for heat and calculating the capacity of the need for heat as described in Annex 2.8.

b) Identifying existing heat generating installations

Existing heat production installations in each municipality were identified in Chapter 7.1.

c) Identifying sources of waste heat

Existing waste heat sources were identified and their potential to be connected to DH systems is described in Chapter 7.1.4.

Identifying heat demand characteristics limiting the use of waste heat

Without developing low-temperature heating networks, in most cases waste heat can only be used with heat pumps that need to be powered. Electricity consumption is estimated to be converted to heat in a 1:1 ratio.

Calculating the optimal distribution of sources and the required heat capacity to for the development

The optimal power distribution between DH heat generating installations is selected individually for each system taking into account the power of that system and its unevenness during the year. The power mix of installations is chosen from among the following technologies:

- Biofuel (pellets, chips)
- Solar collectors
- Waste heat
- Heat pumps

The distribution of heat pump and biofuel boiler technologies is selected based on the system's capacity of the need for heat and its unevenness during the year by calculating financial costs of each technology for the reference year. To meet the need for heat which turns up only during peak periods, natural gas is usually the most suitable solution, and in absence of the possibility to use natural gas, it is biofuel pellets.

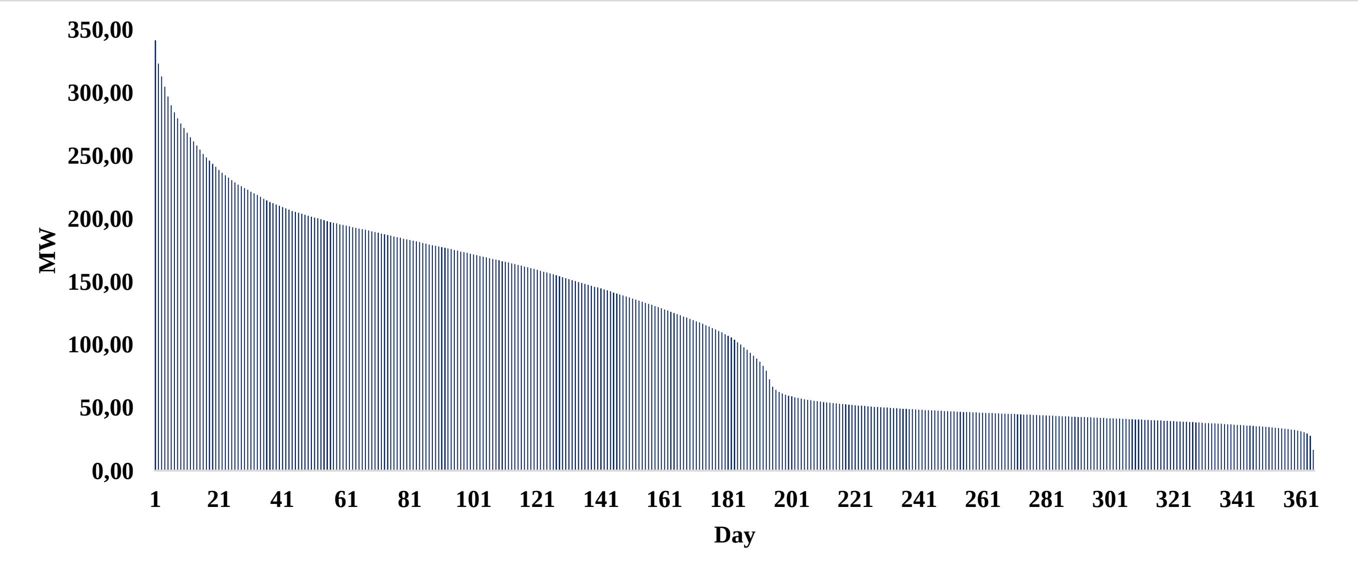
As the use of solar panels and waste heat is assessed separately, the final mix of heat production technologies for DH systems is selected based on the following logic:

- The power of fuel oil, liquid fuel and other fuels is assumed to be zero in the future, i.e. they will no longer be used
- Heat produced by biofuel cogeneration plants in the cold season is considered not to be decreasing
- All existing heat production from waste remains as is, no new capacity is developed but the amount of heat produced during the warm season decreases

- The capacity of biofuel installations is selected to meet the need for heat during the cold season
- Waste heat is used as much as can be used in a specific DH system
- The capacity of solar collectors is established such as to meet the total heat demand during the warm season which remains after waste heat, cogeneration plants and waste incineration. In absence of other sources, solar panels supply up to 15% of total annual need for heat in the DH system
- The power of heat accumulators is set at 60% of the power of solar panels for the proper operation of solar panels and meeting the need for heat around the clock. Batteries can also be used during the cold season to reduce gas consumption and boost the use of biofuel but this option has not been evaluated within the scope of this Study

The chart below shows daily power distribution day-on-day in a system of 1 TWh annual demand. It is therefore estimated that more than 300 MW will be needed for less than 5 days per year.

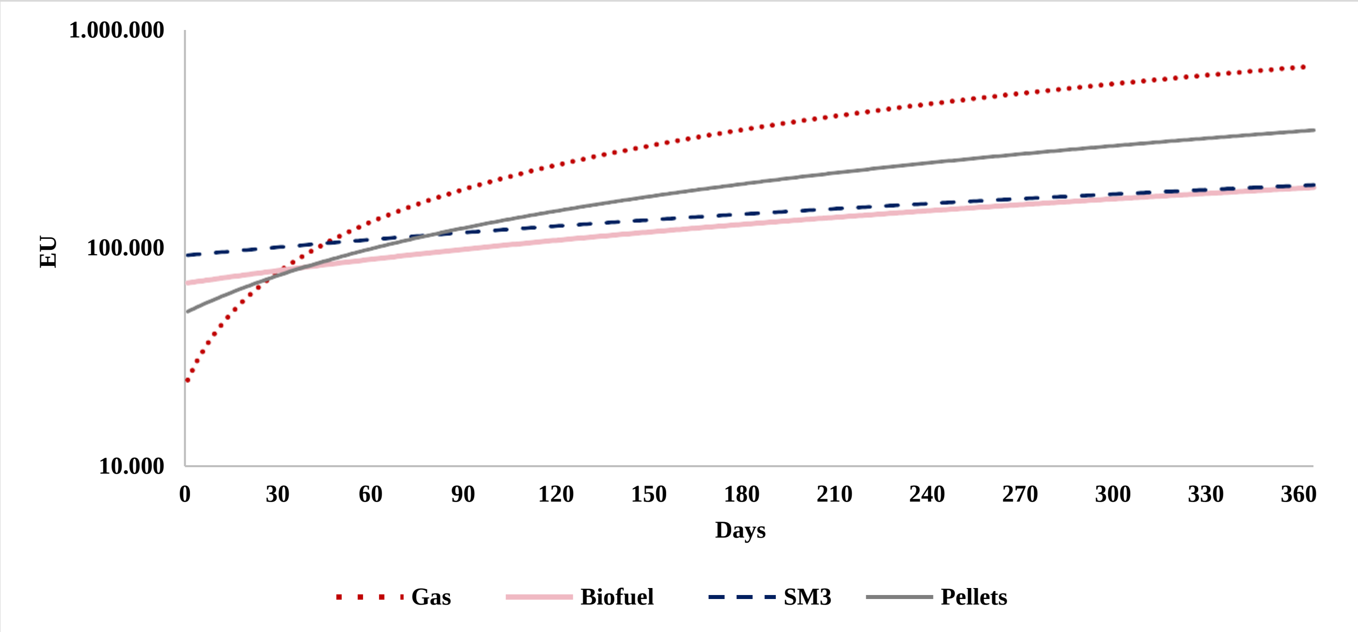
83 Figure. Average annual daily heat demand capacity of the network with 1 TWh annual heat demand



Source: authors of the Study

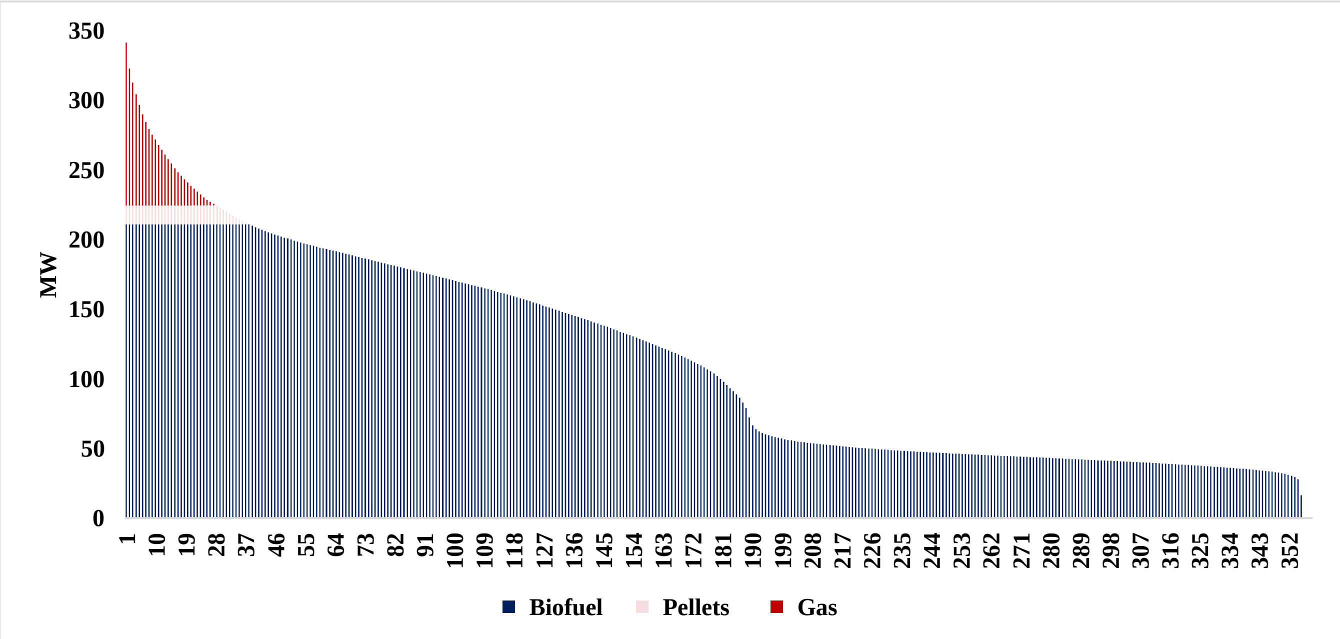
Thus, the cheapest solution according to the schedule of technologies is selected for each day, see below.

84 Figure. Cost of operation of a 1 MW heat generating unit



Source: authors of the Study

85 Figure. Capacity of equipment used for meeting the need for heat by type of fuel

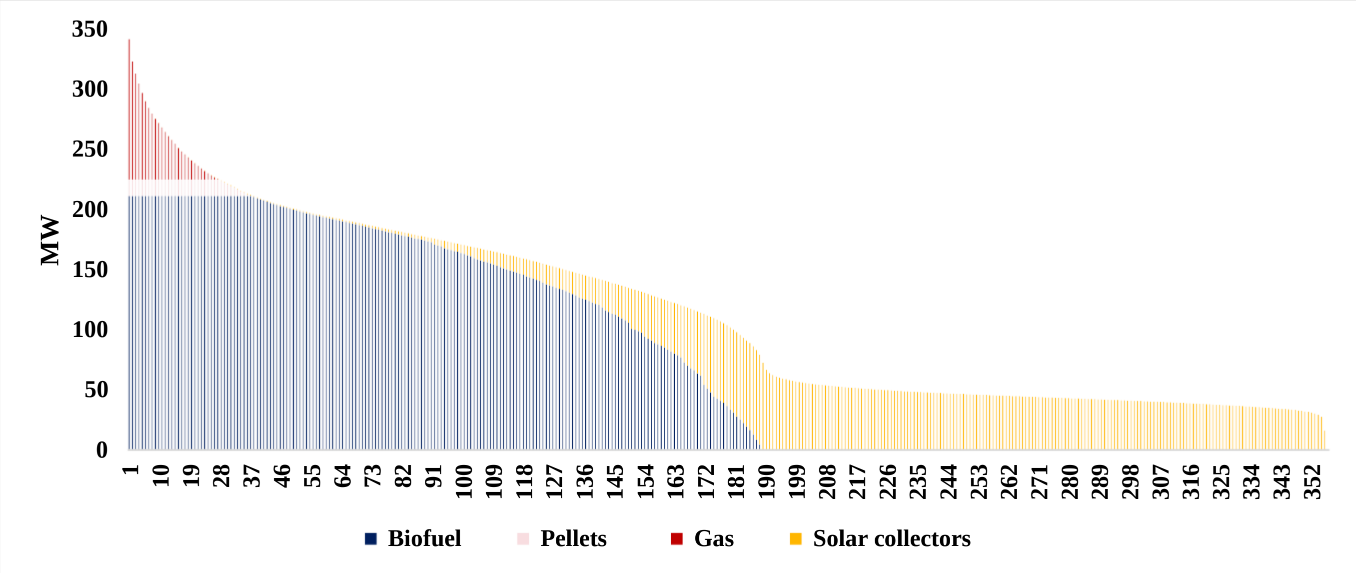


Source: authors of the Study

When developing district heating networks, it is appropriate to install solar collectors with batteries in order to reduce the price of heat for consumers and the amount of fuel used. Solar collectors would allow for a complete replacement of fuel incineration during the warm season and, during the transition period, would allow using it less.

Heat content generated by solar collectors day-on-day was calculated based on data on average solar radiation in Lithuania between 2005 and 2020 and technical data on solar collector efficiency. The result is shown in the figure below:

86 Figure. Capacity of equipment used for meeting the need for heat by type of fuel, including solar collectors



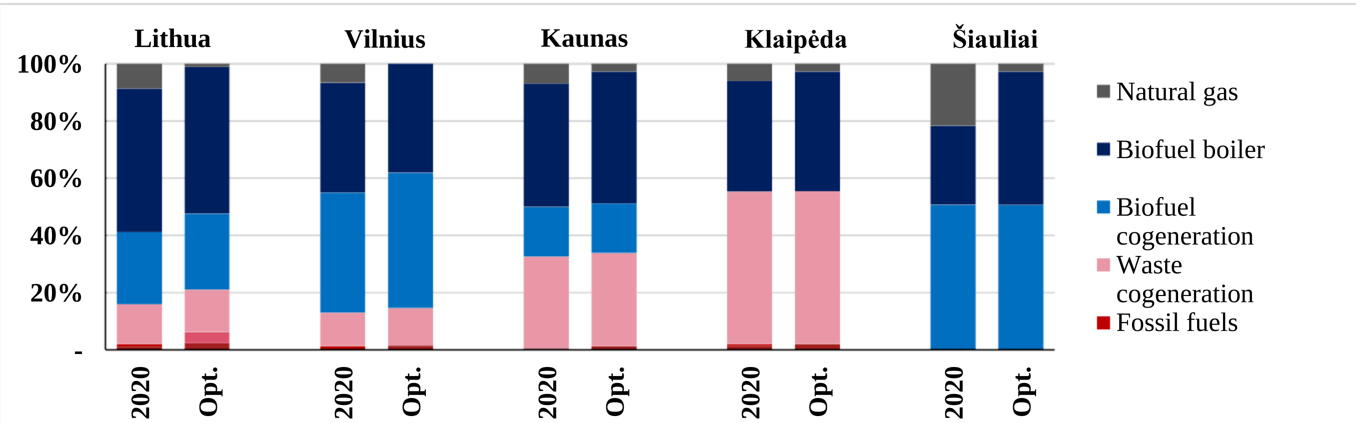
Source: authors of the Study

Solar collectors are not suitable for use in systems with a sufficient amount of waste heat or heat generated by cogeneration/waste incineration plants, which should be released into the environment as a result of heat production in solar collectors.

Batteries installed with solar collectors could be used to reduce gas usage on certain days but this effect is highly dependent on the hourly curve of the need for heat in each system, so it is not assessed within the scope of the Study.

Taking into account that existing heat sources of biofuel cogeneration and waste incineration plants are maintained also taking into account waste heat sources to be used (for details see Chapter 7.1.4) and the resulting data on the optimal district heating production algorithm, the eventual result for Lithuania and the five largest DH system networks in Lithuania is shown in the figure below. For details see the chart below.

87 Figure. Capacity of equipment used for meeting the need for heat by type of fuel, including solar collectors



Source: authors of the Study

2.7 Annex. Assumptions for calculating socioeconomic damage caused by production sources

CO_2 emission factors. Same factors apply for all sectors

Fuel	tCO_2/TJ	Source	Comments
Petroleum products	77,4	1. EPA	
Coal	105,0	2. STR	
Solid fuel	100,0	2. STR	
Peat	100,0	2. STR	
Waste	55,00	3. EPA	Indicator 110 (considering that the non-renewable component accounts for 50% of waste)
Natural gas	55,34	3. EPA	

Sources:

1.EPA – Lithuanian national GHG inventory reports:

https://am.lrv.lt/lt/veiklos-sritys-1/klimato-kaita/sesd-apskaitos-ir-prognoziu-ataskaitos-nacionaliniai-pranesimai

https://am.lrv.lt/uploads/am/documents/files/Klimato_kaita/LTU_2022_2020_14032022_235822_started.xlsx.

2. STR – Technical Construction Regulation STR 2.01.02:2016

https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/15767120a80711e68987e8320e9a5185/asr.

3. EPA – net calorific values and emission factors for fuels in Lithuania

https://aaa.lrv.lt/lt/veiklos-sritys/klimato-kaita/es-atl-prekybos-s Sistema/informacijos-mainu-centras.

PM factors. Factors apply by sector

Source: EMEP/EEA air pollutant emission inventory guidebook 2019

https://www.eea.europa.eu/publications/emep-eea-guidebook-2019.

Households

Fuel	g/TJ	Reference, comments
Petroleum products	1.900	Residential plants, 'Other' Liquid Fuels / Tier 1
Coal	398.000	Hard Coal and Brown Coal / Tier 1
Solid fuel	398.000	Applicable carbon value
Peat	398.000	Applicable carbon value
Natural gas	1.200	Residential plants, Gaseous fuels / Tier 1
Biofuel (efficient)	140.000	Residential - Conventional boilers < 50 kW (Wood) / Tier 2
Biofuel (inefficient)	740.000	Residential plants, Solid biomass / Tier 1

Services

Fuel	g/TJ	Reference, comments
Petroleum products	3.000	Fuel oil (Distillate fuel oil) / Tier 2
Coal	108.000	Hard Coal and Brown Coal / Tier 1
Solid fuel	108.000	Applicable carbon value
Peat	108.000	Applicable carbon value
Natural gas	780	Gaseous Fuels / Tier 1
RES gas	780	Gaseous Fuels / Tier 1
Biofuel	98.500	Wood combustion <1MW – Boilers / Tier 2

Industry

Fuel	g/TJ	Reference, comments
Petroleum products	12.000	Liquid Fuels / Tier 1
Coal	3.400	Applicable value for DH sector
Solid fuel	108.000	Solid fuels / Tier 1
Peat	108.000	Solid fuels / Tier 1
Natural gas	780	Gaseous Fuels / Tier 1
RES gas	780	Gaseous Fuels / Tier 1
Biofuel	70.000	Biomass / Tier 1 (minimum value)
Waste	3.000	Tier 1

DH system

Fuel	g/TJ	Reference, comments
Petroleum products	19.300	Heavy Fuel Oil (Tier 1)
Coal	3.400	Hard coal / Tier 1
Solid fuel	108.000	Applicable value for the industry sector
Natural gas	890	Natural gas / Tier 2
RES gas	890	Natural gas / Tier 2
Biofuel	66.000	Biomass / Tier 2 (minimum value)
Waste	3.000	Tier 1

Estimates of CO_2 and PM emissions damage. Same factors apply in all sectors

Source: CPMA methodology for the preparation of investment projects

https://ppplietuva.lt/lt/viesuju-investiciju-projektu-rengimas/metodikos-ir-leidiniai/investiciju-projektu-kuriems-siekiama-gauti-finansavima-is-europos-sajungos-strukturines-paramos-ir-ar-valstybes-biudzeto-lesu-rengimo-metodika-1.

Indicator	2022 value	Comments
CO_2 damage	114 EUR/t	Applies to all sectors
PM damage: 2.5_Low	16,704.59 EUR/t	Applies to households and the service sector
PM damage: 2.5_High	7,897.6 EUR/t	Applies to the industry and the DH sectors

2.8 Annex. Calculation of the capacity of the need for heat

The need for heat in a building consists of two components:

- Capacity of the need for heat for hot water preparation
- Capacity of the need for heat for space heating

Capacity of the need for heat in a building is calculated based on the following formula

$$Q_{max} = Q^{h}_{max} + Q^{KV}_{max}$$

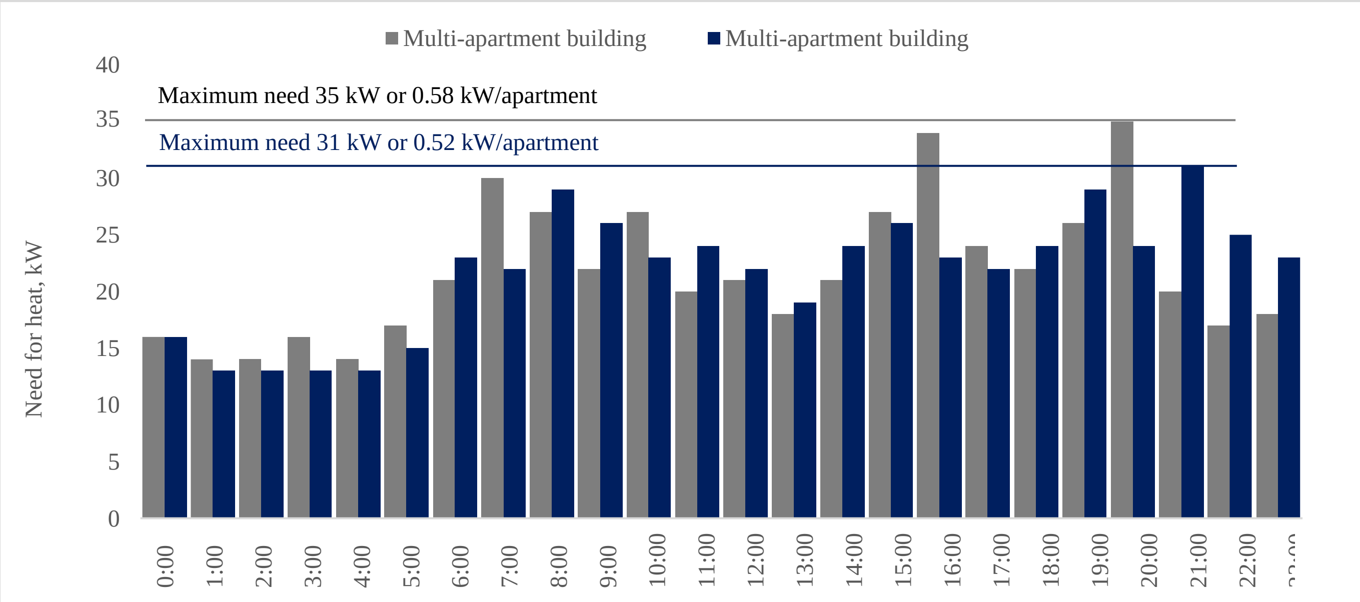
Where Q_{max} – highest cumulative capacity of the need for heat in a building, MW; Q^{h}_{max} – highest capacity of the need for heat in a building for space heating, MW; Q^{KV}_{max} – highest capacity of the need for heat in a building for hot water preparation. The input data for this formula are detailed below.

Capacity of the need for heat for hot water preparation

The evaluation was carried out based on 25 different types and heights of multi-apartment buildings with 8 to 108 apartments per building. Estimation is based on actual hourly consumption of a heat substation between June and September inclusive. The calculation includes the need for heat to ensure circulation and hot water preparation. Combining simultaneous heat consumption of buildings allows estimating simultaneous consumption of 800 apartments.

When establishing the dependence of the maximum need for heat on the number of apartments, actual heat needs of multi-apartment buildings are analysed. Below is an example of how capacity of the need for heat is established for individual multi-apartment buildings and how they are combined in order to estimate consumption imbalances. Two multi-apartment buildings of similar size are selected with 60 apartments each, and a typical day of hot water consumption is selected.

88 Figure. Hourly need for heat for hot water, kW

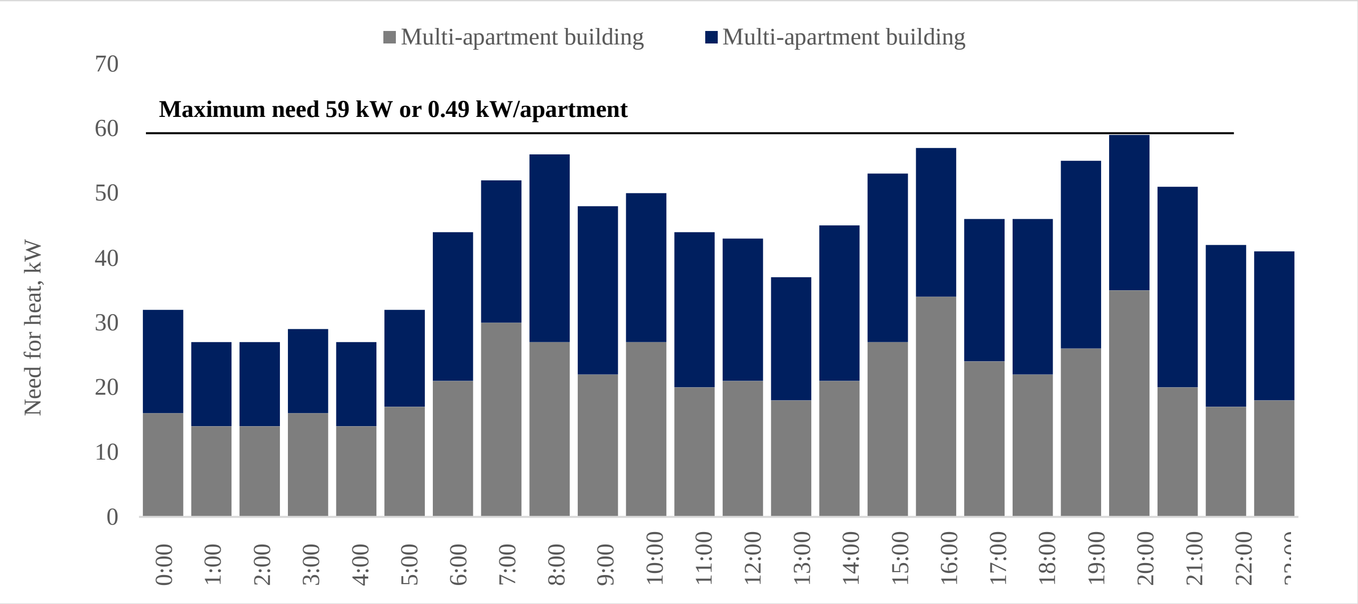


Source: authors of the Study

Graphic data show that although the consumption profile of both multi-apartment buildings is similar (with clearly expressed morning and evening consumption peaks), the multi-apartment building No 1 reaches its peak consumption at about 21:00 when consumption reaches 35 kW, or 0.58 kW/apartment while the multi-apartment building No 2 reaches the peak of the need for heat at 20:00 and it is only 31 kW, or about 0.52 kW/apartment.

Meanwhile, if we combine consumption of these multi-apartment buildings into one, conditional consumption will cover 120 apartments and its maximum capacity of the need for heat for hot water on this day would reach 59 kW, or 0.49 kW/apartment.

89 Figure. Hourly need for heat for hot water, kW



Source: authors of the Study

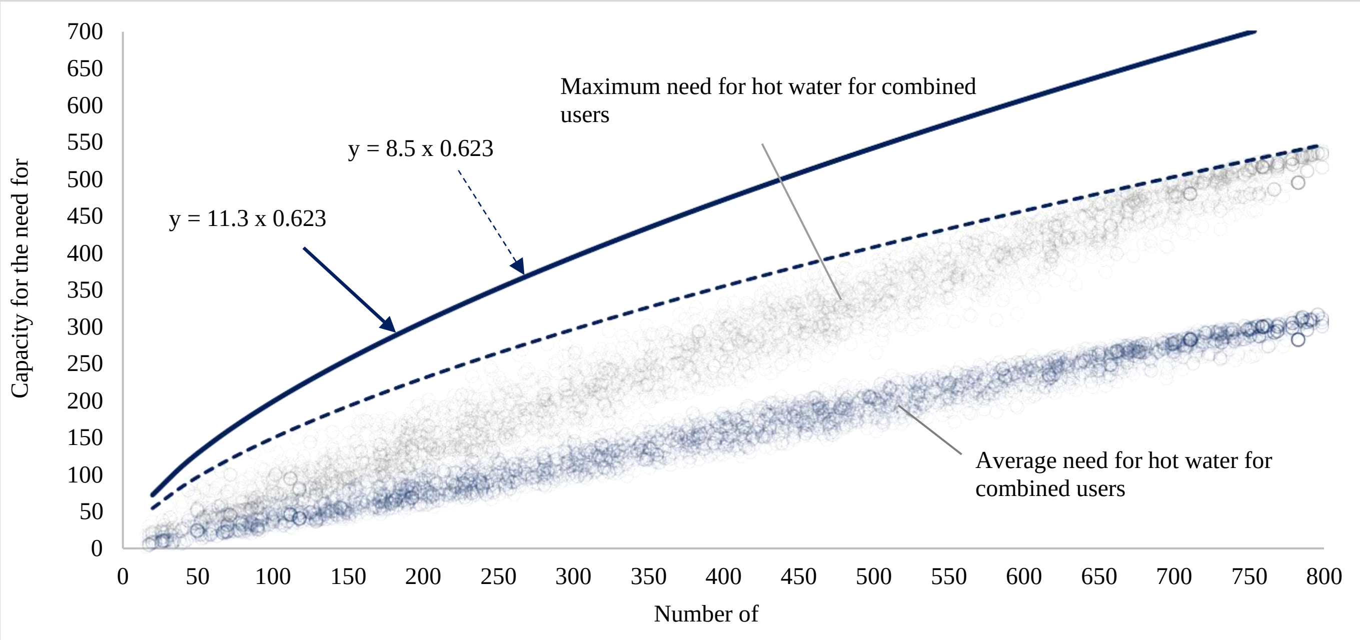
In this way, we get the result that with a larger number of apartments, due to the unevenness of consumption, the relative need for hot water per apartment decreases.

The following example shows only one day's need for hot water preparation while an analysis of the need over a longer period of 4 months brings about the following results:

1. Multi-apartment building No 1: maximum need 40 kW or 0.67 kW/apartment
2. Multi-apartment building No 2: maximum need 37 kW or 0.62 kW/apartment
3. Multi-apartment buildings No 1 and No 2: maximum need 69 kW or 0.58 kW/apartment

Combining different multi-apartment buildings and different numbers of multi-apartment buildings in different combinations (in random order), a set of results was obtained and displayed graphically.

90 Figure. Correlation between the need for heat for hot water preparation and the number of apartments



Source: authors of the Study

The data provided show that although the average need for heat increases linearly with the number of apartments, the maximum need for hot water is significantly higher and if you draw a curve through the highest values obtained, a step function is obtained:

$$Q^{KV}_{max} = 8.5 \times (Q_{apts})^{0.623}$$

Where Q^{KV}_{max} – maximum capacity of the need for heat for hot water preparation; Q_{apts} – number of apartments (dwellings).

For the purposes of the assessment, it should be borne in mind that the calculation was carried out using a sample of only 25 buildings. Meanwhile, the number of multi-apartment buildings in the country is significantly higher and the consumption of such multi-apartment buildings excluded from the estimation may vary.

To reach a higher level of confidence of the calculation result, the sampling error is estimated. Statistical methods help to calculate that the result obtained must be multiplied by a factor of 1.329 in order to obtain a 99.9% confidence.

$$Sampling\ error = \frac{z_{0.999} \times 0.5}{\sqrt{n}} = \frac{3.29 \times 0.5}{\sqrt{25}} = 0.329$$

Here, $z_{0.999}$ is the standard estimate that gains the value of 3.29 at the 99.9% confidence level; n is the estimated sample of values.

Thus, the estimation of the sampling error leads to a preliminary estimate of the need for hot water based on the following formula:

$$Q^{KV}_{max} = (1 + 0.329) \times 8.5 \times (Q_{apts})^{0.623}$$

$$\boldsymbol{Q^{KV}_{max} = 11.3 \times (Q_{apts})^{0.623}}$$

Taking into account the actual situation that in absence of a heating system centralised at least at the building level, boilers or storage tanks are usually installed, which distribute the need for heat over time, the estimated capacity of the heating system for hot water preparation for 1 to 5 apartments is 4 kW per apartment, so the table below is obtained.

248 Table. Heating system capacity for hot water preparation

Number of apartments	Heating system capacity for hot water preparation		
	Decentralised system capacity	District system capacity	Capacity per apartment
1	4	4	4,0
2	8	8	4,0
…	…	…	…
6	24	35	5,8
7	28	38	5,4
8	32	41	5,2
9	36	44	4,9
10	40	47	4,7
...	…	…	…
100	400	199	2,0
...	…	…	…
1.000	4.000	836	0,8
...	…	…	…
10.000	40.000	3.508	0,4

Source: authors of the Study

Capacity of the need for heat for space heating

The need for heat for heating is established based on the formula below,

$$Q_{h_{max}} = Q_{h_{AVG}} \frac{\theta_c - \theta_{min}}{\theta_c - \theta_{avg}}$$

Where Q_{max} – maximum need for heat for heating the building, MW; Q^h_{AVG} – average need for heat capacity for heating the building, MW; θ_c – average room temperature °C (the value of 20°C is used); θ_{min} – average lowest outdoor temperature during the heating season, °C (the value of -28°C is used); θ_{avg} – average outdoor temperature during the heating season
°C (the value of -0,6°C is used).

$$Q_{h_{AVG}} = \frac{Q_{annual} \times \beta}{24 \times n_h}$$

Where Q_{annual} equals annual need for heat MWh; β equals the share of heat used for space heating (the value of 71.4% is used reflecting the average heat content for space heating based on the data of consumers connected to the DH system); n_h equals the average number of heating days (the value of 225 days is used).

2.9 Annex. Data on heat generation installations

Data on district heat generation installations

Data on district heating generation equipment were collected from two main sources:

- the NERC collects data on heat production equipment of all regulated heat suppliers and heat producers using a standard form "Technical indicators of heat generation". However, these data do not include unregulated heat producers.
- Baltpool collects data on those heat producers who participate in heat auctions, i.e. all unregulated independent heat producers but also regulated ones who participate in heat auctions.

These two sources therefore have information on all heat generating installations.

However, the NERC data do not contain information about the address, contacts or other information that allows linking the heat generating unit to the database. Baltpool data, on the other hand, do not detail the year of construction of the heat production equipment and the power of economisers. This means that addresses were found from publicly available sources and linked to the database through mechanical search. In the later stages of the Study, the data will be verified and their correctness confirmed.

The table below provides a summary of the heat production equipment capacity (MW) by municipality and source of production, singling out the power of economisers. A complete list of installations connected to district heating networks is provided as an annex to this report.

249 Table. Capacity of district heat generation installations (MW)

Data by municipality	Biofuel	Waste	Natural gas	Fuel oil	Liquid fuels	Other fuels	Power of economisers	Cumulative power[141]
Group I	**802**	**125**	**3.698**	**2.024**	**447**	**85**	**163**	**5.432**
Alytus City Municipality	35	0	244	135	4	0	5	281
Vilnius City Municipality	270	60	1.725	994	88	0	40	2.092
Kaunas City Municipality	221	0	551	210	201	0	40	1.341
Klaipėda City Municipality	130	65	519	323	0	67	37	644
Šiauliai City Municipality	47	0	236	189	2	2	26	344
Panevėžys City Municipality	64	0	230	174	0	0	11	306
Visaginas Municipality	35	0	193	0	152	16	5	424
Group II	**139**	**0**	**221**	**160**	**42**	**9**	**19**	**477**
Jonava District Municipality	28	0	92	58	0	0	2	123
Marijampolė Municipality	26	0	52	48	2	9	10	142
Mažeikiai District Municipality	41	0	0	0	40	0	0	84
Utena District Municipality	43	0	77	55	0	0	8	128
Group III	**141**	**0**	**268**	**85**	**104**	**3**	**26**	**537**
Elektrėnai Municipality	49	0	66	0	7	2	0	124
Ukmergė District Municipality	8	0	31	0	15	0	4	47
Druskininkai Municipality	20	0	81	0	0	1	8	114
Palanga City Municipality	11	0	90	41	0	0	3	105
Šilutė District Municipality	28	0	0	0	28	0	5	61
Tauragė District	24	0	0	44	54	0	7	86

Municipality								
Group IV	**169**	**0**	**249**	**106**	**55**	**5**	**18**	**560**
Group V	**350**	**70**	**671**	**127**	**269**	**13**	**55**	**1.386**
Total, MW	**1.601**	**195**	**5.108**	**2.502**	**916**	**115**	**281**	**8.392**

Source: NERC, Baltpool, authors of the Study

In the table, the cumulative power (with economisers) does not match the sum of the columns because in the reports presented by the NERC, one boiler may incinerate more than one type of fuel but this does not increase the cumulative power of the boiler, e.g. a boiler of 50 MW

141 With economisers.

rated capacity can burn both natural gas and fuel oil. Such a boiler will therefore be marked as a unit with a capacity of 50 MW both for natural gas and for fuel oil but only a power of 50 MW will be recorded in the cumulative power column.

Data on decentralised heat generation installations

Data on decentralised heating generation equipment were collected from five main sources:
1. DSO – Gas consumption data from the distribution system operator
2. DSO – Electricity consumption data from the distribution system operator
3. EPMA – the Environmental Projects Management Agency
4. EPA – Environmental Protection Agency
5. ENA – Lithuanian Energy Agency
6. SPSC – Centre for Certification of Construction Products
7. RPR – Real Property Register

EPMA collects data in the Boiler Replacement Tool, thus obtaining information about newly installed biofuel boilers and heat pumps in a particular building. This is the most reliable data source.

EPA collects data on the amount of fuel energy consumed by enterprises and the power of installations by fuel type.

SPSC data about the heat source are provided with a unique building number and the type of the heat source is identified but there is no information about the power of the heat source.

Although the RPR covers the entire building stock and no further linkage is required, information may no longer be up-to-date for older buildings, the capacity of the installation is not indicated and the reference to the heat source used is often generic, e.g. 'individual district heating system' is used. In absence of significant building modifications in the RPR, the information on the type of heat source is not updated for such buildings.

Natural gas consumption data were received from the DSO on consumers who had signed a household gas supply contract. This means that all buildings consuming more than 168 m^3 per dwelling (apartment) are identified as buildings using gas for heating.

Data of electricity consumers have been received from the DSO on consumers who had signed a household power supply contract. Consumers with a difference in electricity consumption between the cold season (November to March) and the warm season (May
to September) account for at least 30% of the estimated need for heat in the building are identified as buildings using electricity for heating.

In the light of the comments above, the following procedure for ensuring the reliability of information was established:
1. If EPMA or EPA has data on a building, only data from these sources is used for it
2. If EPMA or EPA does not have data on a building but there is an SPSC energy performance certificate, the data from this source are used
3. If EPMA, EPA or SPSC does not have data on a building, the data specified in the RPR is used
4. If gas or electricity consumption data have been obtained from the DSO and no data have been obtained from EPMA or EPA, if it is indicated in the data, a corresponding attribute is used showing that gas or electricity is used for heating.

5.

250 Table. Summary of decentralised heat sources

Source	Hierarchy	Capacity of the unit	Reliability
EPMA	1	Actual	High
EPA	1	Actual	High
SPSC	2	Estimated	Medium
RPR	3	Estimated	Low
DSO gas	As an auxiliary source SPSC and RPR	Estimated	High
DSO electricity		Estimated	Low

Source: authors of the Study

The resulting hierarchy means that data received from EPMA or EPA are not duplicated with other data sources. SPSC is only used if data from EPMA or EPA are not available and RPR data are only used if data from SPSC are not available. At the same time, DSO gas and electricity data are used as a separate attribute for SPSC and the RPR.

The capacity of heat generation equipment is determined directly based on EPMA or EPA data if the building has an attribute from there. If there is no attribute pertaining to actual capacity of the heat generation equipment, the latter is calculated in accordance with the procedure described in Annex 2.8.

The table below gives a summary of the number of buildings not connected to the DH system based on the number of buildings from different sources. It should be noted that buildings connected to the DH systems in the municipalities where no DH system data were obtained were assessed based on the data of the SPSC and the RPR. In the case of RPR data, the attribute of connection to DH systems was given only to multi-apartment buildings, SPSC.

251 Table. Data on heat received from decentralised production, number of buildings (units)

Indicator	Single-family	Multi-apartment	Services	Industry	Total	Share, %
Number of buildings	**422.976**	**17.691**	**34.546**	**41.073**	**516.286**	
Incl.					-	
EPMA	18.091	437	10	-	18.538	4%
EPA	-	-	552	2.343	2.895	1%
DSO gas	75.181	3.870	735	226	80.012	15%
DSO electricity	13.815	135	119	8	14.077	3%
SPSC	72.077	2.248	5.483	1.537	81.345	16%
RPR	138.962	8.920	5.452	1.410	154.744	30%
DH system	1.578	21.048	6.169	2.270	31.065	
No attribute	137.093	3.958	24.302	36.304	201.657	39%
With attribute	285.883	13.733	10.244	4.769	314.629	61%
With attribute, part	68%	78%	30%	12%	61%	

Source: RPR, SPSC, EPMA, EPA, DSO, authors of the Study

Heat generation installations

Data on decentralised heating generation equipment were collected from 5 main sources matching heat demand data. For consumers having no attribute pertaining to actual capacity of the heat generation equipment, the latter is calculated in accordance with the procedure described in Annex 2.8.

The table below gives a summary of capacities of decentralised heat generation installations by type of production source. In the absolute majority of cases, power is an estimated value, and if one site has more than one heat generating unit, cumulative power will be respectively higher than needed to meet the need for heat of the building.

252 Table. Capacity of decentralised heat generation installations (MW)

Data by municipality	Biofuel	Natural gas	Other FF[142]	Solid fuels[143]	Heat pumps	Electricity[144]	Solar collectors	Total
Group I	**539**	**1.293**	**342**	**236**	**498**	**67**	**0**	**2.974**
Alytus City Municipality	17	49	4	7	4	2	0	83
Vilnius City Municipality	126	332	9	106	65	36	0	675
Kaunas City Municipality	111	246	103	56	391	16	0	923
Klaipėda City Municipality	164	425	121	19	19	5	0	752
Šiauliai City Municipality	15	50	2	29	11	5	0	112
Panevėžys City Municipality	105	189	104	16	6	2	0	422
Visaginas Municipality	0	0	0	4	1	1	0	6
Group II	**24**	**634**	**275**	**88**	**32**	**9**	**0**	**1.061**
Jonava District Municipality	7	221	14	17	4	2	0	266
Marijampolė Municipality	5	135	0	20	8	3	0	171
Mažeikiai District Municipality	9	263	260	26	14	3	0	574
Utena District Municipality	3	14	0	25	6	2	0	50
Group III	**82**	**100**	**16**	**121**	**32**	**11**	**0**	**362**
Elektrėnai Municipality	34	30	4	14	3	2	0	87
Ukmergė District Municipality	26	24	0	27	4	1	0	83
Druskininkai Municipality	1	5	0	12	4	1	0	23
Palanga City Municipality	1	26	0	6	7	3	0	43
Šilutė District Municipality	8	7	10	33	8	2	0	67
Tauragė District Municipality	12	8	2	28	6	2	0	58
Group IV	**141**	**280**	**22**	**341**	**67**	**29**	**0**	**880**
Group V	**568**	**1.035**	**390**	**697**	**139**	**64**	**0**	**2.894**
Total, MW	**1.353**	**3.341**	**1.045**	**1.483**	**768**	**180**	**1**	**8.170**
Total, %	17%	41%	13%	18%	9%	2%	0%	100%

Source: RPR, SPSC, EPMA, EPA, DSO, authors of the Study

The table below shows the number of installations producing decentralised heat by type of fuel used and municipality. A building can have more than one heat generating unit.

142 Solid and liquid fossil fuels.
143 Boilers capable of burning solid RES and fossil fuels.
144 Sites using it as the main or auxiliary sources of energy.

253 Table. Number of decentralised heat generation installations, number

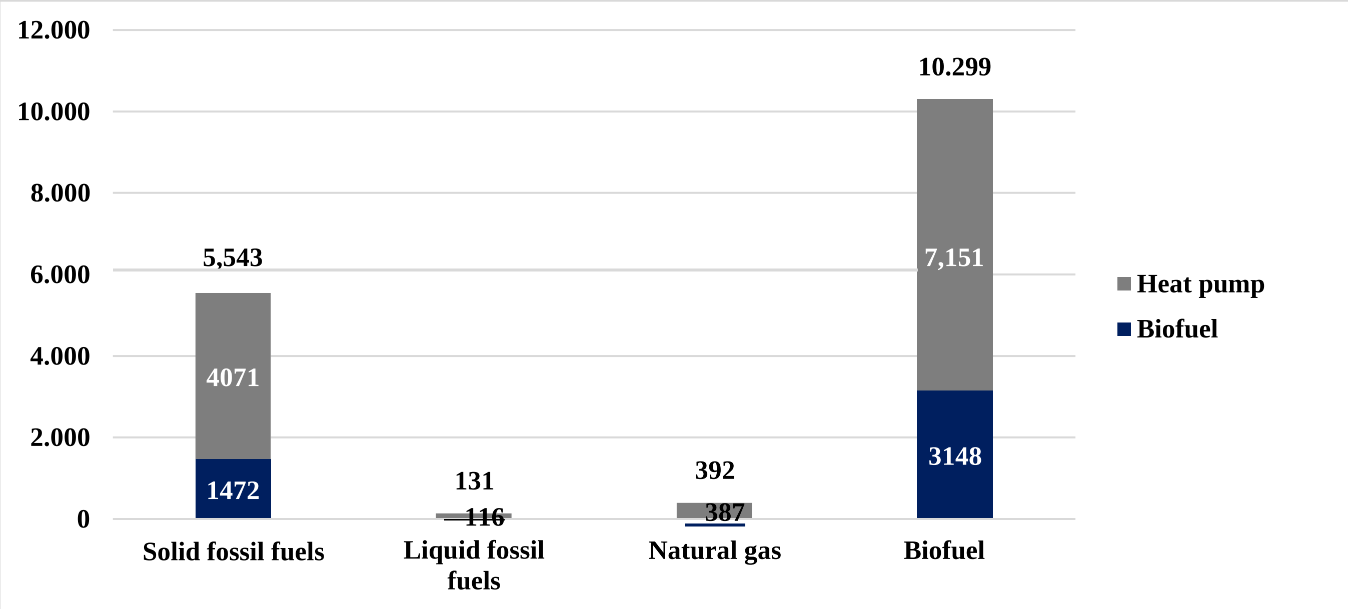
Data by municipality	Biofuel	Natural gas	Other FF	Solid fuel	Heat pumps	Electricity	Solar collectors	Total
Group I	**683**	**44.921**	**319**	**20.738**	**7.303**	**3.828**	**27**	**77.792**
Alytus City Municipality	73	1.412	13	683	270	94	0	2.545
Vilnius City Municipality	196	15.469	103	9.533	3.278	2.070	10	30.649
Kaunas City Municipality	171	16.720	89	5.018	2.264	907	9	25.169
Klaipėda City Municipality	89	3.391	64	930	600	229	1	5.303
Šiauliai City Municipality	88	4.115	13	2.560	493	314	5	7.583
Panevėžys City Municipality	65	3.811	37	1.732	377	184	2	6.206
Visaginas Municipality	1	3	0	282	21	30	0	337
Group II	**455**	**4.397**	**157**	**11.098**	**2.366**	**1.089**	**10**	**19.562**
Jonava District Municipality	102	1.202	20	2.306	330	217	0	4.177
Marijampolė Municipality	168	1.805	24	2.343	714	285	1	5.339
Mažeikiai District Municipality	115	489	106	3.183	894	339	7	5.126
Utena District Municipality	70	901	7	3.266	428	248	2	4.920
Group III	**581**	**5.179**	**219**	**13.014**	**2.510**	**1.118**	**0**	**22.621**
Elektrėnai Municipality	110	830	10	1.814	267	171	2	3.202
Ukmergė District Municipality	122	1.498	1	3.317	288	183	1	5.409
Druskininkai Municipality	36	365	10	1.559	303	135	1	2.408
Palanga City Municipality	6	1.576	12	548	352	150	2	2.644
Šilutė District Municipality	93	209	71	2.891	786	223	1	4.273
Tauragė District Municipality	214	701	115	2.885	514	256	0	4.685
Group IV	**1.171**	**15.762**	**196**	**41.060**	**5.158**	**3.303**	**18**	**66.650**
Group V	**3.085**	**45.195**	**680**	**84.328**	**12.252**	**7.270**	**48**	**152.810**
Total	**5.975**	**115.454**	**1.571**	**170.238**	**29.589**	**16.608**	**103**	**339.435**
Total, %	2%	34%	0%	50%	9%	5%	0%	100%

Source: RPR, SPSC, EPMA, EPA, DSO, authors of the Study

2.10 Annex. Results of the boiler replacement programme and choice of boilers for new buildings

The chart below provides an overview of EPMA data for 2016-2022. A summary of the data analysis of the first semester of the boiler replacement programme showing the number of beneficiaries who replaced an existing solid or liquid fossil fuel or natural gas boiler or an inefficient biofuel boiler and which boiler they chose to install as a replacement (a 5G biofuel boiler or a heat pump).
An overwhelming majority of consumers, no matter what source of heat they used before, opted for a heat pump. This may partly be explained by the fact that a biofuel boiler that is cheaper, especially if not 5G, requires less investment so there are fewer applications for support, and without the support the proportion of biofuel and heat pumps is likely to change. However, this effect is unmeasured.

91 Figure. Data analysis results on EPMA's boiler replacement programme



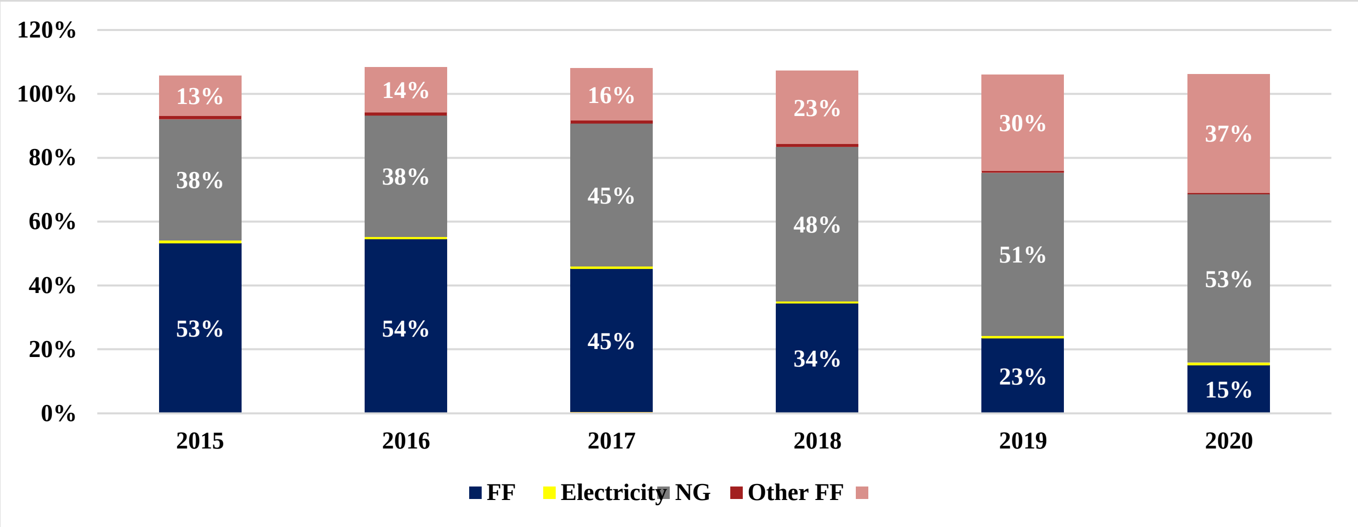
Source: EPMA

At the same time, the analysis of RPR and SPSC data on new buildings on heating technologies consumers chose in newly constructed buildings in 2015-2020 shows clear trends by sector.

Trends in single-family buildings in 2015-2020 (the sum exceeds 100% because one building may have several boilers):

- The share of new single-family houses with a solid fuel boiler decreased from 53% to 15% and, despite the higher cost of installation and operation, more convenient and expensive solutions are opted for more often.
- The share of new single-family houses with a natural gas boiler increased from 38% to 53% where solid fuel boilers were replaced. Consumers opt for natural gas due to more convenient operation as compared to a solid fuel boiler.
- The share of new single-family houses with heat pumps increased from 13% to 37%. This is partly due to the requirements for energy performance classes A+ and A + + for RES share in the energy mix and lower consumption of buildings as well as the growing demand for cooling in energy-efficient buildings with low heat storage.

92 Figure. Analysis of heating systems in new buildings: single-family houses



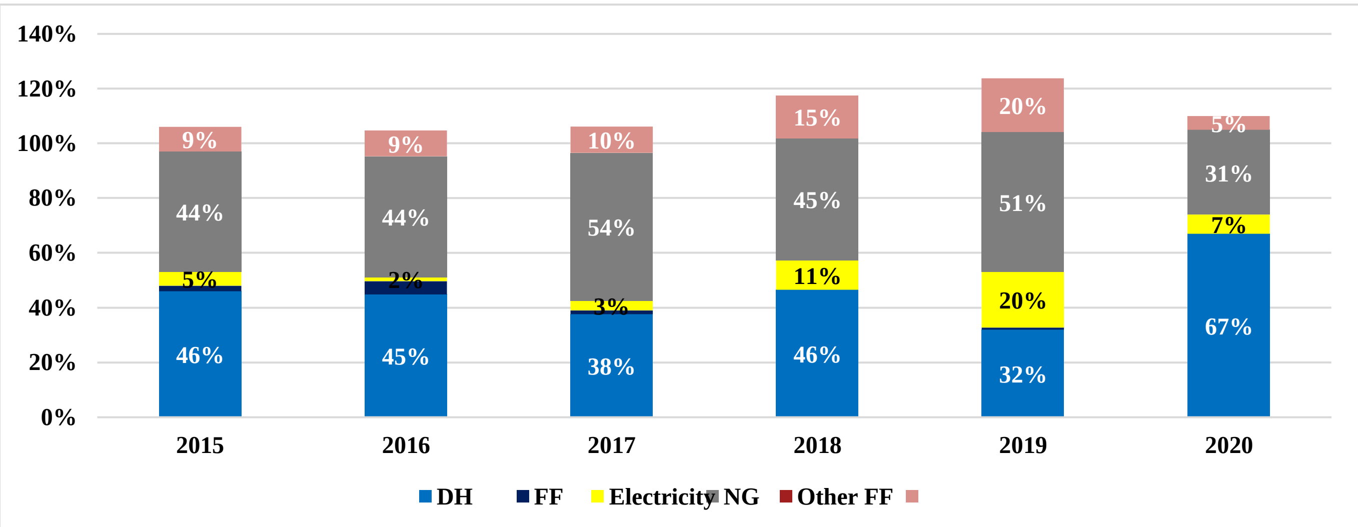
Source: RPR, SPSC

The average number of small multi-apartment buildings for which energy performance certificates and the heating system specified therein are linked is up to 20 per year, so their analysis does not show clear trends.

Trends in medium-sized multi-apartment buildings in 2015-2020 (the sum exceeds 100% because one building may have several boilers):

- The share of new multi-apartment buildings using DH systems fluctuated and increased from 46% to 67%. Significantly larger fluctuations can be seen than in the case of single-family houses as the number of medium-sized multi-apartment buildings with energy performance certificates per year is 100-150, so individual projects where a group of multi-apartment buildings is being built have a significant impact on distribution changes.
- The share of medium-sized multi-apartment buildings using electricity for heat production varies significantly between 2 and 20%.
- The share of multi-apartment buildings with natural gas boilers fluctuates significantly and only in 2020 did it drop from 44% in 2015 to 31% in 2020. However, this decrease does not indicate a trend, it only being a sign of volatility.
- The share of multi-apartment buildings with heat pumps fluctuates and there is no clear growth trend. Although in 2019
  the number of such buildings increased to 20% compared to 9% in 2015, in 2020 such buildings accounted for only 5%.

93 Figure. Analysis of heating systems in new buildings: medium-sized multi-apartment buildings



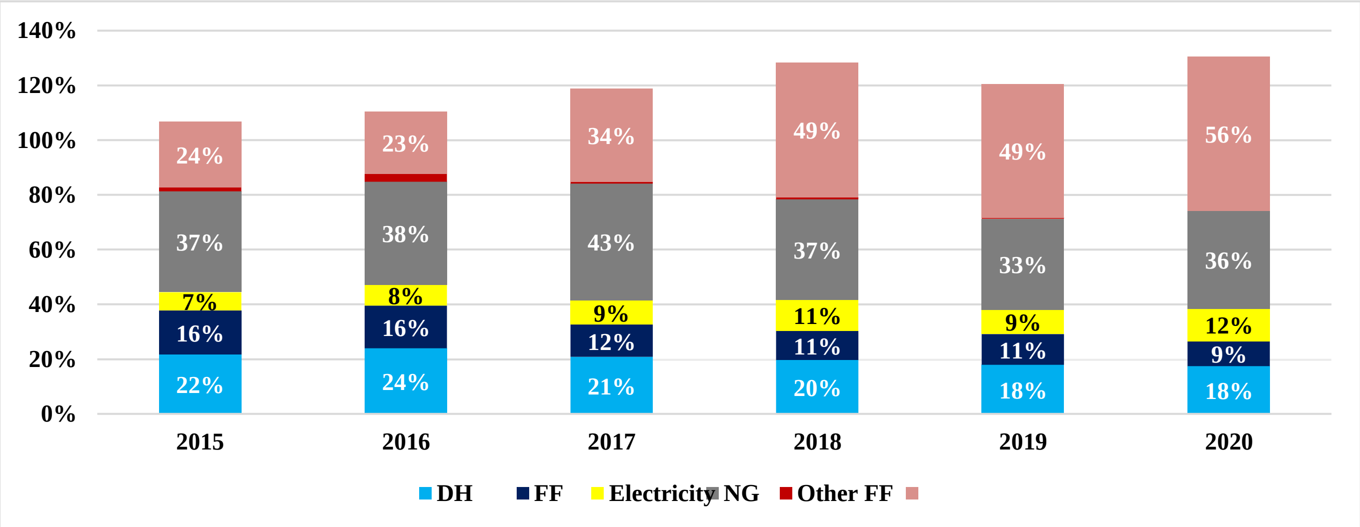
Source: RPR, SPSC

The average number of large multi-apartment buildings for which energy performance certificates and the heating system specified therein are linked is up to 20 per year so their analysis cannot show clear trends. However, with rare exceptions, virtually all large multi-apartment buildings are connected to DH systems. Individual multi-apartment buildings sometimes have a secondary decentralised heat source, which is a heat pump or an electricity-based solution.

Trends in buildings of the service sector in 2015-2020 (the sum exceeds 100% because one building may have several boilers):

- The share of buildings in the service sector using DH systems decreased slightly from 22% to 18%. Taking into account the changes in single-family houses, it is likely that this is only a fluctuation and in the long term the share of buildings in the service sector equipped with a heat pump will increase.
- The share of buildings in the service sector using solid fuels decreased from 16% to 9%, almost by half. This trend is likely to continue, albeit at a slower pace.
- The share of buildings in the service sector using electricity for heat production has increased significantly from 7% to 12%, which may be a long-term trend, as the electric heating system may be the cheapest due to the increase in energy efficiency of buildings and only with an occasional need for space heating or the need to heat to low temperatures.
- The share of multi-apartment buildings with a natural gas boiler fluctuates and there is no clear trend.
- The share of buildings in the service sector using heat pumps has more than doubled, from 24% to 56%. The popularity of heat pumps is boosted by the need to cool the building, especially if a large part of the external components of the building consists of transparent components (glass), due to which indoor air warms up more during the summer.

94 Figure. Analysis of heating systems in new buildings: service sector

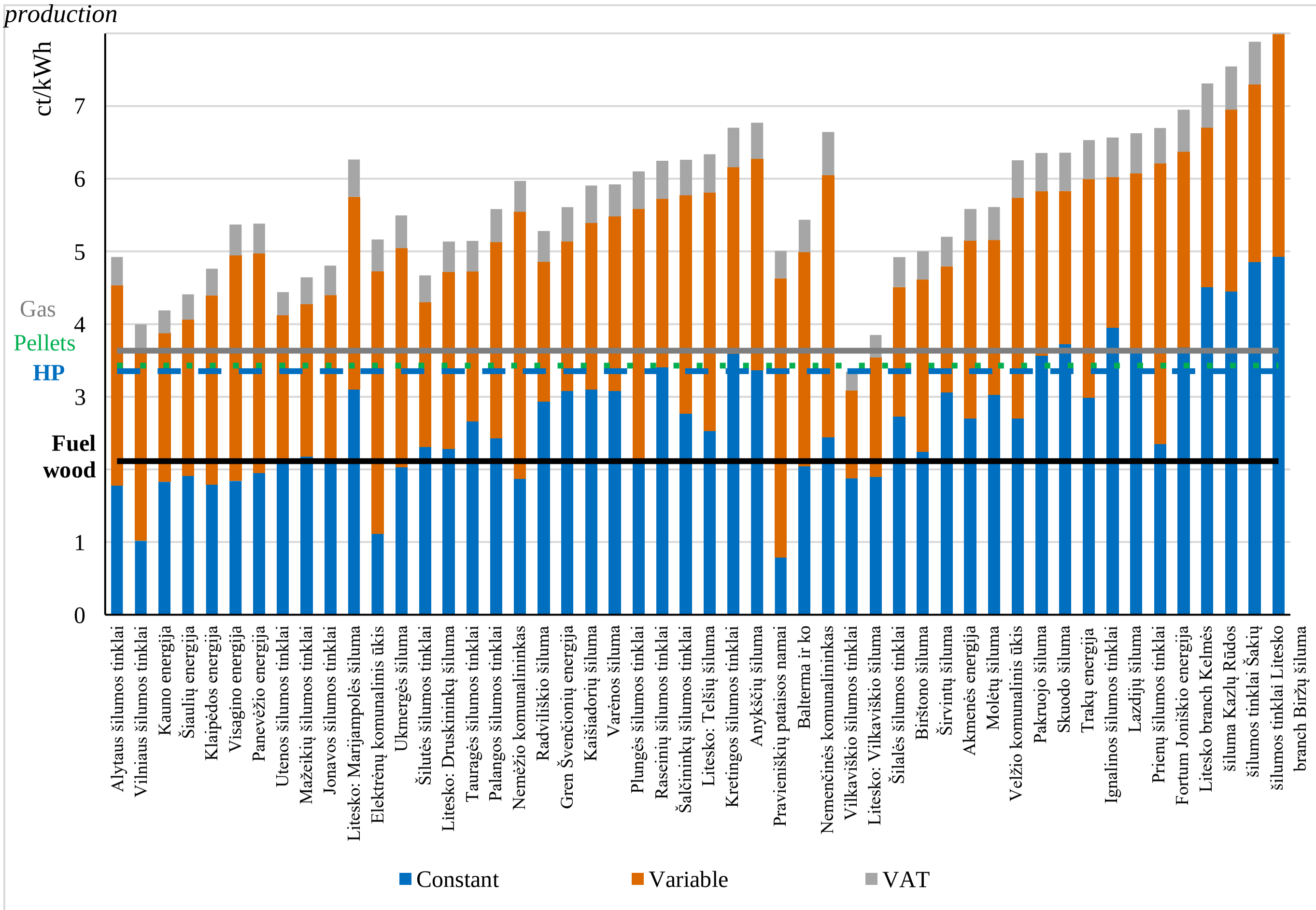


Source: RPR, SPSC

Annex 2.11. Price comparison between district heating and decentralised heating

Taking into account that some heat consumers incorrectly compare the price of heat without including the initial investment, below is a comparison of the price of district heat only with variable costs of decentralised heating (fuel). The comparison reveals the perspective of some consumers in a situation where a decentralised heating system is already in place and the consumer has to decide whether to connect to the DH system.

Figure 95. Comparison between the final DH system price and the variable cost of decentralised heat production



Source: NERC, authors of the

The following conclusions can be

- The price of firewood, if additional costs related to its storage, boiler heating, etc. are not included, is significantly lower than for other heating methods.
- Even if an incorrect comparison of the full price of DH systems only with the price of decentralised heating and operating costs is used, the price of district heating in part of the DH system is at a similar level to electricity costs of a gas, pellet or heat pump.

2.12 Annex. Cost-benefit analysis of technological alternatives

Recommendation 4.1.3.

The demand for heat can be met through a variety of high-efficiency heating solutions. The most cost-effective and beneficial heating or cooling solution can be defined by taking into account:

- resources used as an energy source (e.g. waste heat, biomass or electricity)
- technology used to convert energy resources into energy for the benefit of consumers (e.g. heat recovery or heat pumps)
- a supply system that allows consumers (centralised or non-centralised) to be provided with energy.

In order to simulate the most cost-effective set of technologies for each system, a cost-benefit analysis (CBA) of heat production technologies was performed:

- A list of technologies to be evaluated has been drawn up (technologies that have not been evaluated are not in line with the development priorities of the heat sector in the short term, e.g. sources of production using solid or liquid fossil fuels).
- Each technology has its own set of technological, financial and economic parameters.
- The financial net present value (FNPV) and the economic net present value (ENPV) are calculated for each technology.

The CBA of technological alternatives to decentralised heating was performed by simulating the annual need for heat in a typical household (7 MWh) that uses a heating system with a capacity of 7 kW. Three basic technologies for decentralised heating that can independently ensure full heating of buildings[145] were assessed.

- Natural gas boiler: the technology is assessed based on the CBA as gas boilers can be used to burn not only natural gas but also renewable gas (see Chapter 8.2.2).
- Biofuel boiler: projecting for a 30-year outlook, it is estimated that biofuel boilers running on pellets will best respond to the needs of consumers due to relatively convenient operation and possible automation.
- Heat pump: The CBA analyses aerothermal heat pumps (air-to-water) that have gained popularity due to the ease of installation and lower initial investment and take up a dominant market share of heat pumps in Lithuania.

The summarised CBA results are shown in the table below.

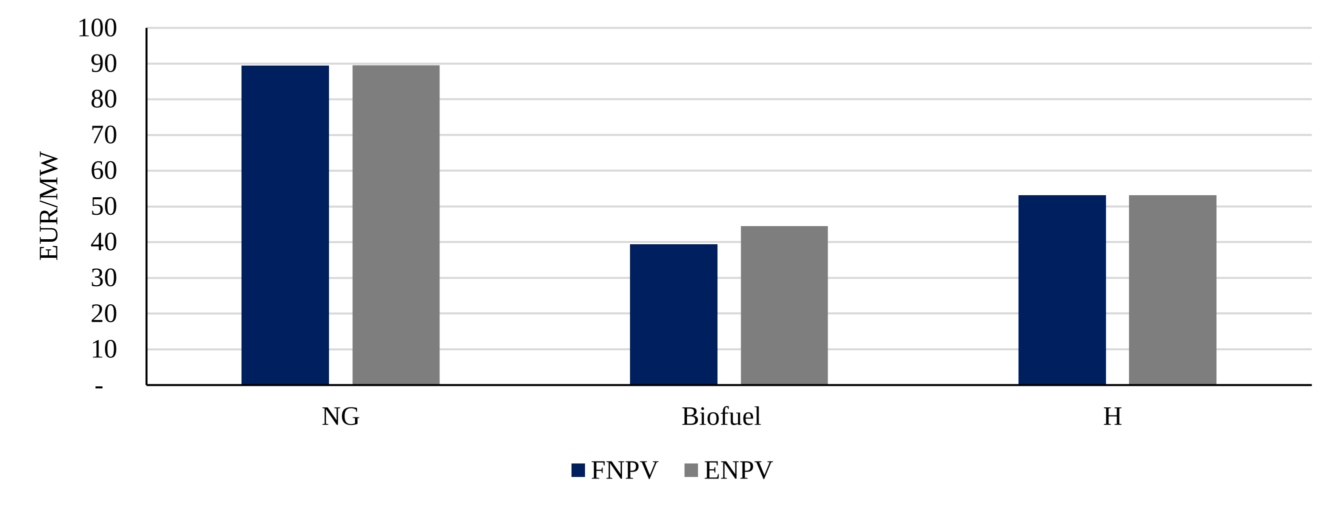
Table 254. CBA summary on technological alternatives (decentralised heating)

Parameters/technology	NG boiler	Biofuel boiler	Heat pump
P1. Efficiency, %	92%	91%	330%
P2. Investment, EUR/kW	250	500	1.000
P3. Operating costs, EUR/MWh	90	45	40
P4. CO_2 emissions, kg/MWh	200	-	-
P5. PM emissions, kg/MWh	0,004	0,5	-
FNPV, EUR/MWh	-90	-39	-53
ENPV, EUR/MWh	-90	-44	-53

Source: authors of the Study

145 Heating with solar collectors is viewed as an auxiliary technology, so no CBA is provided.

Figure 96. FNPV and ENPV of technological alternatives



Source: authors of the Study

As you can see, when simulating the annual need for heat in a typical household (7 MWh), with the parameters of technological alternatives described above:

- The most economically and financially attractive (lowest negative FGDV) technological alternative is a biofuel boiler. However, it is important to take into account that associated additional costs of fuel preparation, storage, loading into the boiler and other related costs are not assessed.
- A slightly more expensive technological alternative is a heat pump, the operation of which is significantly more user-friendly than that of a biofuel boiler. It is therefore projected that this technological alternative would be the priority for some consumers, given its operational convenience.
- With the parameters used, the operation of a natural gas boiler is the most financially and economically expensive technological alternative. The assessment is based on the assumption that by 2050 the damage caused by CO_2 emissions from natural gas will be taxed, so the financial net present value and the economic net present value are the same.

The financial net present value (FNPV) is calculated based on the assumption that an installation will last 16 years.

For the calculation of costs of a heat generating installation related to CO_2 and particulate matter, the estimates specified in the CPMA investment project preparation methodology[146] are used.

146 https://ppplietuva.lt/lt/viesuju-investiciju-projektu-rengimas/metodikos-ir-leidiniai/investiciju-projektu-kuriems-siekiama-gauti-finansavima-is-europos-sajungos-strukturines-paramos-ir-ar-valstybes-biudzeto-lesu-rengimo-metodika-1.

2.13 Annex. Identification of installations generating electricity from renewable energy sources

Data collection sources

Data from the DSO and the NERC were used to identify installations generating electricity from renewable energy sources.

The DSO collects and provides data on equipment used by power generating consumers as defined in the Republic of Lithuania Law on Energy: ‘Consumer generating electricity from renewable sources (‘power generating consumer’) means an electricity consumer or another person generating electricity from renewable sources in electricity generating installations managed by the right of ownership or on other legitimate grounds in order to meet their own needs and the needs of the household…’.

The NERC collects and makes publicly available the following data:

- Permits to generate electricity for non-power generating consumers;
- Permits to build power generation capacity for non-power generating consumers.

Data processing methods

The collected data were processed in accordance with the following procedure:

- All installations using only fossil fuels including natural gas, hazardous waste, waste heat and solid and liquid fossil fuels were eliminated from the NERC data;
- The DSO and NERC data were combined with the RPR and the address register adding the unique number of the building, geographical coordinates of the address and the municipality to the dataset of power generating facilities. If there is more than one building at the same address, the unit is assigned the unique number of the largest building in terms of total surface area.

Calculation of power content generated (by installation)

The results of the calculation of the power content generated by a specific installation in 2020 are presented in the table below. The calculation was performed taking the following steps:

1. Total power content generated (Column B) for each type of energy source (Column A)
2. The average total installed capacity of the installations during the period under consideration (Column C). The formula used for the calculation is as follows:

ĮGv = (ĮGpr + ĮGpb)/2

Where:

ĮGv – Average capacity of installations during

the period ĮGpr – Capacity of installations at

the beginning of the period ĮGpb – Capacity of

installations at the end of the period

The formula is used in order not to distort the calculation of power generation due to the fact that some of the installations were not fully operational throughout the period (e.g. they became operational at the end of the year)[147].

The data published by the Ministry of Energy of the Republic of Lithuania on the installed capacity of power generating consumers and data on permits issued by the NERC for power generation in solar power plants were additionally used to calculate the capacity of solar power plants in 2020.

147 NERC data do not show the exact date of the installation becoming operational (only the date of issue of the permit is indicated).

[148] https://enmin.lrv.lt/uploads/enmin/documents/files/gaminan%C4%8Di%C5%B3%20vartotoj%C5%B3%20prijungimo%20statistika%202022-03-10.pdf.

3. The average total power content generated per 1 MW of installed capacity is calculated (Column D).

255 Table. Calculation of the average power output of an electrical installation by energy source in 2020

Energy source	**Power content generated[149], GWh**	**Estimated average capacity of installations, MW**	**Estimated average power content generated, GWh/MW**
A	**B**	**C**	**D = (B) / (C)**
Waste	75	33	2,27
Biogas	150	27	5,47
Biofuel	251	68	3,67
Solar	108	170	0,64
Water[150]	297	219	1,36
Wind	1.544	506	3,05
Total	**2.425**	**1.024**	**2,37**

Source: authors of the Study

4. Power content generated by a specific installation in 2020 is calculated (average power content generated in MWh * installed capacity of a specific installation). The results are presented in Annex 1.6.1.

<u>Data by system boundaries</u>

The tables below provide analytical data on electricity generated from renewable energy sources (installed capacity in MW) by individual system.

149 https://www.litgrid.eu/index.php/sistema/elektros-energetikos-sistemos-informacija/elektros-gamybos-ir-vartojimo-balanso-duomenys/2287.

150 Excluding Kruonis PSP.

256 Table. Active RES power generation capacity, MW

Municipality	Solar	Hydro	Wind	Biogas	Biofuel	Waste
Akmenė District Municipality	5,44	0,98	3,60	1,00	-	-
Alytus City Municipality	7,99	-	-	0,40	5,40	-
Alytus District Municipality	9,59	-	0,95	0,45	-	-
Anykščiai District Municipality	4,34	1,55	7,75	-	-	-
Birštonas Municipality	0,68	-	-	-	-	-
Biržai District Municipality	2,21	-	0,27	0,80	-	-
Druskininkai Municipality	3,69	0,70	-	-	-	-
Elektrėnai Municipality	17,59	0,20	0,25	2,60	-	-
Ignalina District Municipality	1,96	0,15	-	1,00	-	-
Jonava District Municipality	11,65	-	-	-	-	-
Joniškis District Municipality	1,32	-	0,25	1,80	-	-
Jurbarkas District Municipality	1,87	0,68	27,15	-	-	-
Kaišiadorys District Municipality	7,37	900,80	7,60	-	-	-
Kalvarija Municipality	0,77	-	2,15	-	-	-
Kaunas City Municipality	33,25	202,00	-	0,97	14,99	-
Kaunas District Municipality	32,79	0,20	4,06	3,55	-	26,00
Kazlų Rūda District Municipality	1,41	-	-	-	-	-
Kėdainiai District Municipality	5,93	-	0,23	-	-	-
Kelmė District Municipality	1,86	0,18	9,93	1,00	-	-
Klaipėda City Municipality	6,51	-	0,01	-	1,50	20,00
Klaipėda District Municipality	25,48	-	0,01	2,29	-	-
Kretinga District Municipality	4,94	0,24	108,33	-	-	-
Kupiškis District Municipality	5,82	0,11	-	-	-	-
Lazdijai District Municipality	14,37	0,14	6,50	-	-	-
Marijampolė Municipality	7,77	2,10	2,01	0,68	-	-
Mažeikiai District Municipality	16,74	3,11	53,60	-	-	-
Molėtai District Municipality	7,22	0,09	-	-	-	-
Neringa Municipality	0,17	-	-	-	-	-
Pagėgiai Municipality	0,71	-	88,78	-	-	-
Pakruojis District Municipality	1,08	2,57	6,00	1,00	-	-
Palanga City Municipality	2,15	-	-	-	-	-
Panevėžys City Municipality	9,12	-	-	0,33	2,50	-
Panevėžys District Municipality	8,06	-	-	2,33	-	-
Pasvalys District Municipality	1,74	-	-	5,00	-	-
Plungė District Municipality	3,76	0,94	-	0,40	1,00	-
Prienai District Municipality	4,32	0,20	0,01	-	-	-
Radviliškis District Municipality	10,40	0,45	-	-	-	-
Raseiniai District Municipality	3,92	0,16	0,95	-	-	-
Rietavas Municipality	0,77	-	-	-	-	-
Rokiškis District Municipality	3,00	0,02	0,58	1,83	-	-
Šakiai District Municipality	3,39	-	7,43	1,00	-	-
Šalčininkai District Municipality	1,70	0,18	-	-	-	-
Šiauliai City Municipality	7,11	-	-	-	10,81	-
Šiauliai District Municipality	29,97	-	0,23	1,48	-	-
Šilalė District Municipality	3,05	-	66,46	-	-	-
Šilutė District Municipality	5,83	0,20	81,90	-	-	-
Širvintos District Municipality	9,31	0,57	-	-	-	-
Skuodas District Municipality	1,53	0,38	4,94	-	-	-
Švenčionys District Municipality	2,67	0,20	-	-	-	-
Tauragė District Municipality	6,53	3,01	50,79	0,20	0,75	-
Telšiai District Municipality	5,42	1,46	9,95	-	-	-
Trakai District Municipality	11,62	0,27	0,50	1,65	-	-
Ukmergė District Municipality	10,85	0,26	-	-	-	-
Utena District Municipality	11,06	0,30	-	1,30	2,50	-
Varėna District Municipality	2,62	0,34	-	-	-	-
Vilkaviškis District Municipality	5,43	0,22	3,85	-	-	-
Vilnius City Municipality	40,19	0,83	-	2,36	29,00	20,00
Vilnius District Municipality	26,11	0,11	0,00	0,80	-	-
Visaginas Municipality	0,52	-	-	-	-	-
Zarasai District Municipality	1,60	2,55	1,50	-	-	-

Source: NERC, DSO, authors of the Study

257 Table. Permits to develop RES power capacity, MW

Municipality	Solar	Hydro	Wind	Biogas	Biofuel	Waste
Akmenė District Municipality	0,75	-	169,60	-	-	-
Alytus City Municipality	4,54	-	-	-	2,50	-
Alytus District Municipality	45,98	-	0,35	-	-	-
Anykščiai District Municipality	66,81	-	75,40	-	-	-
Birštonas Municipality	-	-	-	-	-	-
Biržai District Municipality	10,56	-	11,40	-	-	-
Druskininkai Municipality	3,79	-	-	-	-	-
Elektrėnai Municipality	19,76	-	-	-	1,30	-
Ignalina District Municipality	23,16	-	-	-	-	-
Jonava District Municipality	19,97	-	90,14	-	2,50	-
Joniškis District Municipality	2,94	-	-	-	-	-
Jurbarkas District Municipality	16,77	-	126,30	-	-	-
Kaišiadorys District Municipality	82,34	-	10,15	-	-	-
Kalvarija Municipality	2,12	-	-	-	-	-
Kaunas City Municipality	27,67	-	-	-	-	-
Kaunas District Municipality	52,73	-	10,40	-	-	-
Kazlų Rūda District Municipality	1,32	-	-	-	-	-
Kėdainiai District Municipality	59,06	-	-	-	-	-
Kelmė District Municipality	1,31	-	649,00	-	-	-
Klaipėda City Municipality	9,32	-	-	-	-	-
Klaipėda District Municipality	70,03	-	0,60	-	-	-
Kretinga District Municipality	0,68	-	8,30	-	-	-
Kupiškis District Municipality	10,57	-	-	-	-	-
Lazdijai District Municipality	11,09	-	-	-	-	-
Marijampolė Municipality	49,18	-	7,24	-	-	-
Mažeikiai District Municipality	16,04	-	67,50	-	-	-
Molėtai District Municipality	83,76	-	-	-	-	-
Neringa Municipality	-	-	-	-	-	-
Pagėgiai Municipality	-	-	302,00	-	-	-
Pakruojis District Municipality	52,92	-	3,00	-	-	-
Palanga City Municipality	0,15	-	-	-	-	-
Panevėžys City Municipality	18,72	-	-	-	-	-
Panevėžys District Municipality	40,81	-	-	-	-	-
Pasvalys District Municipality	14,55	-	-	-	-	-
Plungė District Municipality	1,03	-	-	-	-	-
Prienai District Municipality	27,91	-	-	-	-	-
Radviliškis District Municipality	109,85	-	16,00	-	-	-
Raseiniai District Municipality	1,56	-	-	-	-	-
Rietavas Municipality	0,26	-	-	-	-	-
Rokiškis District Municipality	1,67	-	70,00	-	0,25	-
Šakiai District Municipality	3,07	-	50,20	-	-	-
Šalčininkai District Municipality	15,38	-	-	-	-	-
Šiauliai City Municipality	3,88	-	-	-	-	-
Šiauliai District Municipality	31,51	-	-	-	-	-
Šilalė District Municipality	1,61	-	-	-	-	-
Šilutė District Municipality	1,17	-	20,55	-	-	-
Širvintos District Municipality	2,68	-	-	-	-	-
Skuodas District Municipality	2,59	-	0,70	-	-	-
Švenčionys District Municipality	80,58	0,32	-	-	-	-
Tauragė District Municipality	26,49	-	9,98	-	-	-
Telšiai District Municipality	1,33	-	324,30	0,25	-	-
Trakai District Municipality	13,83	-	-	-	-	-
Ukmergė District Municipality	7,05	-	-	-	-	-
Utena District Municipality	4,41	-	-	0,14	-	-
Varėna District Municipality	15,08	-	-	-	-	-
Vilkaviškis District Municipality	1,13	-	56,30	-	-	-
Vilnius City Municipality	22,42	-	-	-	80,00	-
Vilnius District Municipality	14,00	-	-	-	-	-
Visaginas Municipality	10,00	-	-	-	1,25	-
Zarasai District Municipality	30,91	-	-	-	-	-

Source: NERC, authors of the Study

3 ANNEX. DATA SOURCES

3.1 Annex. RPR data

3.2 Annex. Heat consumption data from heat suppliers

3.3 Annex. DSO gas consumption data

3.4 Annex. DSO electricity consumption data

Annex 3.5. NERC heat supplier data

3.6 Annex. EPA data

3.7 Annex. ENA data

3.8 Annex. SPSC data

ANNEX 4. SUMMARY OF POLICY MEASURES

Summary of the policy measures described in the Study with key planning documents for the measures

No	Measure	NECAP	DPPM*	Other measures proposed
Policy measures taken				
PM1.	Renovate and/or modernise the heat transmission network	RES23/ ERK13		
PM2.	Modernisation of the heat metering system	RES29.		
PM3.	Upgrade and/or replace worn-out biofuel boilers with other RES technologies	RES17.		
PM4.	Promote the use of biofuels for the production of heat energy in district heating systems	RES18.		
PM5.	Promote the use of RES for DH heat production by assessing the options for using solar technologies, heat pumps and heat storage facilities in DH systems	RES19. RES27.		
PM6.	New biofuel combustion plants in the DH system	RES26.		
PM7.	Promote the use in the DH sector of waste heat generated in industry, in the waste sector or due to cooling energy	RES28.		
PM8.	Implementation of local and RES-based cogeneration power plant projects prioritising Vilnius and Kaunas	RES3.		
PM10.	Removal of excise duty exemption for gas oils intended for heating	APM**		
PM10.	Removal of excise duty exemption for coal, coke and lignite used for business purposes	APM**		
PM10.	Reinforcing economic signals	APM**		
PM10.	Reform of the tax system through the introduction of a CO_2 tax	APM**		
PM11.	Replacement of boilers with more efficient technologies	EE7.		
PM16.	Investment support for climate-friendly farming practices in livestock farms	A4.		
PM20.	Introducing and promoting technological eco-innovations	P10.	P11.1-E.	
PM20.	Implementing modern technologies	P10.	P11.1-E.	
PM21.	Decarbonisation of industry		P17.2.	
PM22.	Promoting the replacement of polluting technologies with less polluting ones	P9.	P10.1-E.	
PM24.	Using renewable energy sources in industry	RES6.	P6.2-E.	
PM25.	Industry 4.0 LAB Net-Zero Plan: promoting innovation to combat climate change. Boosting demand		P18.	
PM26.	A single national measurement system to track progress in business, industry and energy use and pollution reduction		P24.	
PM27.	Implementing alternative fuel measures in industrial enterprises	P1.	P1-E.	
PM28.	Reducing the use of coal, coke and lignite	P7.	P8-E.	
Policy measures planned				
PM14.	Restrict the connection of newly constructed buildings to natural gas grids and the possibility of heating with other fossil fuels in DH areas from 2022	APM**		
PM23.	Study to quantify the need for clean, green and renewable energy industry		P1.	
Additional policy measures proposed				
PM12.	Limiting the use of solid fossil fuels by location			+
PM13.	Removal of excise duty exemption for natural gas used as heating fuel for business purposes	APM**		

PM15.	Limiting the expansion of the natural gas network to newly constructed buildings in all areas			+
PM17.	Promoting research into hydrogen integration	-	-	+
PM18.	Promoting the development of hydrogen production facilities			+
PM19.	Limiting the use of solid fuels for space heating by location			+
PM29.	Changes in the regulatory environment for waste heat			+
PM30.	Feasibility assessment of the development of district cooling networks			+

**DPPM – Development Programme progress measures.*
*** APM – Alternative policy measures*

Source: authors of the Study, NECAP, Development Programme progress measures for individual indicators