Pilot Energy Strategy Gulbene – Strategy for low temperature district heating system implementation in Gulbene municipality

Content

Introduction

Pilot energy strategy for Low Temperature District Heating System implementation in Gulbene Region (hereinafter - Strategy) was developed with the aim to improve district heating (DH) and cooling systems in Gulbene region in order to increase energy efficiency. The document assesses existing heat and cooling supply situations and problems, including the characterization of energy sources.

The strategy assesses the preconditions for DH development (planning documents, regulatory framework, stakeholders, institutional and organizational structure, climatic and geographical conditions) as well as availability of alternative energy resources.

The strategy defines the main directions of DH development - lowering of heat carrier temperature, integration of renewable energy sources (RES) and waste heat, as well as adaptation to the heat load of low-consumption buildings. The technical DH solutions were developed for six DH in parishes (Litene, Stari, Galgauska, Ranka, Lejasciems and Lizums) and Gulbene city. For each DH system, a number of development alternatives have been defined which were compared by using cost-benefit analyses, SWOT analyse and risk analyses. The technical development directions are determined by analyzing the current situation as well as forecasting the long-term changes in heat consumption.

Taking into account the results obtained, the Strategy draws conclusions on the current situation and optimal DH development directions, as well as recommendations on the management of heating systems and provision of services in the long term.

According to the information gathered during the development of the Strategy, the conducted surveys and the results of the implemented energy efficiency projects show that the Gulbene Municipality is moving towards renewable energy based heat supply, which is above the average of Latvian municipalities.

The Gulbene city DH shall improve the monitoring system and continuously evaluate the key performance indicators (including supply and return temperatures). Lowering the temperature in Gulbene should be done in the long term - gradually identifying small districts where low temperature DH divisions can be created. Reducing the temperature of the DH should be taken into account when renovating buildings and their heating systems so that their heating surface is suitable for a reduced flow temperature.

1 Evaluation of the preconditions for the development of DH

1.1. Evaluation of existing planning documents

The main planning document of Gulbene Municipality **"Gulbene Municipality Sustainable Development Strategy 2014-2030"** identifies "Sustainable Energy Efficient Economy" as one of the long-term priorities of the Strategic Economic Direction. Strategy defines several interests of municipality:

- Maintain a steady population of the area by promoting permanent population growth and developing needed infrastructure and services.
- To create an informed and socially active society, to ensure the flow of information between state, municipal institutions, inhabitants and entrepreneurs.
- Improve quality of health care service, and operational emergency medical care availability.
- To develop diversified entrepreneurship throughout the territory of the county, to use the potential of agricultural land and forests. Developing production areas as an essential component of population employment and well-being.
- Diversify the use of agricultural land for traditional and non-traditional agricultural production, product processing, wood industry, crafts, commercial services and other for production.
- To make full use of the potential of the natural and cultural heritage for the development of tourism.
- Promote networking between different service providers and production companies (clusters).
- Develop cooperation with neighbouring municipalities in providing the necessary services.

"Gulbene Municipality Sustainable Development Strategy 2014-2030" sets 3 strategic goals and long-term priorities for the Gulbene municipality, guiding through the wise use of available resources in economic and social activities to the overarching goal of quality of life and quality promotion in every family and society as a whole. One of those aims is "Developed economy, business friendly environment" and "A sustainable economy and a supportive business environment" as a long-term priority.

One of the tasks to achieve the goal of energy-efficient management is defined in the **"Gulbene Regional Development Program 2018-2024"** as "Improvement of utilities". Within the framework of this task it is determined to evaluate the district and local heating system, to renovate heating systems, to install heat meters. In addition, tasks related to improving the energy performance of buildings and developing an energy efficiency plan are defined.

The **"Action and Investment Plan 2018-2020"** defines the planned investments for various building renovation measures, including increasing energy efficiency and improving heating systems. The investment plan also includes the renovation of the heating infrastructure.

Other binding documents for the evaluation of the development of the heat supply system have not yet been prepared. Gulbene Municipality is purposefully introducing an energy management system that will allow for a clearer definition of energy efficiency goals and objectives.

1.2. Regulatory framework

The European Union and its Member States, incl. Since 2013, Latvia has been pursuing a targeted policy towards low carbon development. In 2014, the European Climate and Energy Framework for 2030 was adopted, which provides for a further reduction of GHG emissions of 40% compared to 1990, with a share of at least 32% renewable energy in gross final consumption and at least 32.5% increase in energy efficiency. In the Latvian National Energy and Climate Plan 2021-2030, Latvia has set its climate policy goals for 2030: reducing GHG emissions in the non-ETS sector by 6% and the share of renewable energy in gross final consumption by 50%.

The country's highest long-term development planning document, "Latvia's Sustainable Development Strategy 2030", defines the country's energy independence as a key objective, increasing self-sufficiency in energy resources and integrating into EU energy networks. In the field of renewable energy and energy efficiency, the following seven key actions to be taken, which are comparable with the state and municipal investment unit, have been identified:

1) renovation of apartment buildings and reduction of heat consumption;
2) increasing the efficiency of thermal energy production;
3) investments in district heating systems - reduction of losses in heating networks will allow significant savings in the amount of fuel used for fuel purchase;
4) reduction of electricity transmission and distribution losses;
5) improving the energy efficiency of electric transport and linking it with other transport modes;
6) energy efficient street lighting in cities;
7) promoting rational energy consumption in households: educating citizens and raising their awareness of the potential for energy savings is important;
8) criteria for public and municipal procurement should include energy efficiency and product life cycle analysis.

On 15 December 2011, the European Commission adopted the Energy Roadmap 2050. The Roadmap offers a number of scenarios for the development of the energy sector in the European Union up to 2050. The document proves that decarbonisation is possible and points out that decisions now being made already form the 2050 energy system. The Roadmap lists several conditions that must be met to build a new power system.

- Full implementation of Energy 2020 in the EU is an immediate priority. All existing legislation must be applied and the proposals currently under discussion, in particular regarding energy efficiency, infrastructure, security and international cooperation, must be adopted without delay. There is also a social dimension to the move towards a new energy system.
- Energy efficiency in the energy system and in society in general needs to be significantly improved. The additional benefits of improving energy efficiency in a broader resource efficiency program should help to achieve goals faster and more cost-effectively.

- The development of renewable energies should continue to receive special attention. Given their pace of development, their impact on the market and their rapidly growing share of energy demand, it is necessary to modernize the policy framework. So far, the EU target of 20% renewable energy has proved to be an effective driver for the development of renewable energy in the EU, and consideration should be given to setting benchmarks for 2030 in due course.
- Increased public and private investment in R&D and technological innovation is needed to accelerate the commercialization of all low carbon solutions.
- The EU is committed to ensuring a fully integrated market by 2014. In addition to the technical measures already in place, there are regulatory and structural weaknesses that need to be addressed. Well-designed market structure tools and new forms of cooperation will be needed to maximize the potential of the internal energy market through new investment and changes in the structure of energy sources.
- Energy prices need to better reflect the costs, especially those associated with new investments needed throughout the energy system. The sooner prices are included in costs, the easier the transition will be in the long term. Special attention should be given to vulnerable groups who will face difficulties in transforming the power system. Specific measures need to be identified at national and local level to tackle energy poverty.
- Member States and investors need specific milestones. The Low Carbon Economy Roadmap sets targets for greenhouse gas emissions. The next step is to set a policy framework for 2030, which is a transparent period and is at the heart of investors.

In various laws and regulations, the above objectives can be achieved through joint cooperation. Local and regional authorities play a crucial role in ensuring sustainable development, as 80% of energy consumption and CO_2 emissions are closely linked to urban activities. That is why, following the adoption of the EU Climate and Energy Package in 2008, the European Commission launched the Covenant of Mayors initiative to validate and support the efforts of local authorities to implement sustainable energy policies. The Covenant of Mayors is currently the only movement that brings together local and regional actors to achieve EU goals. Since 2008, 19 Latvian municipalities have joined the initiative, but Gulbene Municipality is not among them.

1.3. Stakeholder evaluation

In order to implement the identified DH development directions, it is important to conduct an analysis of the actors involved in the heating system, which allows to determine which stakeholders' views are relevant to the development of the heating system.

Fig. 1.3.1 shows the analysis of the stakeholders, indicating their impact and involvement. Gulbene Municipality and heat transfer and distribution operator Ltd. Vidzeme Energija are the main stakeholders that have the greatest impact and largely determine the development of DH.

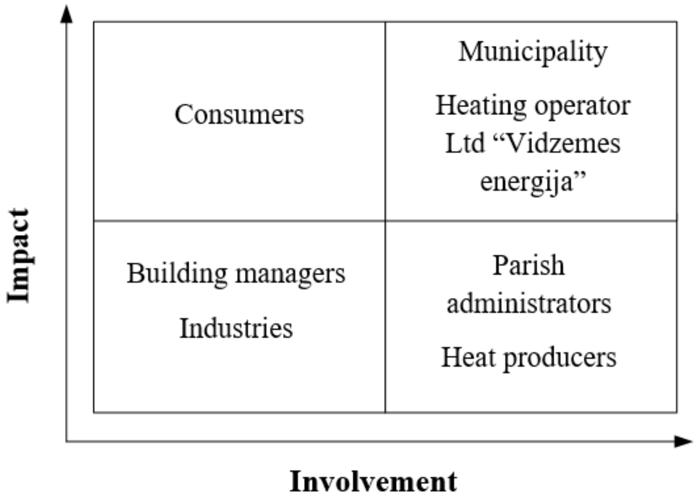


Fig. 1.3.1. Assessment of stakeholder impact and involvement

The stakeholders who have a major influence but who have little involvement in the overall development of DH are consumers. Although the main decision in DH development in the parishes is made by the municipality, various organizational issues are dealt with by the parish authorities. The influence of the heat producers (in this case the CHP plants in Gulbene and Lizums) is less significant, since its main purpose is the production of heat rather than the overall management of the DH. The liability of heat producers is clearly defined in the contracts for the sale of heat.

The less involved and impacting parties in DH development are house managers and manufacturing companies (Konto Ltd, Dimdiņi Ltd, etc.), who have the opportunity to offer their cooperation with the municipality or district heating operator.

1.4. Institutional and organizational structure of heat supply

Planning and organization of heat supply activities in Gulbene city is provided by Ltd Vidzemes Energija, which operates on the basis of a contract with Gulbene Municipality, including direct work with heat users through billing. In this way, Ltd Vidzemes Energija takes full responsibility for the technical, economic and any other risks of its economic and Gulbene DH activities.

Within the framework of a contract signed by the Gulbene Municipality, Vidzemes Energija Ltd. has made private investments in the development of Gulbene DH, for example, by installing heat substations in buildings, building separate sections of the heat supply system as well as installing heat production equipment.

The DH systems of the analyzed parishes are under the control of the municipality - the municipality makes all the necessary investments and maintenance costs by billing the residents for heat energy.

1.5. Climatic and geographical conditions

The heating system is directly influenced by climatic conditions - average outdoor air temperature and duration of the heating season. The normative duration of the heating season in accordance with Cabinet Regulation No. 338 "Regulations on Latvian Construction Standard LBN 003-15" Building Climatology "in Gulbene is 209 days, but the average outdoor air temperature is -1.4°C. Table 1.5.1 summarizes the length of the heating season over the last 5 years and the average outdoor temperature. These indicators are used for heat consumption climate normalisation purposes. The duration of the heating season is based on the assumption that the heating in the buildings is switched on when the average five-day outdoor air temperature is below 8°C and accordingly switched off when the five-day average temperature is above 8°C.

Fig. 1.5.1

Duration of the heating season and average outdoor air temperature during the heating season

Year	Duration of heating season, days	Average outdoor air temperature during the heating season, °C
Regulatory	209	-1.4
2014	202	-0.1
2015	204	1.7
2016	203	-0.3
2017	215	0.8
2018	214	0.1

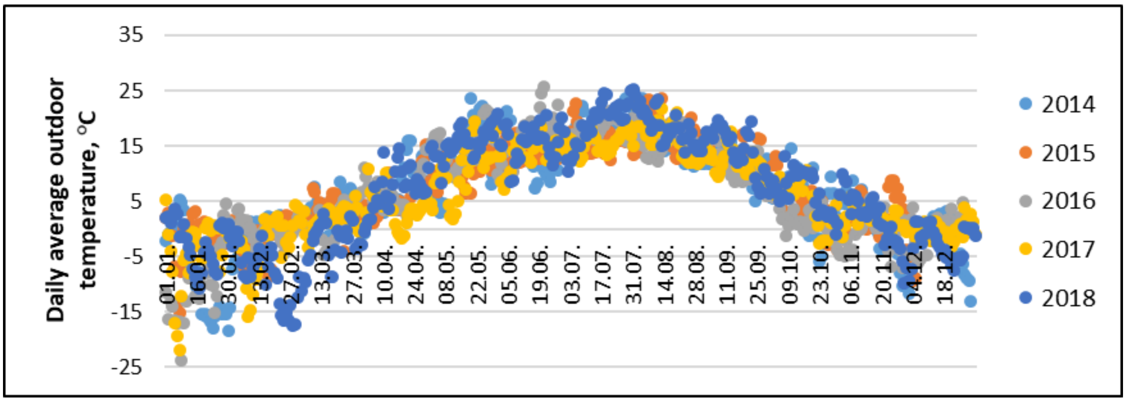


Fig. 1.5.2 Comparison of daily average outdoor temperature in Gulbene

Fig. 1.5.2 shows the daily average outdoor temperatures over the last 5 years. It can be seen that the lowest daily average outdoor air temperature was reached in 2016 at -23.8 °C. Table 1.5.2 summarizes the comparison of the duration of each air temperature period over the last five years and provides an average. The average temperature below -23.8 °C is 4 hours per year. This average distribution of outdoor air temperatures is used to determine heat load curves.

Table 1.5.2

Breakdown of hours by outdoor temperature

Outdoor temperature, °C	Duration, hours					
	2014	2015	2016	2017	2018	Average
<-23.8	0	0	11	9	0	4
-23.8 to -20	12	0	36	25	25	20
-20 to -15	205	15	120	82	97	104
-15 to -10	278	89	222	89	222	180
-10 to -5	402	181	468	246	815	422
-5 to 0	1099	1067	1309	1566	1390	1286
0 to 5	2050	2755	2225	2379	1436	2169
5 to 10	1402	1370	1075	1344	1099	1258
10 to 15	1481	1645	1306	1567	1298	1459
>15	1831	1638	1999	1462	2378	1862

2 Strategic directions for implementation of 4th generation low temperature DH

The development of district heating can be divided into 4 phases, the first 3 of which describe the historical district heating systems, while the 4th phase refers to the future district heating. The heat carrier temperature varies for each system:

- First generation DH networks: heat carrier - steam;
- Second generation DH networks: heat carrier water with a temperature above 100 ° C;
- Third generation DH networks: heat carrier - water below 100 ° C;
- Fourth generation DH networks: heat carrier water with a flow temperature of 60-40°C and a return temperature of 30-25 °C [1].

The 4th Generation DH (4GDH) heating network concept is designed for the climatic conditions of northern European countries and provides the consumer with both the heat needed for heating and the hot water load. Temperature level 55-25°C means the average temperature level associated with this temperature graph (designation accepted in international publications). The concept is to increase the supply temperature during the heating season at lower outdoor temperatures. Temperature levels during this period depend on the availability of higher temperatures at source, economic considerations and technological solutions. Typical flow temperatures during peak periods in the Nordic countries could be 60-75°C.

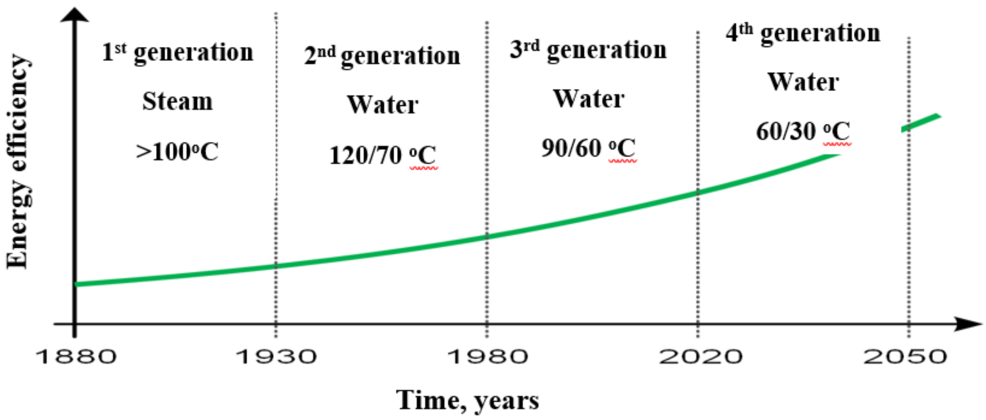


Fig. 2.1.1. Historical changes in district heating

Fig. 2.1.1 shows how DH has changed over time. It can be seen that with each successive generation there is a decisive move towards reducing the temperature of the heat carrier. First generation DH used steam as a heat carrier, which means high temperatures and therefore increased safety risks. With each successive generation, the temperature of the heat carrier decreases.

Fig. 2.1.2 shows the flow temperature levels of the second, third, and fourth generation DH networks. The 4GDH system in this graph is characterized by a maximum flow temperature (in Latvia at -20°C) of 60-70°C, and the corresponding return temperature would be approximately 30°C. The concept of 4GDH development involves different behaviour in the operation of the heat supply system. For example, one approach involves specific temperature values during peak loads, where the temperature could also be raised to 75°C to avoid overloading the heat transfer pipes. The concept involves investing in plastic pipes instead of metal pipes, which would significantly reduce the cost of renovating heating networks.

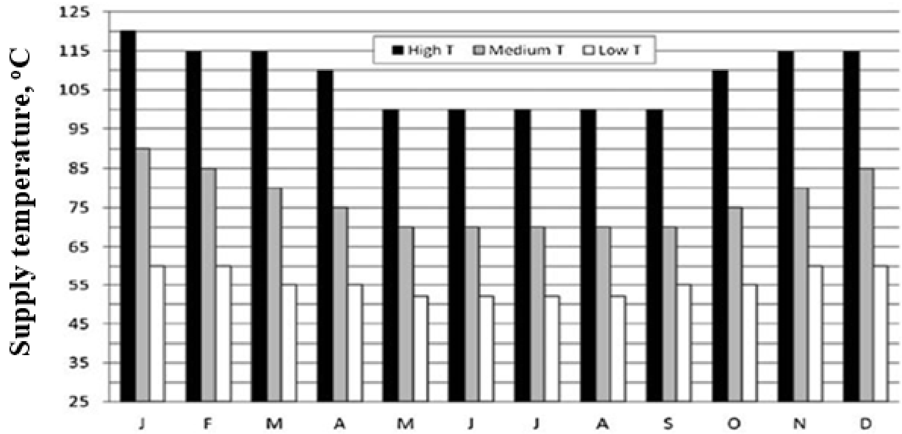


Fig. 2.1.2. Flow temperature T1 for different temperature graphs [1]

The 4GDH concept (see Fig. 2.1.3) is suited for reduced heat consumption through the construction of energy efficient homes and improving the energy efficiency of existing buildings. It is based on the use of low temperature heat sources and extensive use of renewable energy. Usually the DH peak loads are covered by biomass boiler house heat production, while the rest of the annual load is provided by solar thermal systems

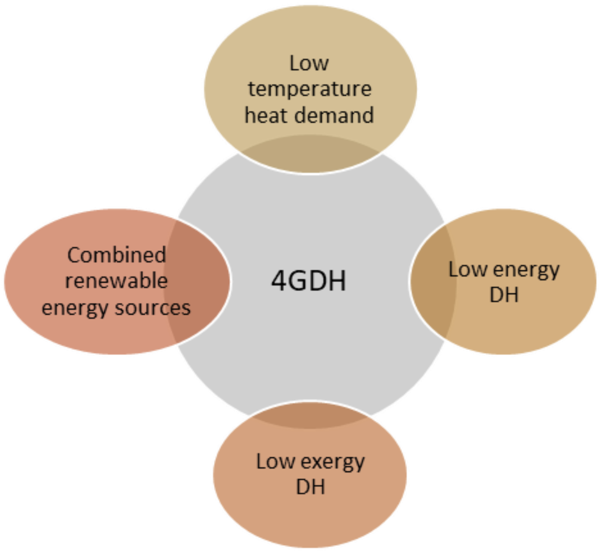


Fig.2.1.3. Concept of 4GDH

2.1. Lowering the temperature of the heat carrier

The implementation of the 4GDH low temperature system concept can be implemented in different ways:

- Simultaneously implementing the reconstruction of the heating system, creating low-temperature combined renewable energy sources and rearranging the buildings connected to the low-temperature heating system;
- Incrementally: first with the energy consumer, who will need to reorganize the building's heating system or individual heating unit, and then organize the changes to the heat source;
- Combined reorganization of heat transfer systems, as heat network pipelines are usually replaced in stages and dismantling of newly installed industrially insulated pipelines is inefficient. It is important to invest in low-temperature, cheaper pipelines where replacement of old pipelines is economically viable.

Gradually, the combined option for the introduction of the low temperature DH system is more sustainable and economically easier to justify.

The optimum temperature for the supply and return of heating networks is one of the most important issues addressed by all district heating companies [1]. The choice of supply and return temperatures affects the diameters of the heating network pipelines. The higher the heat carrier temperature, the lower the amount of water that can transport the required amount of heat, and the smaller the diameter of the piping;

On the other hand, increasing the water temperature in the networks increases the temperature difference and increases the heat loss from the surface. Some authors [2] investigates and evaluates the usefulness of various measures and technical solutions in real conditions of DH - reliability and efficiency of heating network operation. One of conclusions is that lowering the temperature of the flow heat carrier allows to reduce the losses of the district heating system. If this temperature is lowered by 2°C during the summer season, losses can be reduced by about 2.2%. If the temperature is changed from 130°C -70°C to the temperature regime 115°C -70°C during the heating season, then heat loss reduction reaches 5%. [2]

The temperature difference between supply and return flow is an additional aspect that must be taken into account, because the electricity consumption for heat transmission is directly related to the heat flow, which decreases with increasing temperature difference (see Fig.2.1.4).

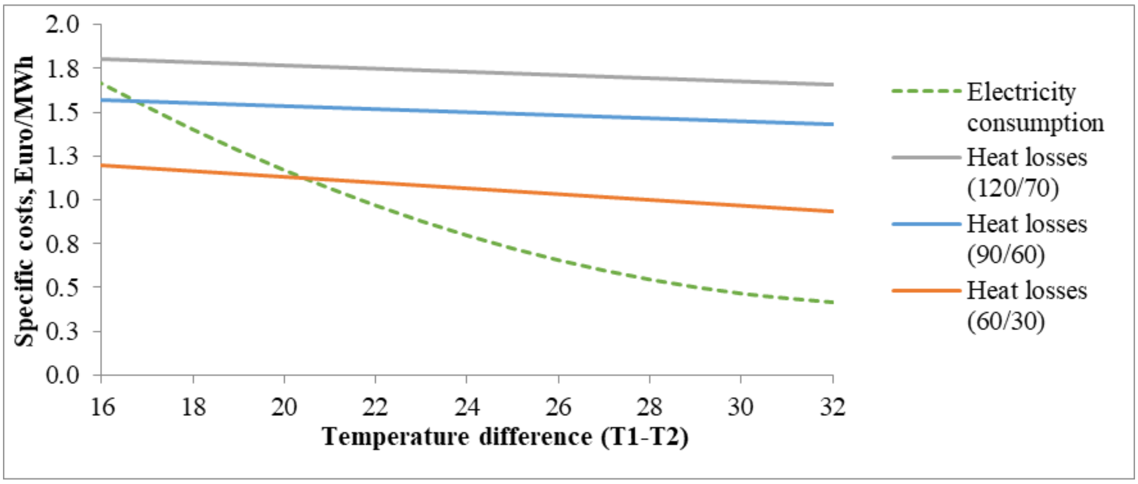


Fig. 2.1.4 Specific transmission cost dependence of supply and return water temperature difference

Several studies [8-10] have analyzed the possibilities of lowering the temperature of the domestic hot water. According to Latvian legislation, the temperature of the hot water at the point of dispensation must be kept above 55°C to prevent the formation of dangerous Legionella bacteria [11]. According to German standard W551 [10], the hot water temperature can be below 50°C if the total amount of water circulating in the system (excluding heat exchanger) is less than 3 l. Because of the design of the heating system and the hot water supply in passive and low-consumption buildings with the smallest possible pipe diameters, it is possible to reduce the total amount of water circulating in the system and comply with this German standard. This increases the efficiency of 4GDH as hot water preparation up to 50°C is one of the bottlenecks.

2.2. Integration of alternative energy sources

There are many different energy sources and technological solutions for producing heat. The choice of the most appropriate heat source is influenced by various criteria and priorities. The transition to low-temperature heat supply allows efficient use of low-potential heat (excess heat from industrial processes, ambient heat, solar energy, etc.) [12]. Therefore, when planning the development of the heat supply system, it is necessary to identify the available low-temperature heat sources that can be used to cover the heat load of the DH, as this can make a significant contribution to reducing the environmental impact.

The Fig. below shows a comparison of different energy sources and corresponding conversion technologies for low and high potential heat generation. As can be seen, in industrial and other processes, the use of excess heat, which is usually discharged into the environment, should be given priority [13]. This type of heat is usually low-potential, so high-temperature DH requires a heat pump, but low-temperature heat can be used directly without additional conversion technology.

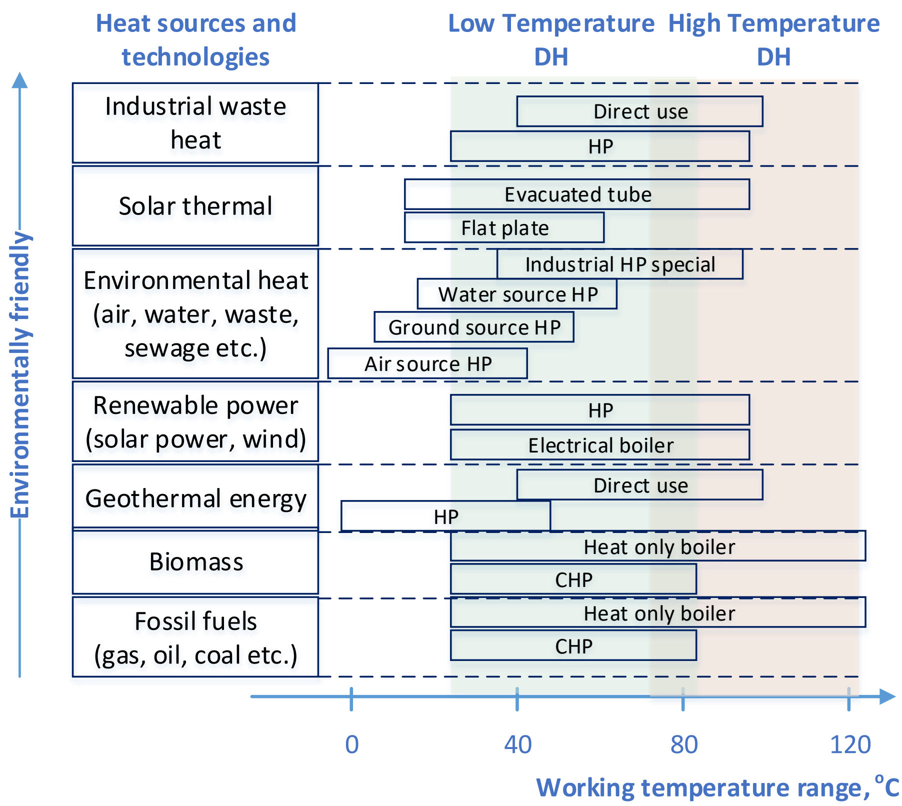


Fig. 2.2.1. Comparison of different energy sources and heat production technologies [14-15]

If it is not possible to use surplus thermal energy, the use of renewable energy sources (solar and geothermal) should be considered. Low temperature DH allows more efficient use of ambient heat (air, water, earth), however, using such heat sources requires evaluate the performance of the heat pump (COP, power consumption and associated emissions).

Biomass, which is a more independent source of energy, can be used to cover the heat load that cannot be covered by the heat sources mentioned above. Both biomass boilers and cogeneration plants are usually used for heat production. In addition, cogeneration plants benefit significantly from low-temperature heat supply as more electricity can be generated.

2.2.1. Use of biomass

Forests are one of the largest natural resources in the Gulbene region, accounting for 54% of the total area. The total area of forests exceeds 101 thousand. ha, 54.2% of forest land is owned by government, 38.2% is owned by individuals, 6.5% is owned by legal persons and 0.2% by local government. The largest forest areas are located in Lejasciems parish, Ranka parish and Stradu parish. In all forests together, the dominant species is pine - 42%, birch - 26%, spruce - 22% and other tree species. [22]

The use of forest resources should be developed in an environmentally friendly and rational way, preserving the ecological, economic and social functions of forests, promoting high quality forest production and developing high-value-added and end-of-life technologies for wood processing companies. Logging and woodworking residues, which cannot be recycled into higher quality products, should be used primarily for energy production.

Vidzeme Planning Region is the richest forestry region in Latvia. The amount of wood harvested from forests in Vidzeme Planning Region in 2007 was 3390 thousand. m³, but outside forests - 27 thousand. m³. The regional total wood used for energy production from a single forest available for wood supply was 2.6 m³ of roundwood equivalent / ha. According to Vidzeme Development Plan, in 2007 there were 172 wood processing companies operating in the region. Wood resources are mainly used for the production of wood products (76%), pulp (30%) and energy (6%). Half of the Vidzeme region's DH uses biomass - woodchips, logs and other products.

Based on the information provided in the study [52], there is no doubt that the regional supply of wood resources is sufficient for the heating of Vidzeme. Meanwhile, it is very important that wood biomass is used efficiently in district heating systems. The prices of wood and pulp are 2-3 times higher than those of wood fuels and have been the main driver for a large share of the woodworking industry (75%).

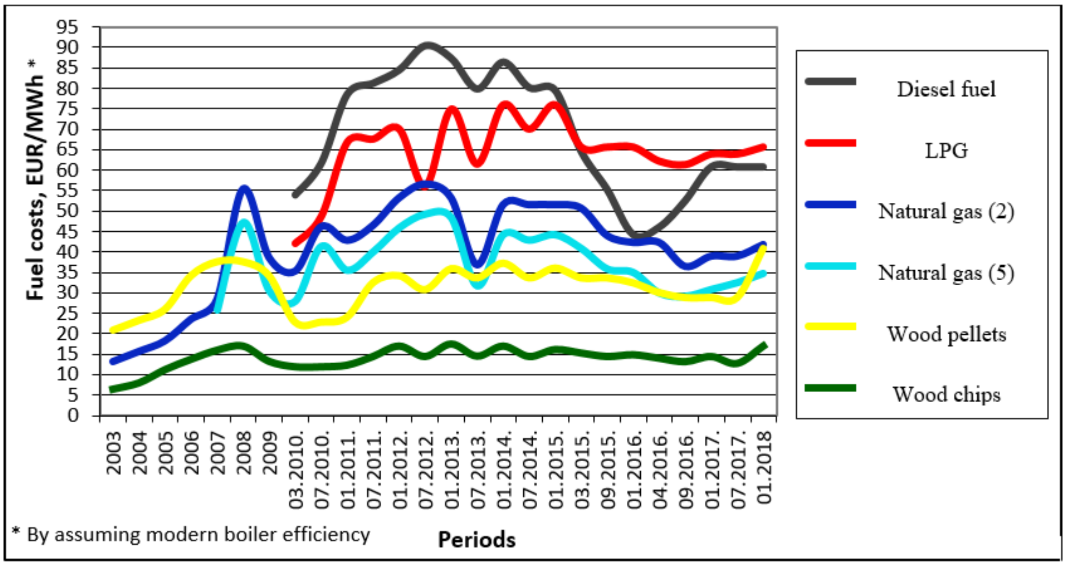


Fig. 2.2.2. Dynamics of different fuel price changes [23]

Fig. 2.2.2 shows a comparison of the different fuel price changes. The price of wood pellets is slightly lower than the price of natural gas, except for January 2018, when the price increased sharply due to adverse weather conditions. Fort the further analyses the price of pellets used is 181 EUR/t and the lowest heat of combustion is 4.3 MWh/t. For the production of sawdust pellets we use dried sawdust and sawdust. Dried sawdust and shavings are crushed and pressed. Increasing the pressure raises the temperature of the feedstock, which is needed to activate the lignin from the wood fiber cells that hold the pellet together. Pellets have a lower moisture content and higher calorific value than wood chips, which also results in a higher price.

2.2.2. Use of excess heat

At present, both the global and Latvian industrial sectors generate large amounts of low-temperature heat surpluses, which are mainly discharged into the environment during industrial processes. Research shows that the heat losses from industrial processes are huge. For example, in the US metallurgical and non-metallic sector, about 20-50% of energy is lost in the form of waste heat [16]. The same is true for cement production. Another important source of heat surplus is the various data centers that run continuous cooling processes on servers and other equipment [17]. Several studies on heat recovery and reuse have been conducted [18-21]. In many cases, this thermal energy can be usefully used internally to heat hot water, preheat incoming air in a furnace, and so on. This replaces the fuel share in heat production, increased efficiency, reduced emissions and costs. However, in many cases where the remaining heat is of low potential or the company's heat consumption is low, this energy may be passed on to other consumers.

An important factor for using excess heat is the distance between the heat source and the consumer. For the most part, in spatial planning due to the health of the population, industrial areas are located separately from residential areas. If the distance between the source and the consumer is too large, this will lead to additional investment in the construction of the heating network and greater losses in heat transmission. Therefore, when planning the use of this type of heat, the largest economically justifiable distance from the heat source to the consumed is 5-10 km for small towns and 20-30 km for larger ones [20]. The situation is different with the location of data centers - they are usually located close to DH heat networks. Primarily, these heat sources need to be identified and matched to appropriate heat consumption. In order to identify heat sources, it is necessary to map them by determining the amount of excess heat as well as the temperature potential.

Another aspect to consider is the variability of the production process, which depends on the demand for the products, the weather, the working condition of the equipment, etc. Consequently, excess heat cannot be used as the sole source of heat. In such a system, it is necessary to integrate an additional heat source that can provide backup heat capacity if the excess heat cannot cover all the heat consumption.

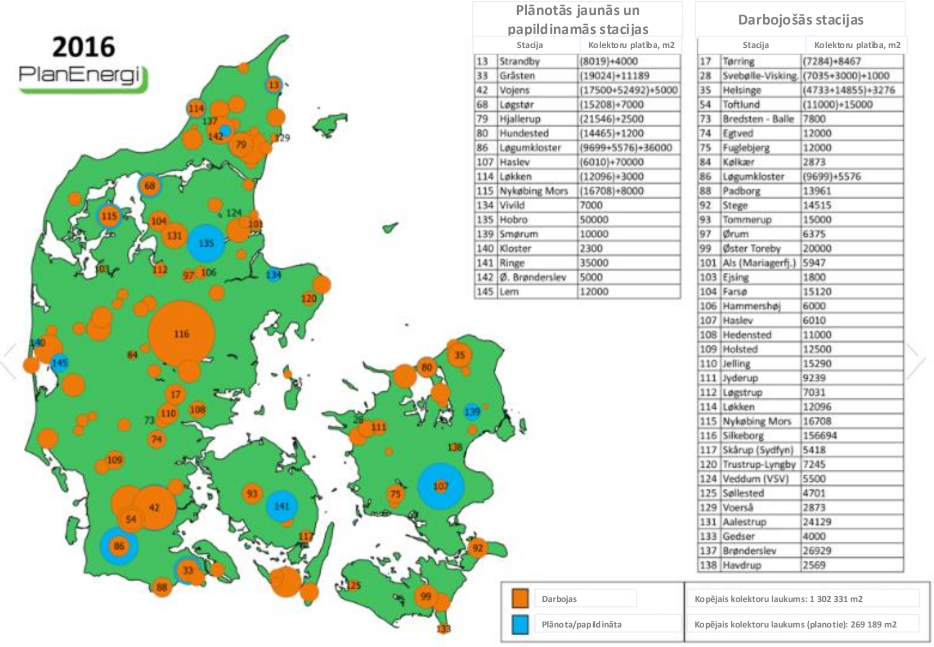
The potential benefits to the company generating heat surpluses and transforming those to DH are:

- Improved efficiency of the industrial process
- revenue from the sale of thermal energy,
- good repute as well as tax credits (if applicable).

The DH operator, in turn, obtains cheaper heat, which reduces operating costs and offers heat tariffs. Cheaper heating tariffs and improved environmental quality, if the waste heat replaces fossil fuels, are a benefit for society as a whole and for consumers of thermal energy. An additional benefit is the lower prices for services and products that a company could provide if it were to operate more efficiently and generate additional revenue from the sale of excess heat. Such a model of stakeholder interaction (see Fig. 2.2.3) demonstrates that all stakeholders and policy instruments such as financial support or tax incentives can provide additional incentives to agree on the use of excess heat.

2.2.3. Solar thermal energy

Experience in other countries shows that DH can also economically integrate solar thermal technologies [24]. The fastest-growing projects of this kind are in Denmark, where around 100 solar thermal systems (including CHP) have already been built in 2016 with integrated solar collectors of over 1.3 million m² [25]. Fig. 2.2.4 shows the solar collector stations installed and planned in Denmark up to 2016. The picture shows the solar panels.



Plānotās jaunās un papildināmās stacijas

Stacija		Kolektoru platība, m2
13	Strandby	(8019)+4000
33	Gråsten	(19024)+11189
42	Vojens	(17500+52492)+5000
68	Løgstør	(15208)+7000
79	Hjallerup	(21546)+2500
80	Hundested	(14465)+1200
86	Løgumkloster	(9699+5576)+36000
107	Haslev	(6010)+70000
114	Løkken	(12096)+3000
115	Nykøbing Mors	(16708)+8000
134	Vivild	7000
135	Hobro	50000
139	Smørum	10000
140	Kloster	2300
141	Ringe	35000
142	Ø. Brønderslev	5000
145	Lem	12000

Darbojošās stacijas

Stacija		Kolektoru platība, m2
17	Tørring	(7284)+8467
28	Svebølle-Visking	(7035+3000)+1000
35	Helsinge	(4733+14855)+3276
54	Toftlund	(11000)+15000
73	Bredsten - Balle	7800
74	Egtved	12000
75	Fuglebjerg	12000
84	Kølkær	2873
86	Løgumkloster	(9699)+5576
88	Padborg	13961
92	Stege	14515
93	Tommerup	15000
97	Ørum	6375
99	Øster Toreby	20000
101	Als (Mariagerfj.)	5947
103	Ejsing	1800
104	Farsø	15120
106	Hammershøj	6000
107	Haslev	6010
108	Hedensted	11000
109	Holsted	12500
110	Jelling	15290
111	Jyderup	9239
112	Løgstrup	7031
114	Løkken	12096
115	Nykøbing Mors	16708
116	Silkeborg	156694
117	Skårup (Sydfyn)	5418
120	Trustrup-Lyngby	7245
124	Veddum (VSV)	5500
125	Søllested	4701
129	Voerså	2873
131	Aalestrup	24129
133	Gedser	4000
137	Brønderslev	26929
138	Havdrup	2569

Fig. 2.2.4 High-capacity solar collectors already installed and planned in Denmark [25]

The annual average solar radiation (radiant heat) in Latvia is 1000-1100 kWh/m² per year, which means that the sun shines approximately 1700-1900 hours per year [26]. Solar energy potential in EU Member States is shown in Fig. 2.2.5. The Fig. shows the amount of solar radiation on an optimum angle and a south-facing surface. Solar energy available in Latvia is similar to countries such as Germany, Denmark, the Netherlands, etc. [26].

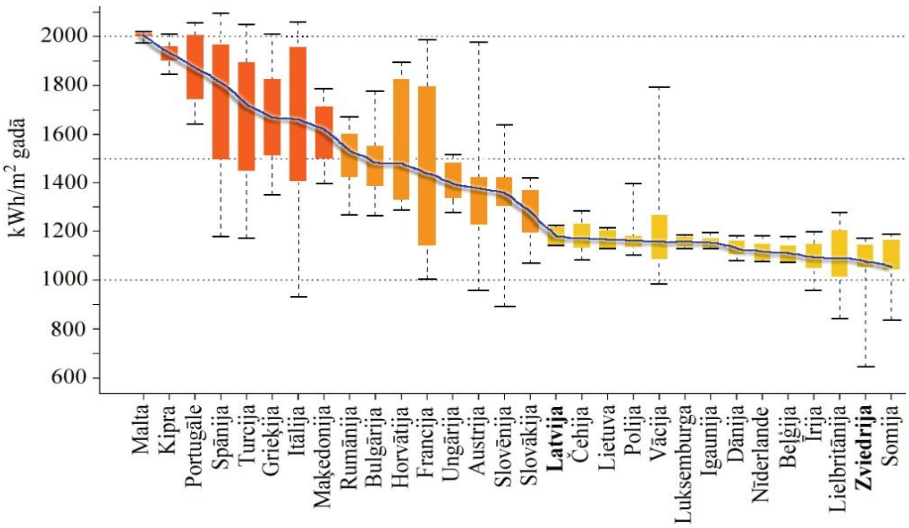


Fig. 2.2.5 The amount of solar radiation available in European countries [26]

The efficiency of solar collectors is strongly influenced by the temperature of the heat carrier. Fig. 2.2.6 shows the efficiency curves of different solar collectors as a function of the difference between the heat carrier and the ambient temperature.

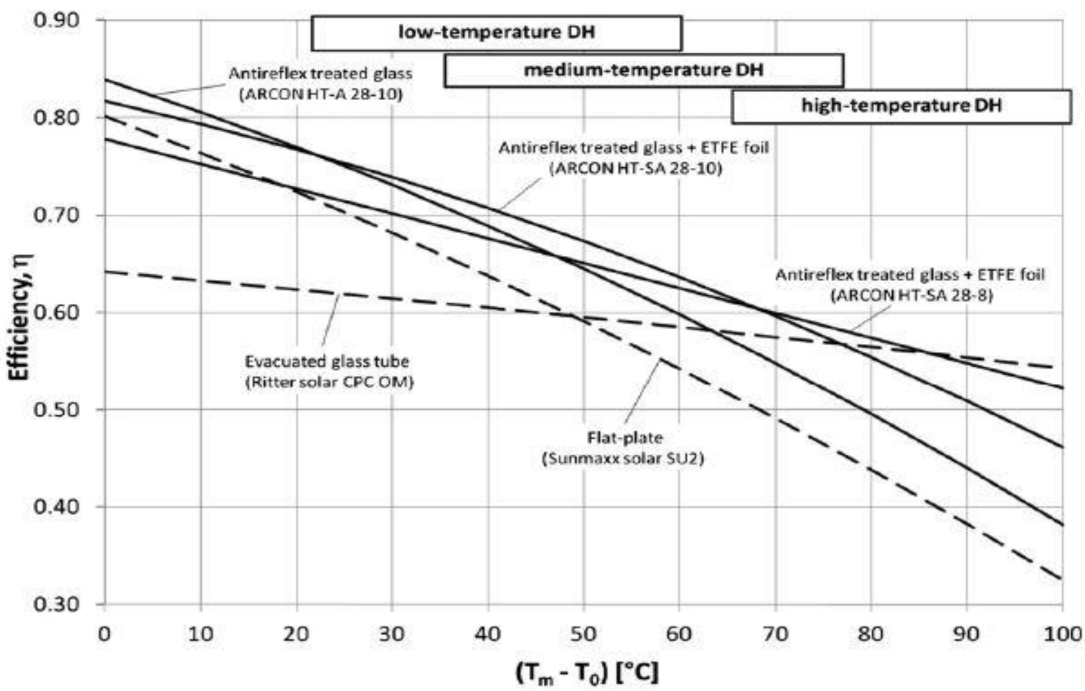


Fig. 2.2.6 Solar collector efficiency versus temperature difference between heat carrier and ambient temperature [27]

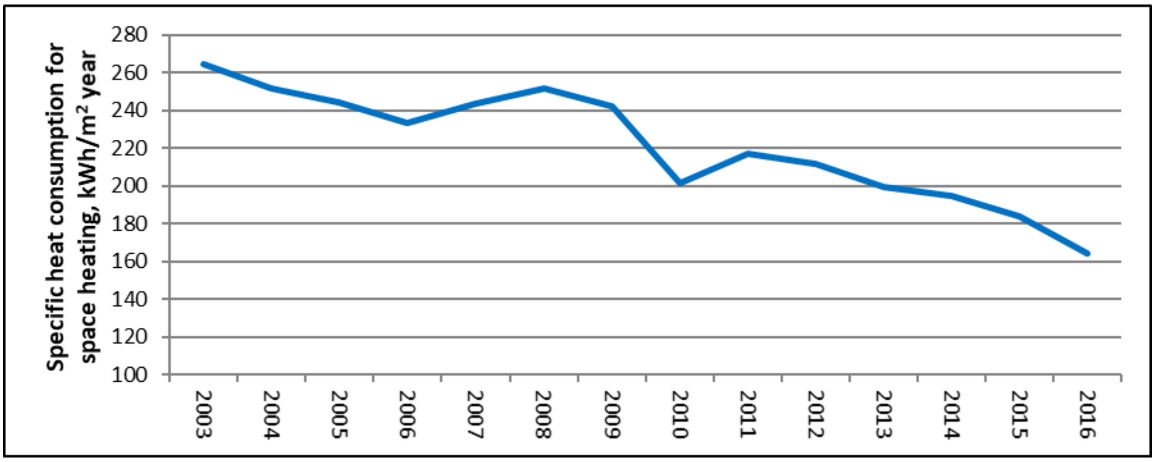
Fig. 2.2.6. depicts schematically low, medium and high temperature DH systems, respectively. Although the Fig. shows different types of collector efficiency curves, they all have the same tendency - efficiency increases with the difference between ambient and heat carrier temperatures, suggesting that lowering the coolant temperature significantly increases the efficiency of the solar collector and

can therefore generate more heat. Also in the largest solar DH integrated solar collectors, the heat carrier temperature varies between medium and low temperature DH.

These examples show that the use of solar thermal energy is also possible in regions with lower levels of solar radiation, such as Gulbene and the lowering of heat carrier temperature in DH network is one of preconditions for effective development of solar DH system.

2.3. Improving the energy performance of buildings

At present, the average heat consumption of buildings in Latvia is about 160 kWh/m². Fig. 2.3.1. shows that the average specific heat consumption of buildings for heating has decreased from 264 kWh/m² to 184 kWh/m² since 2003. This trend is expected to continue. Renovation of buildings as well as construction of new energy-efficient buildings contributed to this decrease.



2.3.1. Changes in average heat consumption of buildings for heating in Latvia [29]

The most important factor determining the development tendencies of Latvian buildings is the age structure. According to the Central Statistical Bureau [30], most of the Latvian buildings (about 63%) were built during the Soviet period, between 1941 and 1992. About 26% of the buildings in Latvia were built before 1940, and about 11% were built after 1993. This factor should be taken into account when planning the development of the heating system, as most of the buildings built during the Soviet period were added to the DH. These buildings should be renovated in the coming years, which would significantly reduce heat consumption and thus the demand for heat.

Cabinet of Ministers Regulations on the Latvian Construction Standard LBN 002-01 [32] establish reference values of thermal technical parameters for external structures for newly constructed, reconstructed and renovated buildings. Cabinet of Ministers Regulations No.383 "Regulations on Energy Certification of Buildings" set forth requirements for heat energy consumption in new buildings and buildings after renovation. Minimum energy performance requirements for buildings to be converted or renovated:

- multi-apartment residential buildings - heating consumption does not exceed 90 kWh/m² per year;
- for different types of single-dwelling and two-dwelling buildings - heating consumption does

not exceed 100 kWh/m² per year;

- for non-residential buildings - heating consumption does not exceed 110 kWh/m² per year.

In its turn, the minimum allowable level for new buildings will be reduced every year until almost zero energy buildings will be reached in 2021 (see Table 2.3.1).

Table 2.3.1

Minimum level of energy performance of buildings

Period of approval of the building design concept	Residential buildings		Non residential buildings	
	Apartment buildings	One-or two-apartment buildings	State owned buildings	Other buildings
Until 31.12.2016	≤ 70 kWh/m² year	≤ 80 kWh/m² year	≤ 100 kWh/m² year	≤ 100 kWh/m² year
From 1.01.2017 to 31.12.2017	≤ 60 kWh/m² year	≤ 70 kWh/m² year	≤ 90 kWh/m² year	≤ 90 kWh/m² year
From 01.01.2018 to 31.12.2018	≤ 60 kWh/m² year	≤ 70 kWh/m² year	≤ 65 kWh/m² year	≤ 90 kWh/m² year
From 01.01.2019 to 31.12.2020	≤ 50 kWh/m² year	≤ 60 kWh/m² year	nearly zero energy building	≤ 65 kWh/m² year
From 01.01.2021	nearly zero energy building	nearly zero energy building	nearly zero energy building	nearly zero energy building

These rules stipulate that not only the heat consumption of existing buildings will be reduced, but also that of new buildings will be lower. Recognizing the high operating costs of buildings, the buildings with thermal energy consumption well below the legal requirements are already planned and constructed in Latvia. Currently, the concepts and performance indicators of low-consumption and passive houses are not defined in Latvian legislation. The Cabinet Regulation on the energy certification of buildings refers to the concept of "nearly zero energy building", which consumes less than 30 kWh/m² per year for heating purposes, and classifies buildings as less than 40 kWh/m² per annum in the building rating scale [32]. Experience in other countries has shown that the concept of low-consumption and passive buildings can reduce the operating costs and environmental impact of buildings, but the construction costs of such buildings are significantly higher. Currently, most passive houses are built in Germany and Austria, but the concept has also been developed in the Nordic countries, such as Denmark. [33] The described building development trends in Latvia suggest that, from a long-term perspective, significant changes will also be needed to the existing DH, which will have to adapt to lower heat consumption.

2.4. Experience of other EU countries in implementing 4GDH

Although Latvia has not yet implemented low-temperature 4GDH, it is already successfully operating in several European countries, such as Denmark, Sweden, Germany, Austria, etc. Below are examples of typical low temperature DH projects as well as solar DH project, which also operate at lower heat network temperatures.

2.4.1. Lustrup, Denmark

The Lustrup private house district is one of the most widely studied low temperature DH pilot project, where low temperature DH provides heating and hot water for 7 row houses with 40 flats of 87m^2 and 110m^2. The total heated area for this project is 4115 m^2. The heat consumption of the building is 37 kWh/m^2 per year, of which 31.4 kWh/m^2 is used for space heating. The apartments use both radiators adapted to lower heat supply temperatures and the floor heating. The low temperature heating system in Denmark was completed in 2011 [44].

This heating system has a higher pressure (10 bar) to provide the necessary flow to the end user. Increased pressure creates additional electricity consumption but is offset by reduced heat loss [45].

In buildings, the consumer has various heating units installed. Some consumers have heat exchangers installed (total 30), while some other consumers have additional heat storage tanks (total 11). The diagram below shows the scheme of the heating system for this pilot project. The Fig. 2.4.1 shows the flow rates at different points in the system, as well as the distribution of consumers with different types of heating units. It can be seen that most consumers use a relatively simple heating unit solution with a heat exchanger.

The hot water distribution system has been carefully designed so that each hot water installation has its own pipeline inlet as well as minimized pipeline diameters. Consequently, the amount of water for the hot water supply, including the volume in the hot water heat exchanger, is kept below 3 l. This amount is the maximum volume of water that ensures safety against the risk of Legionella bacteria. [46]

This pilot project is a typical example of how low temperature DH can be integrated into existing DH with higher heat carrier temperature. There is no additional heat source in the area as the heat is provided directly from the existing medium temperature DH. The required temperature is achieved by mixing the return flow with the supply flow using special valves and temperature sensors.

The results of several years show that the pilot project can successfully cover the consumption of heating and hot water with low potential heat, which is confirmed by the feedback of the inhabitants. The heat loss of the pilot project amounts to 17% of the delivered amount, which is about three times less than the standard heat supply schedule for particular district.

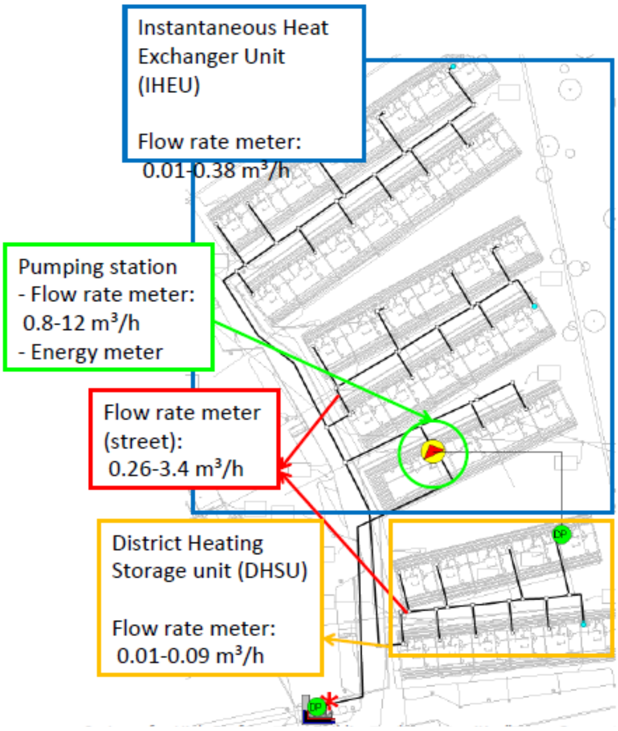


Fig. 2.4.1. Low temperature district heating in Denmark, Lystrup [45]

The example of Lystrup shows the low temperature DH system for newly built low consumption buildings and cannot be applied in Gulbene directly, but the technical solutions are feasible for energy efficient renovated buildings.

2.4.2. Albertslund Concept

An example of a low-temperature DH implementation in renovated buildings is in Albertslund, a suburb of Copenhagen. The buildings of the southern Albertslund were built between 1963 and 1968. In the municipal plan, to undertake major building renovations over the next 10 years to meet the climate targets of becoming CO_2 neutral by 2025.

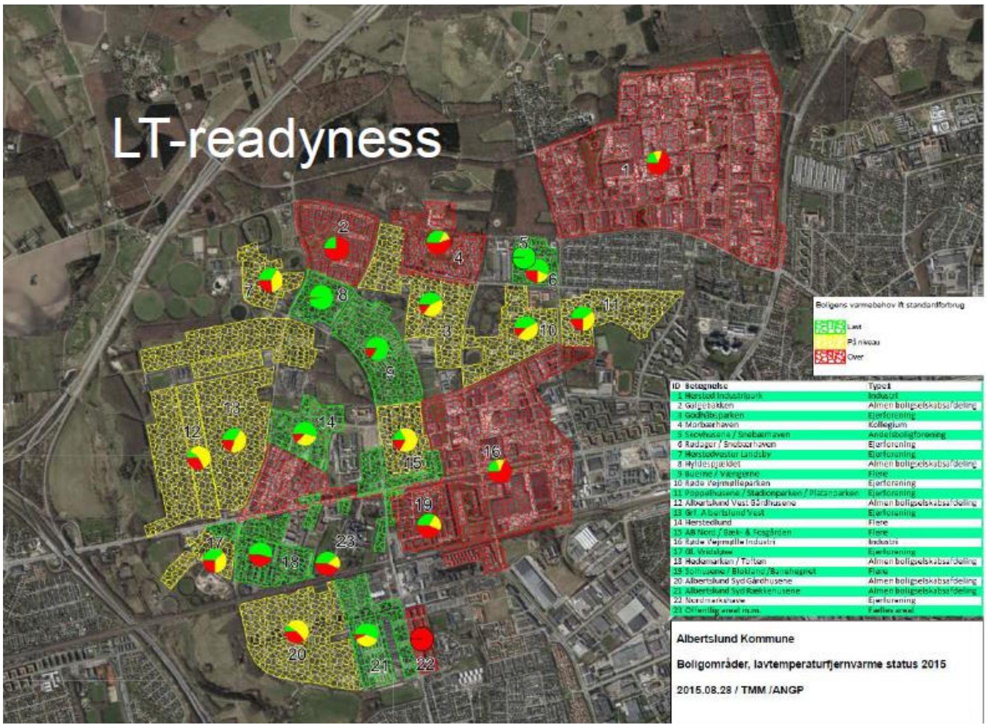


Fig. 2.4.2. Alberstlund city plan with marked areas ready for low-temperature district heating [47]

In the city, 97% of the delivered heat comes from DH. The main source of heat is a biomass cogeneration plant and waste incineration plants. DH is a non-profit organization based in Denmark. The picture above shows a city plan showing different areas of readiness for different areas to implement a low-temperature system. The city development plan includes renovating most buildings, replacing the DH heating route with a length of 350 km and implementing a low-temperature heat supply system by 2025.

Fig.2.4.3. Example of renovated building and installed low temperature heaters [48]

One of the examples of renovated buildings is two-storey apartment buildings, where after the reconstruction the energy consumption for heating was reduced by 60%. The buildings are equipped with low-temperature radiators with an inlet flow temperature of 580C. The return flow from the radiators is passed on to the floor heating system. Specially designed hot water heat exchangers with a total water capacity of 0.5 l are installed for hot water preparation and are cold when not in use. [48]

The low-temperature heat system introduced in Albertslund allows efficient use of low-potential residual heat. One of the implemented projects is heat recovery from IT company Ltd. Jaynet server rooms with the help of installed heat pump. The heat pump removes excess heat from the server rooms and raises the temperature to 75°C. Part of the heat is used for heating the building, while the rest is transferred to the district heating system, which produces up to 1 GWh of heat per year. Although cooling with a heat pump is more expensive than a conventional system, the benefits are derived from the heat sold.

The Alberstlund concept highlights the important role of municipality and long term planning to implement low temperature district heating. The Municipality of Gulbene should be the driver of the development of district heating by making the reduction of temperature a task of the future and making recommendations for its reduction.

2.4.3. Sonderby, Denmark

Another pilot project is located in an existing building area called Sønderby (Soenderby), a suburb of the Danish capital Copenhagen. The pilot project covers part of the community buildings - 75 separate brick houses built in 1997/98. The living space of each house is 110-212 m^2 with a total heated area of 11,230 m^2.

Due to the inefficiency of the existing heating system, it was decided to design and connect a new low-temperature DH for the buildings. New substations with specially adapted heat exchangers for hot water and heating were installed in each home. The heating networks have only been replaced and adapted to 4GDH technology for increased operating pressure and lower temperatures. The main source of heat is the return flow of the DH in the nearest district, which is heated by the supply flow if necessary.

All buildings have been redesigned with a hot water supply system to minimize the total volume of water to 3 litres. Underfloor heating, which is suitable for low temperature DH, is used as the internal heating system.

Fig. 2.4.4 Sonderby Pilot project Buildings and Single-family House [49]

The system performance indicators show that the "cold" return flow from the nearest standard DH can cover 80% of the building's heat consumption. The average supply temperature is 55°C and the return temperature is 40°C, which is higher than predicted due to errors of some individual heating units.

This project demonstrated that the 4th generation DH concept also works in existing buildings with floor heating as a space heating system. The results show that the customer can be supplied with a heat carrier with an inlet temperature of approx. 55°C, which meets both heating requirements and safe hot water supply. The introduction of low temperature heating reduced both the specific heat loss to about 13% and increased the overall heat efficiency by providing a lower return temperature. This is one of solutions how the low temperature DH can be phased in Gulbene city by merging energy efficient buildings and un-efficient buildings.

2.4.4. Model of Västerås

Västerås is a growing industrial, commercial and logistics city located in central Sweden, about 100 km from Stockholm. In 2007, the municipality approved the Energy Development Plan, which was a catalyst for increasing energy efficiency and reducing environmental impact. The Municipal Real Estate Department has invested SEK 100 million to accelerate the renovation of existing buildings and increase energy efficiency. The energy plan also included strict energy performance standards for new buildings under construction on municipal land.

In the city, DH is provided by the municipal company Malarenergi, which owns a waste cogeneration plant. The relatively low cost of electricity and the increased energy efficiency of buildings made it economically unattractive to add new single-family homes to the existing heating system. To overcome this problem, the district heating operator and the Department of Real Estate developed a low-temperature DH concept combining technological solutions with a business model to make district heating in energy efficient buildings profitable. The standard DH temperature is lowered to 60°C by means of a heat exchanger. Cheaper plastic pipes are used to connect buildings to the heat network because it does not need to withstand such high temperatures. [50]

An additional aspect of the new low temperature DH (Model of Vasteras) is the switching of household appliances (dishwashers, washing machines, dryers, bathroom floor heating) from electrical to DH, which allows to increase the specific heat density (kWh/m^2) in these low heat consumption areas.

One example of DH-attached buildings is the four low-consumption Raseglet apartment buildings, built by a municipal property company in collaboration with a heating utility. In buildings, heating, hot water preparation and domestic heating have been provided with low-temperature DH since 2013. The main conclusion of the project is that this technological solution does not make the apartments much more expensive, but in the long run provides economic savings due to low heating costs. [50]

The example shows that there should be close collaboration between energy supplier and Gulbene municipality to achieve efficient DH solutions and the low temperature DH concept can be developed together. In addition, the heat density should be one of main indicators in Gulbene to analyse the DH system development.

2.4.5. Solar DH in Germany

One of the 4GDH solutions is the use of solar thermal energy and integration of solar collectors. The development of solar DH in Germany was mainly driven by the Solartermie project. Within this project, since 1996, 11 pilot projects have been implemented - district heating systems with integrated solar collectors and seasonal heat accumulation [58]. In almost all of these projects, the heating system is designed with a lower heat carrier temperature (50-65°C) to increase overall system efficiency. With the systems in place for over twenty years, it is possible to evaluate their performance and potential improvements.

One of the projects implemented in Germany is Friedrichshafen, where 4050 m^2 of solar collectors are built on the roofs of buildings and the accumulation of energy is provided by an accumulation tank with a total volume of 12 000 m^3. In total, this system provides 23,000 m^2 of living space with heat. Two gas boilers provide peak load coverage for the system to operate independently [51]. The hydraulic diagram of the system is shown in Fig. 2.4.5. The scheme separates the residential areas "rz1" and "rz2" which were built with a time lag.

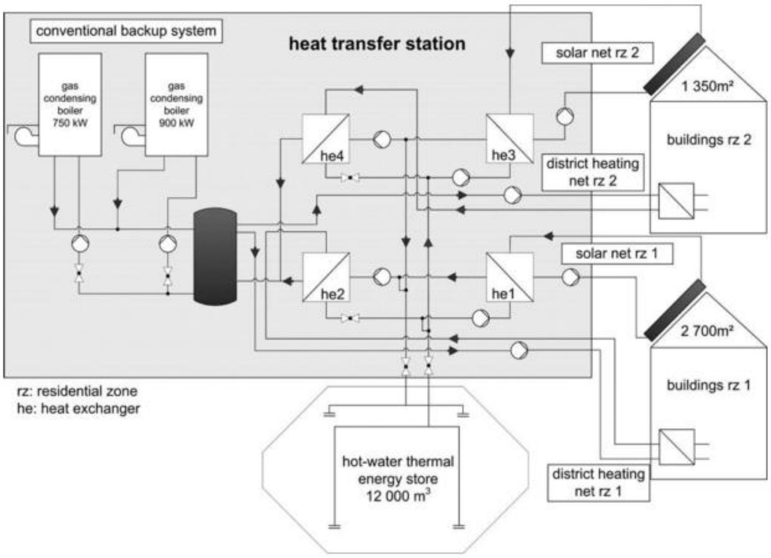


Fig. 2.4.5 Hydraulic diagram of integrated solar heating system in Friedrichshafen [51]

Monitoring data shows that the efficiency of collectors installed in Friedrichshafen ranges from 291 to 400 kWh per m^2 collector effective area per year, depending on the solar intensity. The share of solar thermal energy in the total heat consumption varies from 21 to 33%, which is lower than the planned, when installing the system (43%).

The examples from solar DH system shows that such innovative solar system could be used also in Gulbene municipality and can be further analysed to determine the techno-economic parameters.

3. Evaluation of alternatives for low temperature DH implementation

3.1. Gulbene city

3.1.1. Evaluation of the existing heating system

Gulbene district heating system (DHS) consists of interconnected boiler house and CHP plant, heating network and energy consumers. The main energy sources providing heat supply in Gulbene are as follows:

- woodchip boiler house at Nākotnes Street 7 (installed capacity at the end of 2015 - 10.5 MW), which is serviced by licensed heat transmission and distribution company LTd. Vidzemes energija;
- Bioeninvest Ltd. woodchip cogeneration station at Miera Street 17 (thermal capacity 5 MW, electric capacity 0.999 MW), from which Ltd Vidzemes Energija has been purchasing thermal energy since 2012;

The main characteristics of heat sources are summarized in Table 3.1.1

Table 3.1.1 The main characteristics of heat sources

Heat source	Boiler name and type	Capacity, MW	Installation year in boiler house	Boiler efficiency, %	Energy source
Nākotnes iela 7	Polytechnick PR6000 U	6	2009	82%	Wood chips
Nākotnes iela 7	ECOCOAL-R	4,5	1996	75%	Wood chips
Miera iela 17	Turbodent CHP Split 10	5	2012	-	Wood chips

Fig. 3.1.1. Boilers installed in boiler house at Nakotnes street

The woodchip boiler ECOCOAL-R (4.5MW) (see Fig. 3.1.1) is the property of the Municipality of Gulbene, which it received as a gift from the Danish government in 1996. The boiler was manufactured in 1983 and was used in Denmark before being brought to Gulbene. Originally coal was used as fuel, but before installation in Gulbene it was rebuilt to use woodchips. The Austrian woodchip boiler Polytechnick PR6000 U (6MW) (see Fig. 3.1.2) was installed by Vidzemes Energija Ltd. in 2009.

Table 3.1.2 summarizes the main heat production data for 2016-2018. The average amount of heat transferred to consumers is 24 523 MWh per year, but the total amount of heat produced is 30 537 MWh, of which 21 056 MWh or 69% is purchased.

Table 3.1.2. Main data of Gulbene DH heat production and supply

Parameter	2016	2017	2018
Produced heat, MWh per year	9508	9114	9819
Purchased heat from CHP, MWh per year	20954	21184	21031
Total, MWh per year	30462	30298	30850
Heat losses, MWh per year	5601	6112	6330
Heat losses, %	18%	20%	21%
Delivered to consumers, MWh per year	24861	24186	24520
Wood chip consumption, m^3 per year	15516	14143	15585
Energy from fuel, MWh per year	12568	11456	12624
Average efficiency	76%	80%	78%

The average consumption of woodchips is 15 081 m^3 per year. Vidzemes Energija Ltd purchases fuel once a year from one supplier. The average efficiency of both boilers in the Nākotnes Street 7 boiler house fluctuates within 80%. The efficiency values are given in Table 3.1.2. Such efficiency coefficient for boilers of a given age is within the normal range. The efficiency of new woodchip boilers ranges from 85 to 90%.

Fig. 3.1.3 graphically shows the amount of heat produced and purchased in the Gulbene DH from 2012-2018. As can be seen, since 2012 this proportion has increased and in 2018 68% of the total amount of heat energy was purchased from CHP. The total amount of thermal energy has increased slightly since 2015, which can be explained by new heat consumers and differences in climatic conditions.

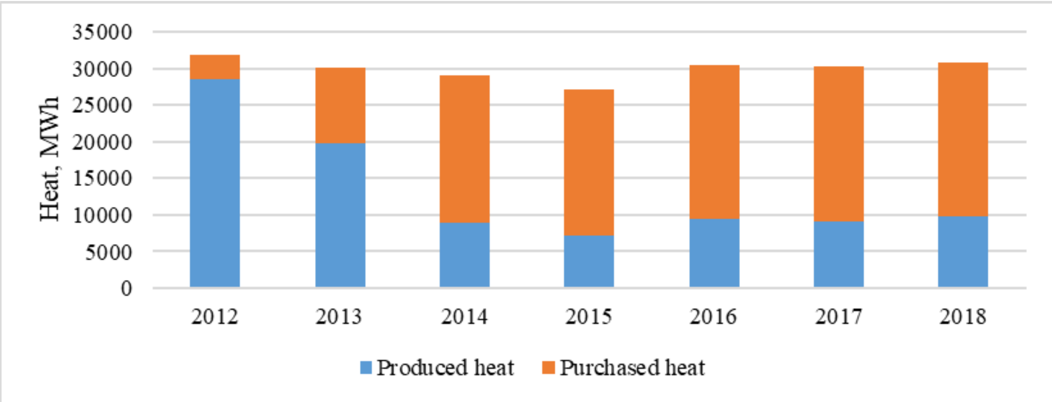


Fig. 3.1.3. Produced and purchased heat energy in Gulbene DH

The heat consumption of buildings depends on the climatic conditions. The heat consumption for heating is adjusted to the climatic conditions and the results are shown in Fig. 3.1.4. Hot water consumption is based on the average summer heat load and is applied to the rest of the year. The average adjusted heat consumption for the last 3 years is 27,166 MWh.

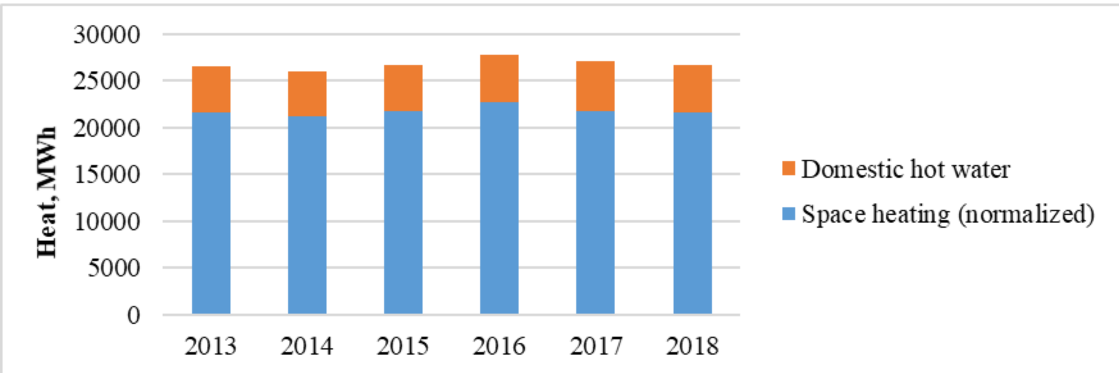


Fig.3.1.4 Normalized heat consumption for heating (blue) and hot water (red) production

Heat carrier temperature curve

Analyzing the available heat carrier temperature data (Fig. 3.1.5), a correlation between the flow temperatures and the average outdoor temperature was determined for the particular period. Using the obtained regression equations, a boiler house temperature curve is constructed (Fig. 3.1.6).

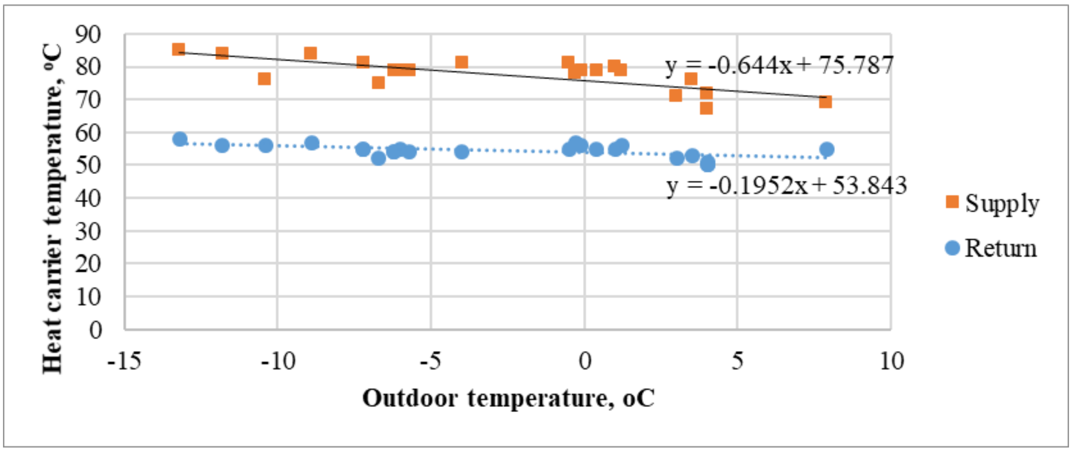


Fig. 3.1.5 Correlation of supply (red) and return (blue) flow with outdoor air temperature

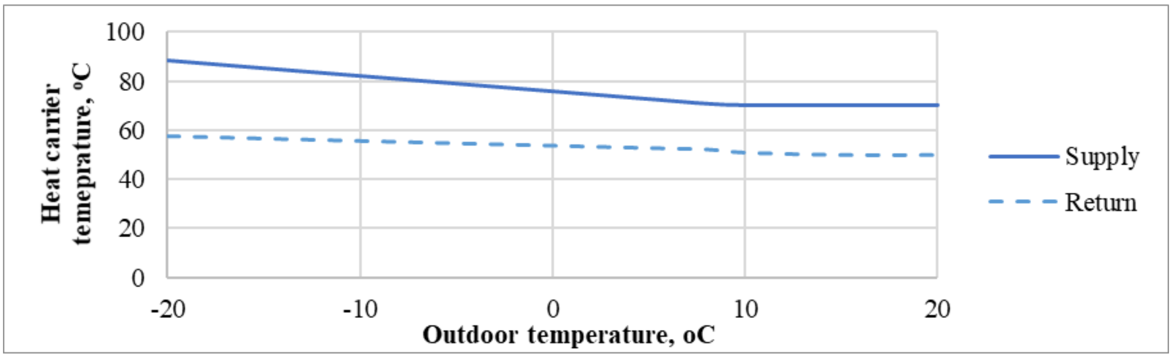


Fig. 3.1.6 Gulbene DH temperature curve

Fig. 3.1.6 shows that the boiler house is currently operating at 90/60 temperature mode. In order to more accurately determine the supply and return flow temperatures, historical data collecting and evaluation is needed. The temperature graph shows that a temperature difference of 30°C at -20°C is possible. However, during the heating season, when the outdoor air temperature is higher, the temperature difference narrows, quantitative regulation is made and additional electricity is consumed to organize the water flow in the networks.

Heat load curve

The total installed capacity of the boiler house at Nākotnes Street 7 is 10.5 MW, while the installed heat capacity of "Bioeninvest" Ltd. at the cogeneration plant is 5 MW. In order to determine the correspondence of the installed capacity to the actual heat consumption, load graph analysis was performed (see Fig. 3.1.7).

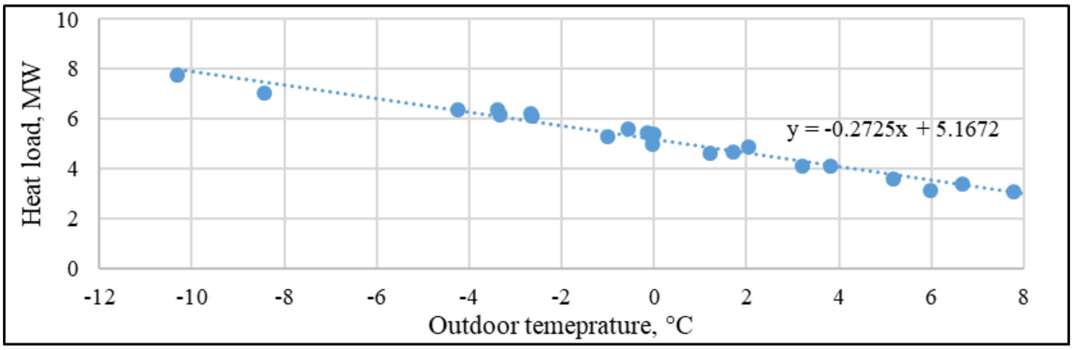


Fig. 3.1.7 Correlation between heat load and outdoor air temperature during heating season

Taking into account the correlation between the heat consumption capacity of Gulbene Dh consumers and the actual outdoor air temperature, a heat load graph was drawn up (see Fig. 3.1.8).

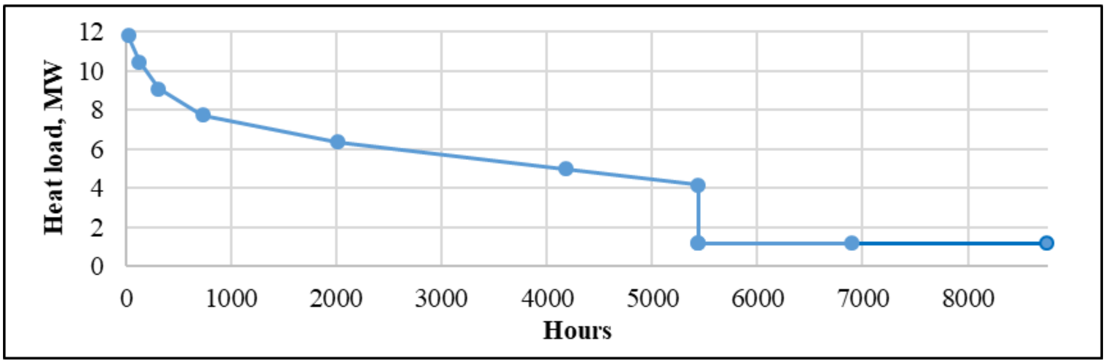


Fig. 3.1.8 Average heat load curve of Gulbene city for 2016-2018

As can be seen in Fig. 3.1.8, the maximum load over the last three years is almost 12 MW, which is comprised of heating, hot water and heat losses. The average summer load is very low at 1.2 MW.

Heating network

The total length of Gulbene DH heating network is 12.1 km. 81% of heat network are owned by Gulbene Municipality (9.8 km), while the remaining 19% are owned by private companies and SIA Vidzemes Energija.

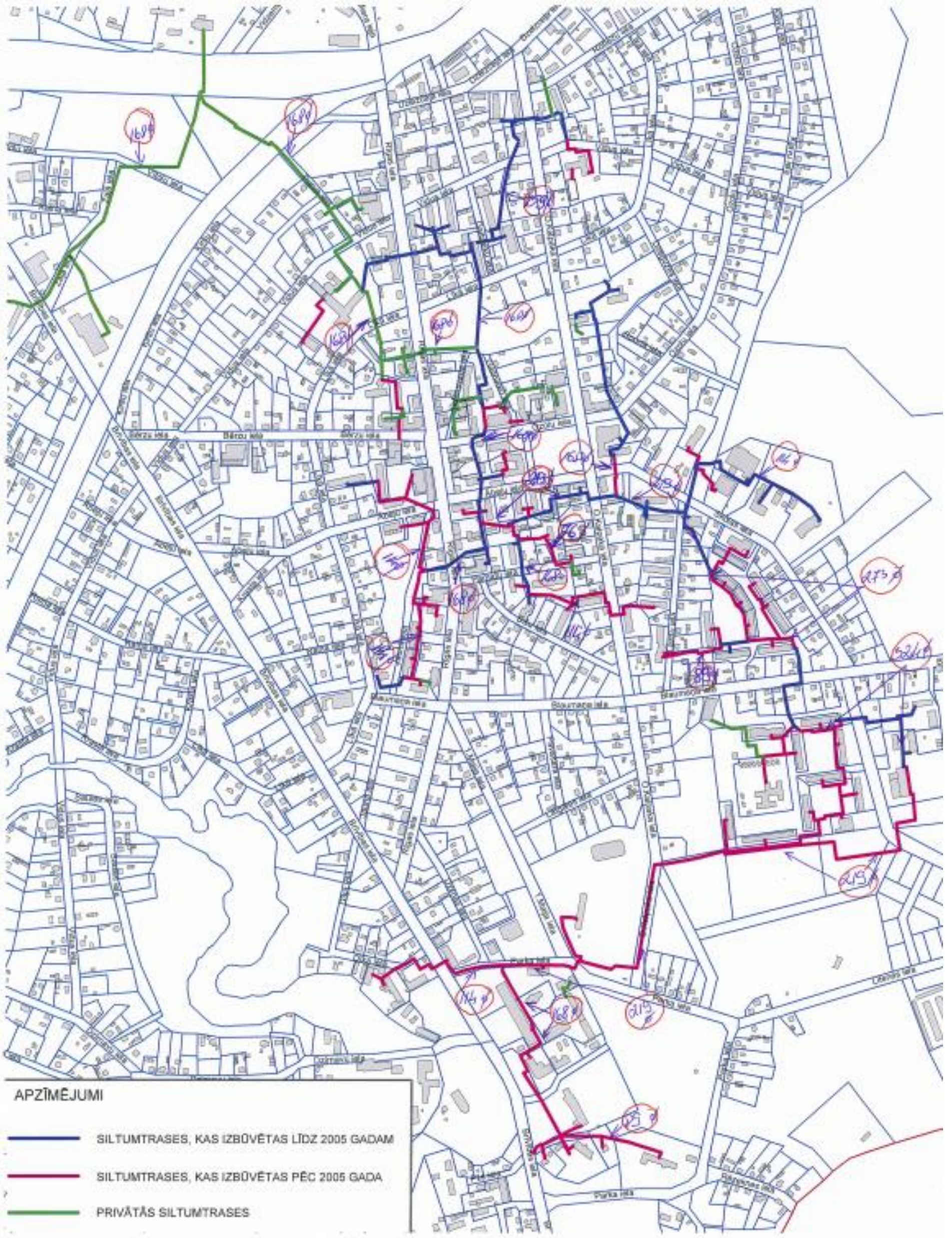


Fig. 3.1.9. Heating network of Gulbene DH

Fig. 3.1.9 shows the scheme of the heating pipelines with marked private heating networks (green) and heating networks of other owners, which divide the heating lines built before 2005 (blue) and after 2005 (pink). Table 3.1.3 summarizes the diameters and lengths of all pipelines. The weighted average diameter of heating networks is 146 mm.

Based on information provided by Ltd. Vidzemes Energija the total amount of industrially insulated heating networks in Gulbene city DH is about 90%. The average heat losses in the heating pipelines over the last 3 years have been in the range of 18-20%. According to Latvian regulations, heat losses in heating pipelines should be below 17%.

Table 3.1.3 Overview of diameters and lengths of heat pipelines

Diameters of pipelines, mm	Length of pipelines, m
DN323	314
DN273	494
DN219	1537
DN168	3310
DN159	519
DN139	402
DN114	2114
DN108	189
DN89	871
DN76	1258
DN60	721
DN48	191
DN42	157

Consumers

Fig. 3.1.10 presents the heat consumption data for the main consumer groups in 2013-2018. The largest group of consumers of thermal energy are apartment buildings with a total heated area of 103 thousand m². The second largest consumer group are legal entities whose heating area is currently unknown.

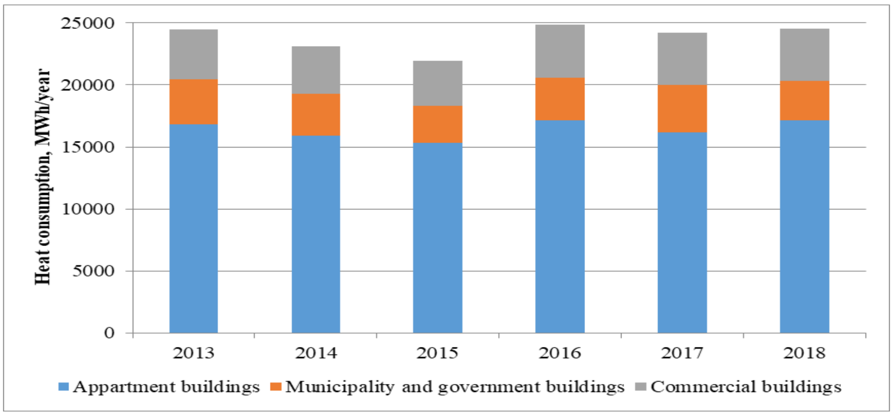


Fig.3.1.10. Heat consumption for different groups

An analysis of the specific heat consumption of apartment buildings shows that the average specific heat consumption for space heating is approximately 123 kWh / m² heated area per year. As can be seen in Fig. 3.1.11, in 8 buildings the heat consumption for heating is below 100 kWh / m² per year, which can be explained by the fact that the buildings are insulated (for example, the building at 39 Rīgas iela).

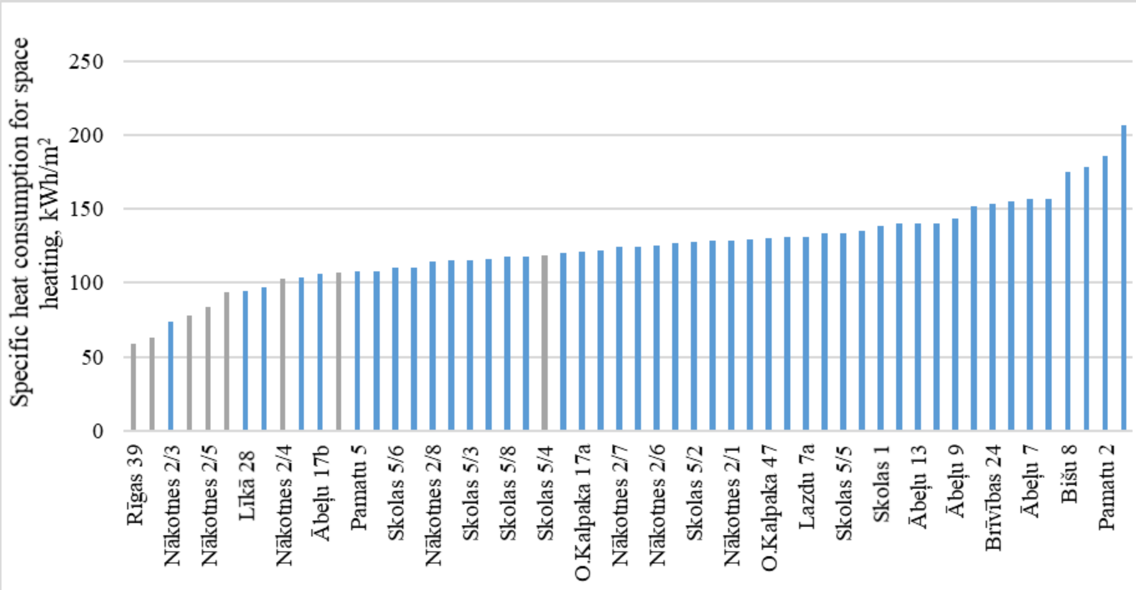


Fig. 3.1.11 Average specific heat consumption for heating in apartment buildings over the last 6 years. Renovated buildings are grey

As shown in Fig. 3.1.11, the apartment building sector has the potential to reduce heat consumption by up to 70 kWh/m² per year. Buildings on Rigas Street 59, Pamatu Street 2, 1 Ābeļu Street and elsewhere have the greatest potential.

The specific heat consumption of municipality buildings for heating is given in Fig. 3.1.12.

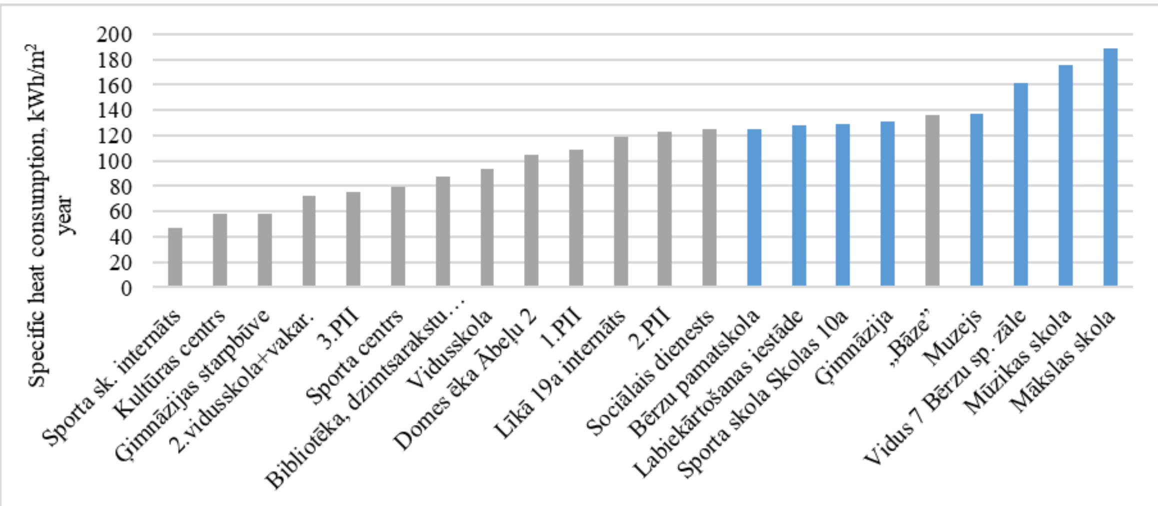


Fig. 3.1.12 Specific heat consumption in municipality buildings. Renovated buildings are grey

As can be seen in Fig. 3.1.12, energy efficiency improvement works have already been carried out in most of municipality owned buildings. The "Bāze" youth center can be considered as renovated as it is a cultural and historical monument and has taken all possible energy efficiency measures. The social service building (Sociālais dienests) was rebuilt and insulated in 2017. The average specific heat consumption for heating in municipality buildings is 112 kWh/m². The specific heat consumption for heating ranges from 47 kWh/m² to 128 kWh/m² per year. Further research would be needed to determine the reasons for the high heat consumption in some of renovated buildings.

3.1.2. Forecasted changes in heat consumption

The assessment of thermal energy consumption took into account the possibility of increasing the energy efficiency of buildings, which would reduce the total amount of thermal energy produced. Fig. 3.1.13. shows that since 2003 the average (normalized) specific heat consumption of buildings for heating has decreased only slightly from 140 kWh/m² to 138 kWh/m².

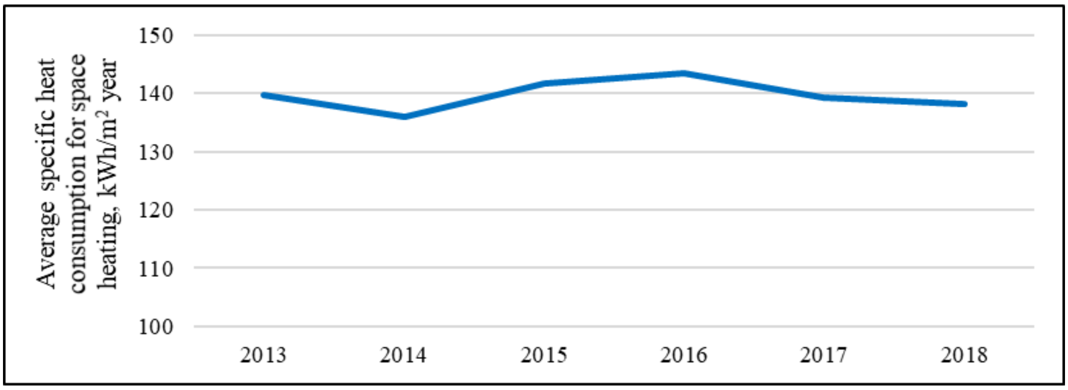


Fig. 3.1.13 Changes in average heat consumption of buildings for heating in Gulbene

In order to determine the heat load after increasing the energy efficiency of buildings, it was assumed that municipal and apartment buildings with a specific heat consumption for heating of more than 140 kWh/m² per year would be insulated and their specific heat consumption would be reduced to 90 kWh/m². 16 apartment and municipal buildings meet these preconditions or 13% of the total number of buildings connected to the DH. It should be noted that hot water consumption would remain unchanged as part of the building renovation. As a result, within the framework of energy efficiency improvement, the potential reduction of heat consumption was estimated to be about 1020 MWh per year, or 5% of the existing consumption of apartment and municipal buildings. Assuming that the energy consumption of business-owned buildings could also be reduced by about 5%, the total potential heat reduction due to increased energy efficiency is approximately **1230 MWh per year.**

The city also has buildings with existing connections that do not currently use DH services. In order to ensure the sustainable development of the Gulbene DH, it is necessary to restore the heat supply to the buildings with existing connections and to negotiate with potential new customers in the vicinity of the DH system. Increasing the amount of heat transferred will reduce the fixed costs per unit of heat sold. This is also important to reduce the number of air pollution sources in the city.

Table 3.1.4 summarizes the information on potential new DH consumers. The table shows the consumer address, the approximate heat consumption and the potential length of the heating pipeline to be built. The thermal energy consumption of a building will be determined by knowing the building's heated area and the average specific heat consumption of the buildings for heating and hot water in Gulbene, which is 150 kWh/m2 per year. Considering the high investment involved in constructing a new heating pipeline, the potential linear density of heat consumption for each new consumer or group of consumers, if the new heating pipeline combines several buildings, is also determined.

Table 3.1.4 Overview of potential consumers

Address	Forecasted heat consumption MWh per year	Estimated length of heat pipes, m	Linear density of heat consumption, MWh/m
Brīvības street 72	258	25	**10.3**
Rīgas street 68	76	10	**7.6**
Baložu street 4B	333	50	**4.1**
Baložu street 4	301	105	
Brīvības street 56	596	130	**3.7**
Bērzu street 17B	30	45	
Bērzu street 17A	22	20	
Bērzu street 17C	153	23	
Brīvības street 16	72	21	**3.4**
Līkā street 1A	155	60	**1.7**
Brīvības street 44	53	68	
Brīvības street 42	101	26	
Brīvības street 42	60	38	
Līkā street 6A	72	60	
Rīgas street 65	142	65	**1.5**
Rīgas street 69A	8	35	
Robežu street 8	53	170	**1.2**
Robežu street 10	53	33,2	
Robežu street 12	52	33,2	
Robežu street 14	46	33,2	

Robežu street 16	45	33,2	
Robežu street 18	45	33,2	
Ozolu street 39	84	23	
Robežu street 23	125	85	
Kļavu street 30	51	62	
Robežu street 20	47	0	
Ozolu street 74	53	80	
Ozolu street 76	55	80	
Dzelzceļa street 1	67	110	
Dzelzceļa street 8	264	0	
Dzelzceļa street 1A	54	118	
Blaumaņa street 1A	105	150	**1.1**
Blaumaņa street 1B	133	66	
Miera street 4	53	157	**0.6**
Miera street 1B	45	59	
Miera street 5	85	90	
Brīvības street 66A	19	35	**0.5**
Klēts street 4	64	140	**0.5**
Dzelzceļa street 14	72	180	**0.4**
Blaumaņa street 52A	52	220	**0.4**
Blaumaņa street 56A	79	141	

Table 3.1.4 shows that buildings with a heat density of more than 1.5 MWh/m could be connected to the DH primarily. The connection of buildings to the DH with a heat density between 1 and 1.5 should be further analyzed, but the connection of the other buildings would only be beneficial if there are additional consumers in the new phase. Consequently, it is assumed that the potential increase in heat consumption from new customers could be in the range of 2,400 to 3,700 MWh per year.

3.1.3. Description of future pathways

Energy efficient heat production from renewable energy sources

Gulbene DH already produces all its heat from renewable energy sources - biomass, but for efficient use of fuel it is necessary to ensure maximum heat production efficiency.

Wood chips are used as fuel in the boiler house of SIA "Vidzemes Enerģija". The average moisture content of woodchips is 40-60%. This means that much of the heat produced is consumed to evaporate moisture from the fuel. Evaporated moisture is released into the atmosphere in the form of flue gases. Installation of a condensation type economiser or flue gas condenser is an option to increase the efficiency of heat production (see Appendix 1).

To increase the share of renewable energy in the energy balance, the use of solar energy is being analyzed as an alternative. Solar energy can be used to produce both thermal energy through solar collectors and electricity through solar panels. As the available heat surplus from the wood processing plant is to be used primarily in the city of Gulbene, the installation of a solar collectors for heat production during the summer period is not considered (Appendix 2).

Temperature lowering

In order to reduce heat transfer losses, a gradual reduction of the temperature of the heating network should be the main strategic development direction of the Gulbene DH. Potential reduced temperature graphs (80/55 and 70/45) are shown in Fig. 3.1.14.

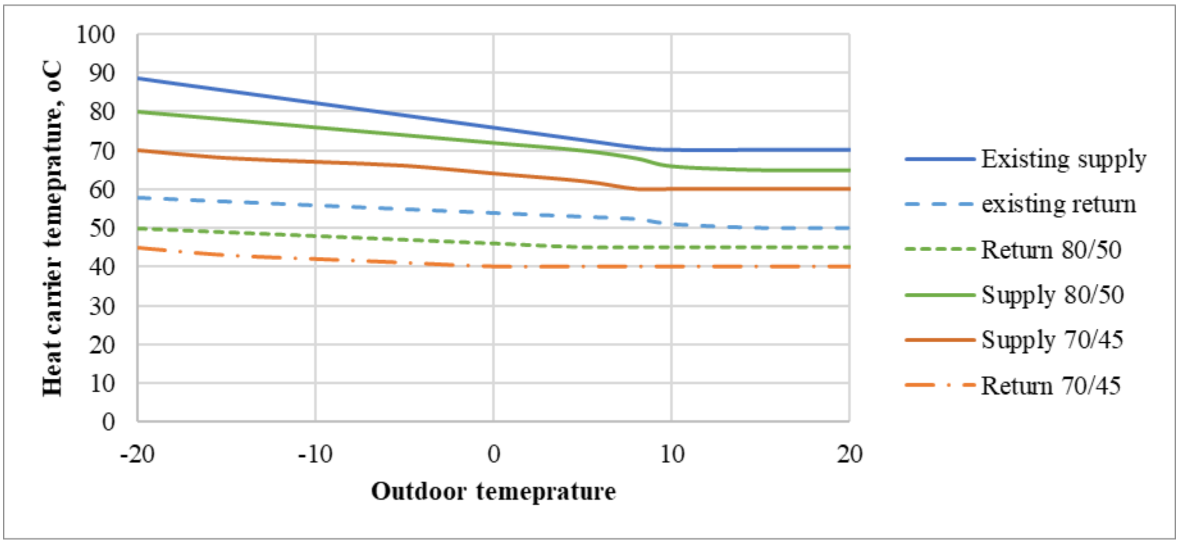


Fig. 3.1.14 Potential temperature graphs

Taking into account the lengths, diameters and technical condition of the Gulbene DH heating network, a heat network model was developed that allows to determine heat losses at different temperature graphs (see Fig. 3.1.15.).

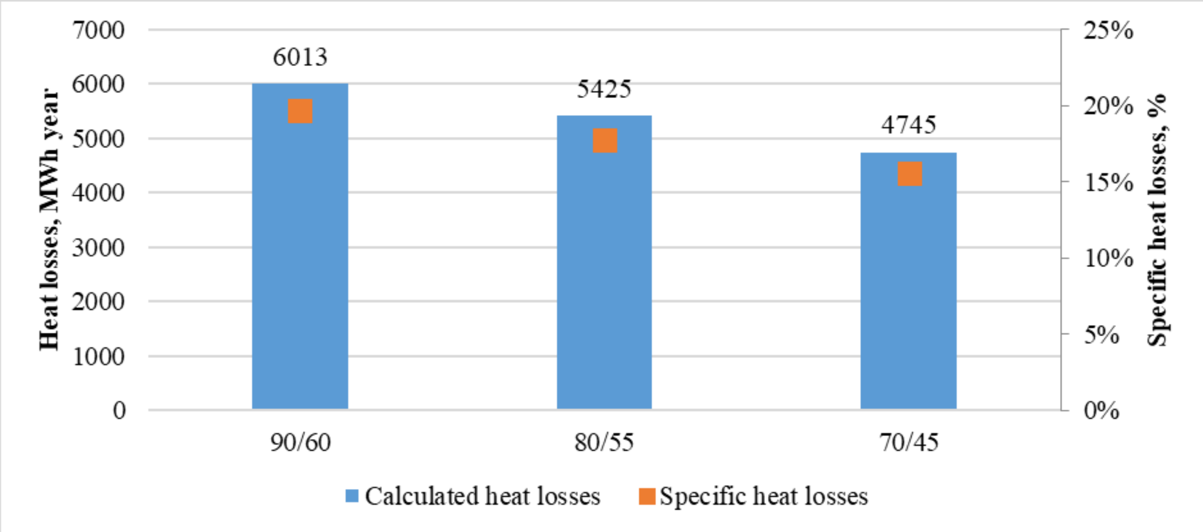


Fig. 3.1.15 Modeled heat losses and specific heat losses at different temperature graphs

At present, the three-year average heat loss amounts to 6,014 MWh per year, or 20% of the produced heat. By reducing the flow to 80°C and adjusting the temperature curve, the total heat loss would be reduced to 5425 MWh per year, while the introduction of the 70/45 temperature curve would save 1298 MWh per year at the expense of heat loss. At a lowered temperature curve, the specific heat losses are reduced to 16% of the amount of heat currently transferred to networks. The main task of lowering the temperature in the heat networks is to ensure the maximum difference between the flow and return temperature so that there is no need to increase the heat carrier flow rate, which would result in higher electricity consumption.

Currently, the Gulbene DH does not analyze the supply and return flow temperature changes. The flow temperature is regulated depending on the outdoor air temperature, but without taking into account the changes in heat consumption during the day. Using temperature optimization programs such as hydraulic modelling tools, it is possible to simulate flow, pressure and temperature behaviour in heat networks and to optimize system performance in real time.

It is easier to lower the temperature of heating networks in mixed-use areas with renovated and non-renovated buildings suitable for the use of energy cascades - return flow from non-renovated buildings is used as a supply flow for energy efficient buildings [40]. Such territory has been identified in the district heating section of Skolas Street, where several municipal buildings and one apartment building are located. As shown in Fig. 3.1.16 four of the seven buildings in this branch have been renovated and have low heat consumption. In the apartment building on Skolas Street 8A, heating is provided only in part of the building. If the heaters in the buildings have not been replaced or installed after the renovation has taken into account the heat requirements of the new building, they can be easily adapted to a low temperature system or to use return flow.

Considering the size, condition and diameters of the district heating pipelines, reducing the temperature from 90/60 to 80/50 at this stage would result in a 46 MWh reduction in heat loss, and a further reduction to 70/45 would save nearly 100 MWh per year.

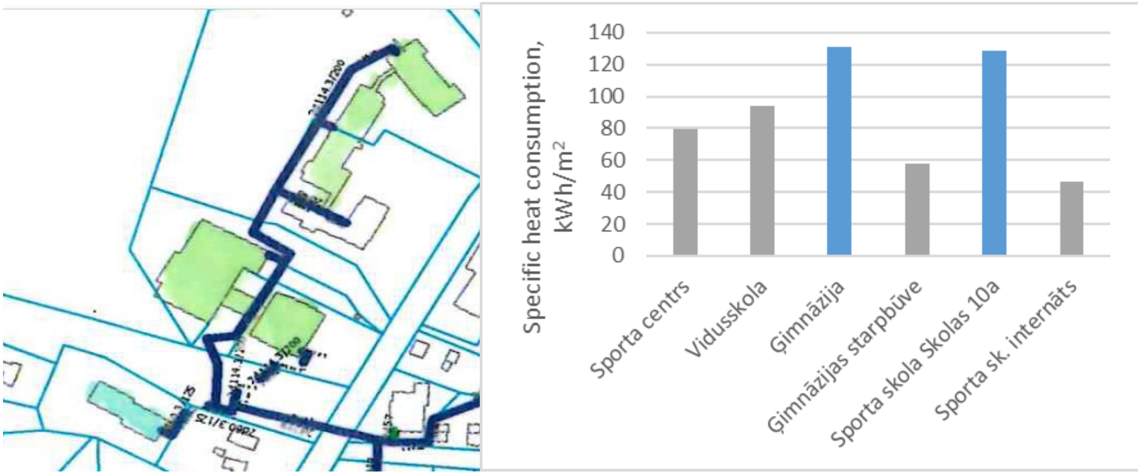


Fig. 3.1.16 Location of Skolas Street buildings and specific heat consumption for heating. Renovated buildings are green

Another branch of mixed-type buildings has been identified on Nākotnes Street, where there are 9 apartment buildings, two of which have been renovated and an insulated kindergarten (see Fig. 3.1.17). The district has several connecting nodes with the DH heat network, so it may be easier to vary with the use of heat carrier streams.

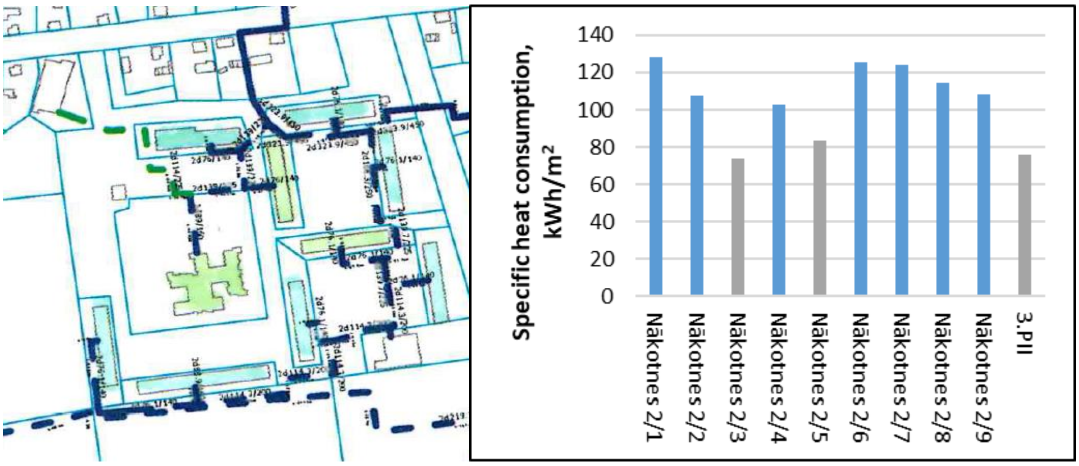


Fig.3.1.17 Location of Skolas Street buildings and specific heat consumption for heating. Renovated buildings are green

The technological solution for lowering the temperature in this type of mixed housing estates is to create a new mixing station with lower temperatures. Such mixing stations can be designed in different ways, but one solution is to combine 2 different streams - existing DH return streams as the main stream for low-temperature buildings with high-temperature downstream streams if necessary (see Fig. 3.1.18). Substations are usually equipped with special pressure boosting pumps to increase pressure and provide a higher flow rate. The main benefit of using return flow as flow in energy efficient buildings and providing a greater temperature difference in heat networks and providing consumers with heat without installing additional capacity.

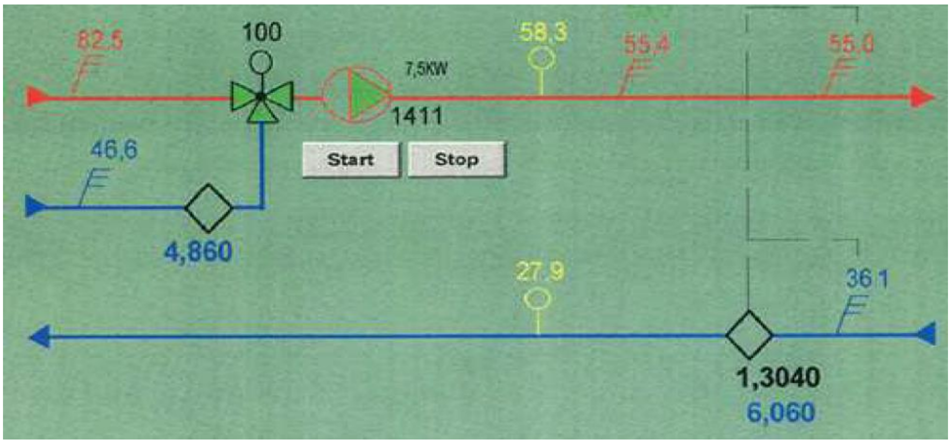


Fig. 3.1.18 Example of a technological solution for a three-stream mixing plant [41]

The temperature reduction of heating networks should be done gradually by adapting existing buildings, heating units and heating networks to a lower temperature heat carrier in the long term.

Integration of waste heat

Integration of waste heat into the DH from the largest wood processing company in Gulbene Ltd."Konto" was analyzed. The company supplied heat to the DH between 2006 and 2013, so the heat substation and heat pipeline is preserved on the site and no additional investment in the transmission system would be required.

The plant is equipped with UNIKONFORT BIOTEC / G-300 boiler with a capacity of 3.00 MW for heat production. The boiler was installed in late 2006. Heat is produced using woodchips and wood residues. About 60-80% of the heat produced is diverted to the wood drying process, while the rest is used to heat buildings and prepare hot water.

The drying process takes place in a total of 6 drying chambers with a theoretical wood capacity of about 500 m^3. The drying process in each chamber is continuous until the wood humidity reaches 6-8%. The downtime of the drying process is usually the time it takes to replace the dried wood with new, non-dried wood in the chamber. This period is longer in the summer, but shorter in winter, averaging 15-25% of the total number of days in the year. During the start of the drying process, the chamber itself and the logs are heated to 60°C. The warm-up phase usually lasts 1 to 2 days. During this period, the dryer with the wood inside takes in the maximum amount of heat it needs. When the first phase of drying is completed and the chamber is heated, the drying proceeds to the next one, i.e. a quiet phase when the excess moisture is slowly removed from the wood. The duration of this phase, depending on the thickness of the boards, is approximately 8 to 20 days. The temperature of the chamber is maintained at 60°C during this period, but the amount of humidity gradually decreases. In the drying process, the hot water from the companies' boiler house is used as a heat carrier. The feed temperature is 95°C and the return temperature is 70°C.

In 2018, Ltd. Konto produced a total of 5036 MWh of thermal energy. As can be seen in Fig. 3.1.22, considerably less heat is produced and consumed in the summer period - about 200 MWh per month, and in winter about 660 MWh per month.

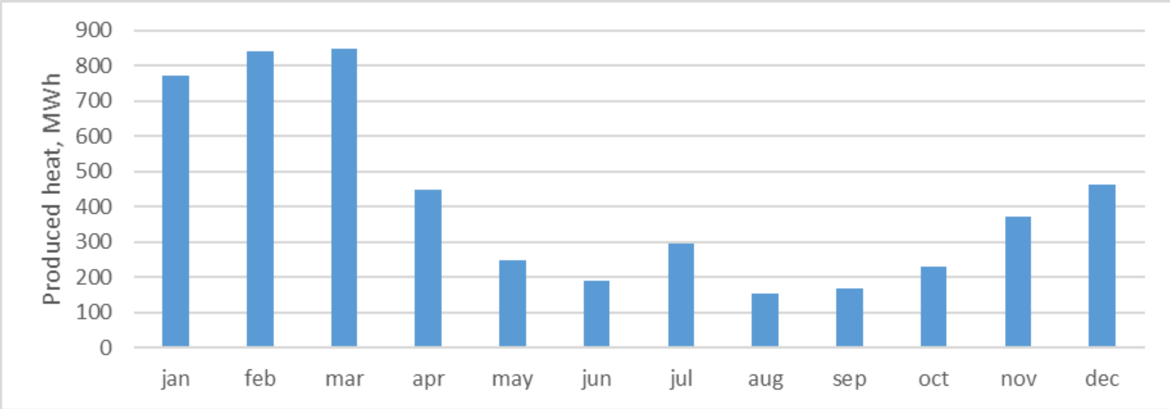


Fig. 3.1.19 Thermal energy produced by Konto Ltd. in 2018

Fig. 3.1.19 shows the modeled heat load of the company according to the obtained input data on the amount of heat produced. It can be seen that the peak load reaches about 1.6 MW and the summer load 0.6 MW.

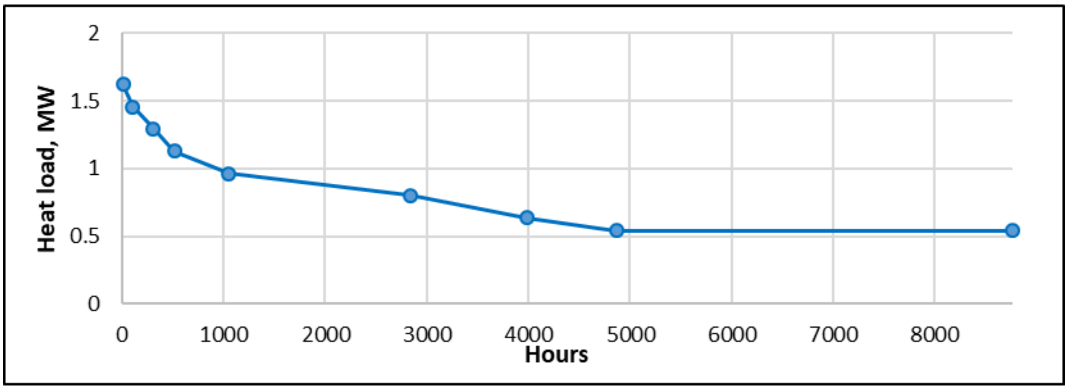


Fig. 3.1.20 Modelled thermal load of Ltd. Konto

From 2006 to 2013, Ltd. Konto supplied heat to the Gulbene DH. Fig. 3.1.24 shows the amount of heat sold by Konto Ltd. by months from 2006 to 2012. The Fig. shows that the amount of sold heat during the summer amounted to 800-1000 MWh per month. Over the years, amount declined gradually.

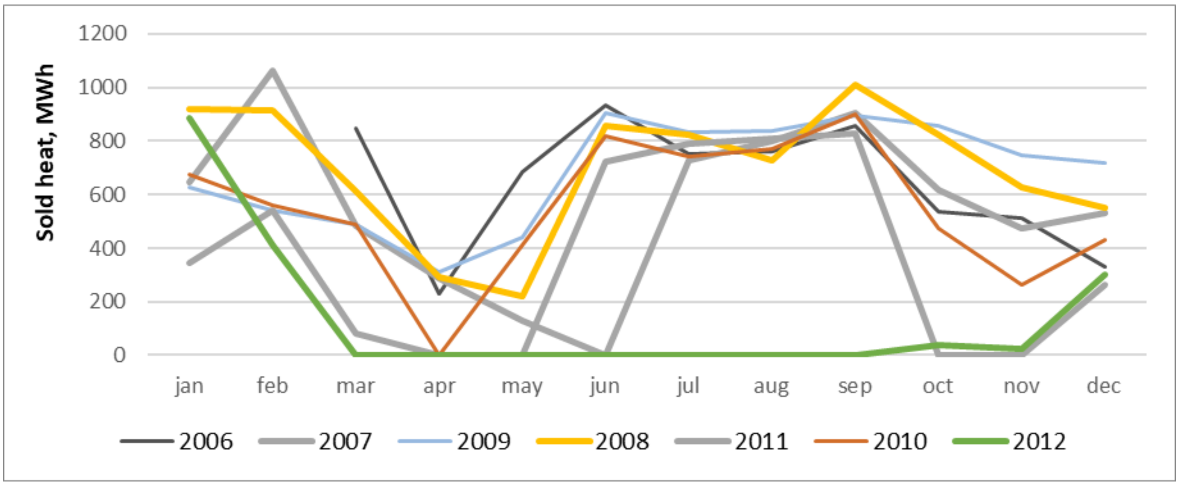


Fig.3.1.20. SIA "Konto" heat sold by DH in 2006-2012

3.1.4. Technical solutions for DH development and resources needed to implement them

Taking into account the strategic development directions described above, 3 technical development scenarios for Gulbene DH are considered and analyzed:

• Scenario 1 - All heat is produced in the boiler house with woodchip boilers. The heating system operates with the current temperature mode. In addition, a solar panel field for electricity generation is installed

• Scenario 2 - All heat is produced in a boiler house with woodchip boilers. The heating system operates at a reduced temperature mode. In addition, a solar panel field for electricity generation is installed

• Scenario 3 - Base load is covered by "Konto" Ltd., the rest of the heat is produced in the boiler house with woodchip boilers. The heating system operates at a reduced temperature mode.

Scenario 1 - Installation of a new woodchip boiler with a flue gas condenser at the existing temperature graph

Two woodchip boilers are now installed in the Nākotnes Street boiler house. The ECOCOAL-R boiler with a nominal capacity of 4.5 MW was manufactured in 1983 and rebuilt in 1996 as a woodchip boiler. The maintenance of the boiler entails additional costs for repair work and the efficiency is low. According to information provided by Vidzemes Energija Ltd., the efficiency of the boiler is 75% and it is necessary to replace this boiler in the nearest future. It is also not known for how long it will be possible to procure heat from the CHP plant. Thus, the possibility to cover all the consumption with boiler installed in the boiler house - woodchip boilers and flue gas condenser - is analyzed.

Scenario 1 assumes that two new woodchip boilers (1.5 MW and 3.5 MW) are installed in the existing boiler house with automatic woodchip feed and additionally integrated storage tanks for optimum boiler operation and daily load balancing.

The scenario assumes that the boiler house is equipped with a 1.5 MW flue gas condenser that can recover the energy consumed to evaporate the moisture and expel it to the atmosphere due to the high temperature of the flue gas. In equivalent projects in Latvia conditions 10-15% of the boiler capacity can be recovered.

Taking into account the potential changes in consumption and heat loss mentioned above, it is assumed that:

- the temperature of the heating networks is not lowered, thus the heat loss remains at the current level.
- Heat consumption is increasing by about 1050 MWh per year, while the peak load is 300 kW.
- The existing Polytechnick PR6000 U boiler is operated to cover the peak load. The heat load distribution is shown in the Fig. below.
- The 1.5 MW woodchip boiler is operated all year round to cover the base load.

As shown in Fig. 3.1.25. base load woodchip boiler would produce about 11 GWh of heat or 35% of the total. The 3.5 MW wood chips boiler would operate with the start of the heating season and produce about 13 GWh of heat (43% of total heat), while the existing boiler produces almost 3 GWh per year. The flue gas condenser (1.5 MW) produces an additional 3.8 GWh of thermal energy per year, assuming that 15% of the heat produced is recovered.

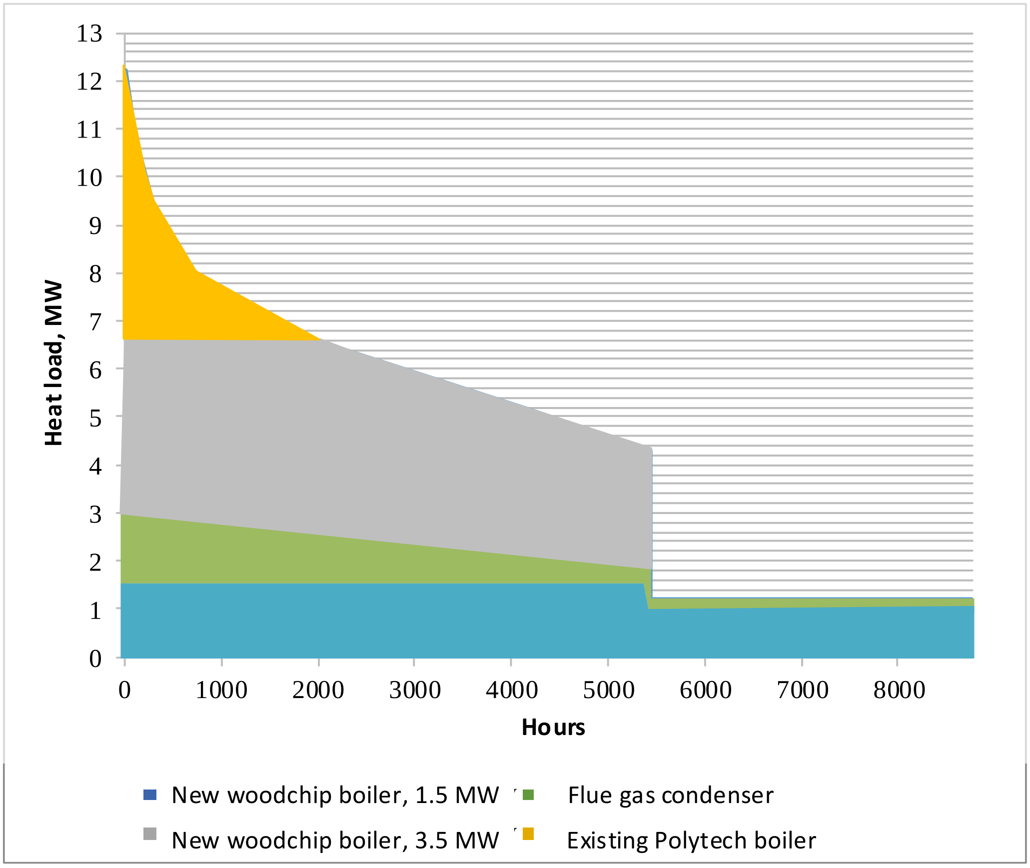


Fig. 3.1.25.Distribution of heat load in Scenario 1

In addition to installing woodchip boilers, the installation of a 170 kW solar power plant to cover the electricity consumption of the boiler house is being evaluated. Fig. 3.1.26 shows the forecast electricity consumption, which is equalized in the spring and autumn, similarly to the summer months.

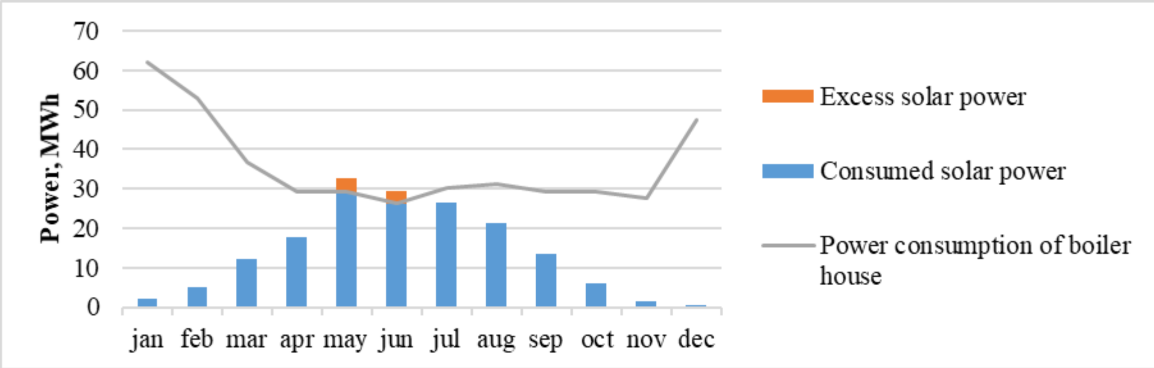


Fig. 3.1.26 Forecasted power consumption of the boiler house, Solar Power Consumption, and surplus solar power

It is predicted that a 1000m^2 solar panel effective area will be installed a*nd almost all solar electricity* (162 MWh) can be directly used for self-consumption.

Scenario 2 - Installation of a new woodchip boiler with flue gas condenser at lowered network temperature

In scenario 2 it is assumed that the temperature of the heating network will be lowered to 70/45 and the heat loss will decrease by 1300 MWh/year. It is assumed that the heat consumption of buildings due to the connection of new consumers will increase as in Scenario 1. As a result, there is no need to increase the capacity of the boiler house.

By reducing the return flow temperature, the flue gas condenser can work much more efficiently. It is assumed that in this scenario the flue gas condenser (2.4 MW) could recover about 20% of the thermal energy. Thus, it is possible to reduce the installed boiler capacity by choosing between 1.5 MW and 3 MW boilers. The load distribution is shown in the Fig. below.

As in Scenario 1, it is assumed that a 1.5 MW base load boiler will be installed, which would produce nearly 11 GWh a year. In addition, a 3 MW woodchip boiler was installed for the base load during the heating season (around 11 GWh per year) and the remaining peak load (2444 MWh or 8%) would be covered by the existing boiler. The flue gas condenser would produce 6 GWh per year.

As in the first scenario, it is assumed that the solar panel field will be used to generate electricity for the boiler house.

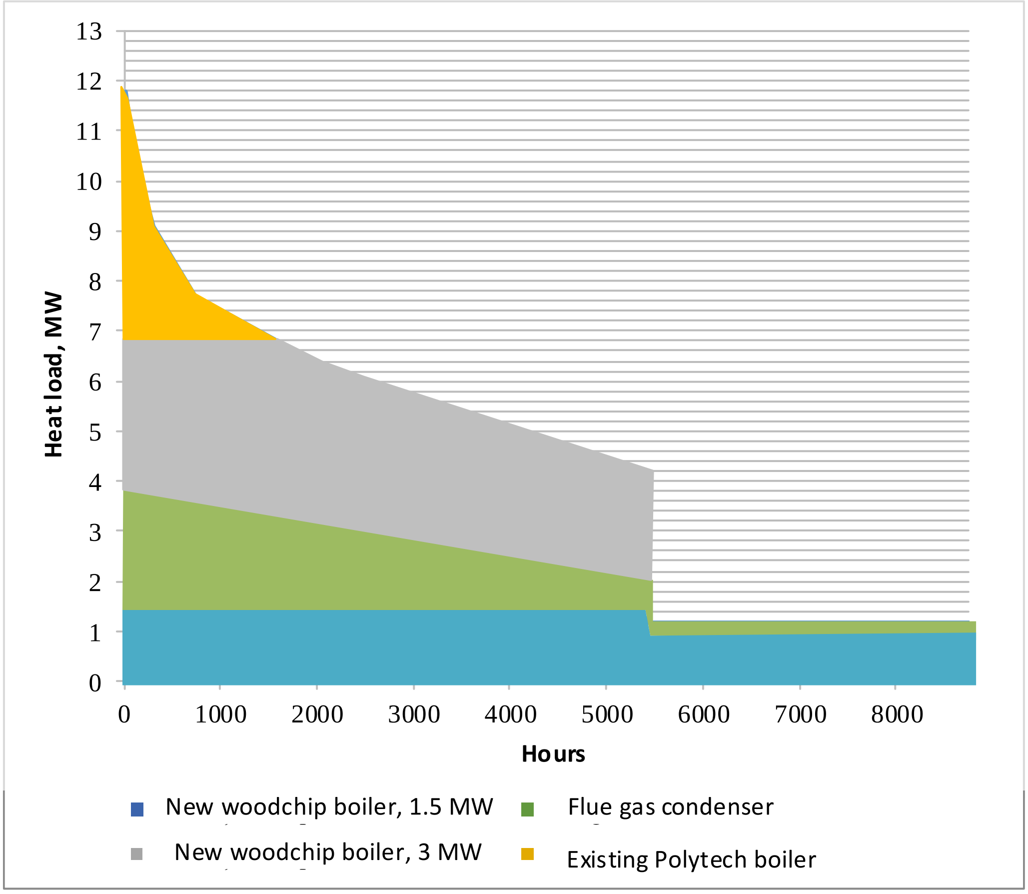


Fig. 3.1.25.Distribution of heat load in Scenario 2

Scenario 3 - Installing a new woodchip boiler with flue gas condenser and integrating waste heat

Taking into account the possibility of integrating waste heat and the heat production trends in Ltd. Konto, the third possible alternative for the further development of the heat supply system is the purchase of heat from Ltd. Konto to cover the base load (approximately 1 - 1.2 MW) (see Fig. 3.1.26). The remain of the heat, as in Scenario 1, would be covered by a 3.5 MW woodchip boiler and flue gas condenser.

In this scenario, DH is assumed to operate at a reduced temperature and heat consumption increases by about 1000 MWh (same as in Scenario 2).

In the assessment of the alternative, it is assumed that part of the heat supplied will be recovered by the company from the drying process and, if necessary, additionally heated by the supply flow of Companie`s boiler house. Such integration of excess heat would increase overall heat production efficiency and reduce heat costs. The scenario assumes that the Gulbene DH would gradually lower the temperature of the heating network, and that these heat surpluses could be used more efficiently, requiring only minimal heating of the heat carrier. In order to determine more precisely the potential for heat recovery from the wood drying process, the company should conduct a detailed energy audit.

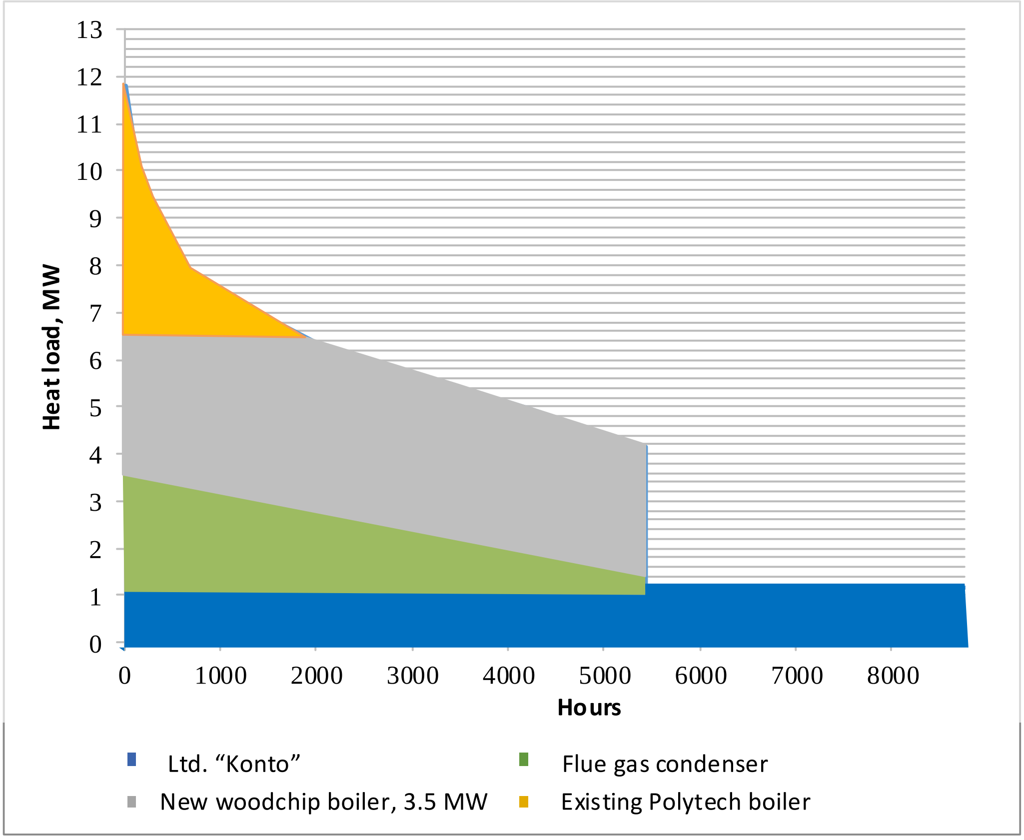


Fig. 3.1.25.Distribution of heat load in Scenario 3

3.1.5. Cost and benefit analyses

All scenarios assume a slight increase in heat consumption due to new consumers. In lower temperature scenarios, it is assumed that heat losses and total heat output will decrease.

Electricity consumption in each of the alternatives is determined by analyzing the specific electricity consumption indicator for the amount of heat produced. When installing new woodchip boilers it is assumed that the specific electricity consumption will decrease from the existing 35 kWh/MWh to 25 kWh/MWh. Conversely, lowering the temperature in the grid may slightly increase the electricity consumption for transmission, which means that in these scenarios the specific consumption is assumed higher - 30 kWh/MWh of heat produced.

The input values, assumptions and calculated results of the 3 technical scenarios proposed for the Gulbene DH development are summarized in the table below.

Table 3.1.5. Overview of analyzed development scenarios

	Existing situation	Scenario 1	Scenario 2	Scenario 3
Temperature curve	90/60	90/60	70/45	70/45

Installed capacity of boilers, MW	10.5	10.5	9.5	8.5
Installed capacity of flue gas condenser, MW	n/a	1,5	2,4	2,2
Heat consumption, MWh per year	24523	25523	25523	25523
Produced heat in boiler house, MWh per year	9480	31307	30267	20683
Heat losses, MWh per year	6014	6014	4745	4745
Purchased heat, MWh per year	21056	n/a	n/a	9584
Power consumption of boiler house, MWh per year	329	783	908	620
Consumed solar power, MWh	n/a	162	162	n/a

An important factor influencing the choice of the most suitable alternative is the amount of investment required. The Fig. below shows the specific costs of the projects implemented in Latvia for the modernization of the boiler house of different capacities (the cost includes the equipment of the boiler, installation and installation). It can be seen that the cost of the same power boilers can be very different. To determine the cost of Gulbene DH new boilers, the regression equation shown in Fig. 3.1.29 is used.

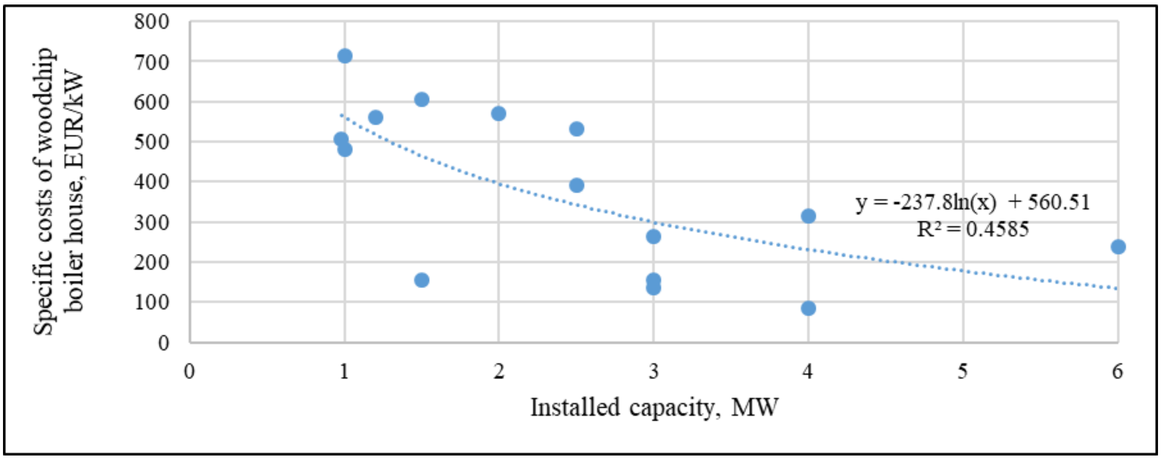


Fig. 3.1.29 Specific costs of woodchip boilers, materials and installation depending on boiler capacity

The cost of the flue gas condenser is assumed to be 100,000 EUR/MW of installed capacity based on the cost of previous projects. The cost analysis also includes the cost of maintaining the flue gas condenser (electricity, NaOH and servicing costs), which is slightly different for flue gas condensers of different capacities.

Table 3.1.6. Assumptions used in the cost/benefit analyses

Assumption	Value
Costs of automated heating unit construction, EUR / heating unit	6000
Length of new heat pipes, m	681
Costs of heat pipe installation, EUR/m	250
Thermal storage tank costs, EUR/m³	900
Specific costs of PV panels, EUR/kW	1000
Price of woodchips, EUR/m³	12
Heat tariff for purchased heat from CHP plant, EUR/MWh	25
Estimated heat tariff for purchased heat from Ltd. Konto, EUR/MWh	22
Power tariff, EUR/MWh	130

The calculation assumes that to adapt to the lower temperature curve it would be necessary to adjust the heating units in the building (replacement of pumps and heat exchangers, installation of additional valves, installation of pumping stations, etc.). These investments cannot be identified without the preparation of a specific technical project. In the long term, when planning a transition to a lower temperature schedule, they may be included in the heating pipeline or the reconstruction of the heating units. Therefore, the current cost analysis assumes that 30 buildings would require refurbishment of heating units. In order to connect new customers, construction of new heating pipelines would be necessary (681 m running length with an average pipeline diameter of 70 mm). Eligible specific investments and assumptions are summarized in the table below.

The calculation assumes that the purchased heat tariff from the CHP plant is 25 EUR/MWh, but in the 3rd scenario the purchased heat tariff is estimated slightly lower. This is due to reason that Ltd. Konto will be able to recover part of the heat from the drying process, thus making the overall heat production efficiency and more cost-effective.

Table 3.1.7 summarizes the results of the cost-benefit analysis. For each scenario, total investments, production costs (fuel, electricity and flue gas condenser operating costs), staff costs, other costs and profit share are identified. For each scenario, the specific costs of heat for the amount of heat sold are determined.

Table 3.1.7 shows that the lowest specific heat production costs under the respective assumptions are in Scenario 3, when part of the heat energy is purchased from SIA Konto. In none of the development scenarios analyzed does the total cost exceed the existing heat cost.

Table 3.1.7 Results of cost/benefit analyses

	Existing situation	Scen. 1	Scen. 2	Scen. 3
Installed boiler capacity, MW	n/a	1.5+3.5	1.5+3	3.5
Volume of accumulation tank, m^3	n/a	10	10	10
Flue gas condenser capacity, MW	n/a	1.5	2.4	2.2
Length of new heating networks, m	n/a	681	681	681
Investments, thous. EUR per year	**n/a**	**3516**	**3486**	**2675**
Boiler equipment and installation costs, thous. EUR	n/a	3000	2700	2100
Accumulation tank cost, thous. EUR	n/a	9	9	9
Flue gas condenser costs, thous. EUR	n/a	150	240	216
Heating network construction costs, thous. EUR	n/a	170	170	170
Construction and adjustment of automatic heat-ing units, thous. EUR	n/a	n/a	180	180
Solar power plant investments, thous. EUR	n/a	187	187	n/a
Production costs, thous. EUR per year	**750**	**613**	**584**	**631**
Cost of fuel, thous. EUR per year	181	520	464	318
Cost of purchased heat, thous. EUR per year	526	n/a	n/a	211
Electricity costs, thous. EUR per year	43	81	97	81
Maintenance costs of flue gas condenser, thous, EUR per year	n/a	13	23	21
Personnel costs, thousand EUR per year	14 4	17 3	17 3	14 4
Number of employees	10	12	12	10
Working hours, months per year	12	12	12	12
Average salary, EUR / month or VSAOI	1200	1200	1200	1200
Investment costs, thous. EUR per year	n/a	176	174	134
Duration of equipment, years	n/a	20	20	20
Other costs and profit share, thous. EUR per year	47 2	47 2	472	47 2
Total maintenance costs, thous. EUR	1366	1434	1403	1381
Specific cost of heat sold, EUR / MWh	55.71	56.18	54.96	54.09

3.1.6. SWOT and risk analyses

To evaluate other factors affecting the development of the heating system, a SWOT assessment has been carried out for each of the scenarios.

The main strengths of Scenario 1 are lower investment costs. Weaknesses, in turn, are associated with high heat losses and fuel costs. The weak point in all analyzed scenarios is the complex heat and storage system adjustment process, which requires careful system monitoring. In turn, the possibility of attracting external financing for the construction of heating systems to promote the development of a common heating system could be considered. The threat identified is the increase in woodchip costs, the reluctance of new consumers to connect to DH when it requires high investment, and the incompetence of designers to harmonize the system.

Table 3.1.8. SWOT analyses for Scenario 1

Strengths	Weaknesses
Lower investment costs Higher share of renewable energy sources Independent heat production High boiler house efficiency	Higher heat losses Higher fuel costs Higher staff costs Adjustment of the accumulation system
Opportunities	**Threats**
Attracting external financing	Increase in woodchip costs Consumers' reluctance to connect to DH Solar system misalignment

The strengths of Scenario 2 are the higher overall efficiency of the heat supply system, as heat transfer losses are reduced and the flue gas condenser operates more efficiently. The weaknesses of the scenario are the higher investment costs associated with adapting consumers to the reduced temperature schedule. The scenario has the potential to attract European Union funding and further lower the temperature of the heat carrier in the case of energy efficient buildings. Potential increases in fuel prices and the designers' incompetence to adjust system operation to lower temperatures are identified as threats.

Table 3.1.9. SWOT analyses for Scenario 2

Strengths	Weaknesses
Reduced heat transmission losses Higher energy efficiency of the overall system	Higher staff costs Adjustment of the accumulation system Customizing consumers to lower temperatures
Opportunities	**Threats**
Attracting external financing Further lowering of the heat carrier temperature	Increase in woodchip costs Consumers' reluctance to connect to DH Solar system misalignment Lack of experience of designers in adjusting low temperature system to DH

The strengths of Scenario 3 are lower specific heat costs, lower investment and labour costs, as well as higher overall system efficiency. The main weaknesses and threats are related to the cooperation with the company, because it is necessary to develop a clear model of cooperation.

Table 3.1.10 SWOT analyses for Scenario 3

Strengths	Weaknesses
Lowest heat costs Reduced heat transmission losses Higher energy efficiency of the overall system	More complex organization of heat supply
Opportunities	**Threats**
Attracting European Union funding Development of cooperation model between heat supply participants.	Increase in woodchip costs Consumers' reluctance to connect to DH Business interruption Lack of experience of designers in adjusting low temperature system to DH

A simplified risk analysis is provided in Table 3.1.11, which analyzes 6 different risks. Risks have a different impact on each of the analyzed scenarios, which are rated high, medium or low.

Table 3.1.11 Risk analysis

Risk	Probability	Impact	Actions to eliminate the risk
Consumer transition to individual heat supply	Scen 1 -average Scen 2-average Scen 3-low	High	Ensuring cost efficiency of DH to minimize heat tariff; Informing consumers about the operation and costs of DH;
New consumers' hesitation to join DH	Scen 1 -average Scen 2- average Scen 3- low	Average	Informing consumers about the operation and costs of DH; Grants for the construction of heating systems
Increase in wood fuel prices	High	Scen 1 -High Scen 2 -Average Scen 3-Average	Increase DH performance to minimize fuel consumption
Investment shortage	High	Scen 1- High Scen 2-High Scen 3-Average	Mobilization of Structural Funds
Inefficient management of heat production and transmission	Average	High	Regular monitoring of DH system performance; Continuous system performance improvement
Shortage of labour	Average	Average	Maximum automation of heat production

Consumers' switching to individual heat supply or the reluctance of new consumers to connect to DH have been identified as high probability risks as it would result in a higher heat tariff. These risks can be mitigated by ensuring cost-effective operation of DH, reducing heat tariffs as much as possible, and informing consumers of the potential benefits of joining DH. Other high probability risks are related to the increase of wood fuel costs and lack of investments for the modernization of the boiler house. Continuous monitoring and periodic evaluation of DH performance (boiler efficiency, heat carrier temperature, heat loss, etc.) is required to prevent the risk of heat generation and transmission equipment errors and maximizing efficiency. As medium risk labour shortage is identified, which can be eliminated by maximum automation of heat production and transmission.

Conclusions and recommendations

The results of the cost-benefit analysis show that the lowest specific heat costs in Gulbene DH can be achieved in a low-temperature scenario where the base load is covered by the wood processing company. The remain of the heat would be covered by a 3.5 MW wood chip boiler and flue gas condenser. The specific heat costs in this scenario amount to 51.61 EUR/MWh, and the total investment - 1.4 mln. EUR. In the assessment of the alternative, it is assumed that part of the heat supplied will be recovered by the company from the drying process and, if necessary, additionally heated by a supply flow. Such integration of surplus heat would increase overall heat production efficiency and reduce heat costs.

Reducing the supply flow temperature of the heating networks to 70°C and proper control of the return flow would reduce the heat transmission losses in Gulbene by 1300 MWh per year, reaching 16% of heat losses from the produced heat energy. With the existing heating tariff, this would save more than € 70,000 a year. Such a transition is possible in the long term by analyzing the possibility of lowering the temperature in the housing estates of the insulated buildings by performing a thorough analysis of the flow and return flow temperature and adjusting the consumer heating units.

In order to further ensure the sustainable provision of DH services in the City of Gulbene, the municipality must clearly define ownership and contractual obligations, separating production, transmission and distribution systems. There are at least three different strategic directions for development: DH for shared management, DH is fully transferred to a private contractor, and DH is managed by the municipality.

The Gulbene city DH shall improve the monitoring system and continuously evaluate the key performance indicators (including supply and return temperatures). Lowering the temperature in Gulbene should be done in the long term - gradually identifying small districts where low temperature DH divisions can be created. Reducing the temperature of the DH should be taken into account when renovating buildings and their heating systems so that their heating surface is suitable for a reduced flow temperature.

When constructing new heat pipelines, it is necessary to carefully choose the optimum pipeline diameter, because unjustifiably enlarged pipeline diameters are one of the main causes of high heat loss. The average diameter of the pipelines in Gulbene is 146 mm.

3.2. Stari in Dauksti parish

3.2.1. Assessment of the current situation

At present, there are three 0.5 MW firewood boilers installed in Staru village, Dauksti parish, for thermal energy production (see Fig. 3.2.1). During the heating season only one of the boilers is mainly operating. Also, the heat load graph (Fig. 3.2.2) shows that the maximum output is close to 0.5 MW.

Fig. 3.2.1 Wood boilers installed in the boiler house

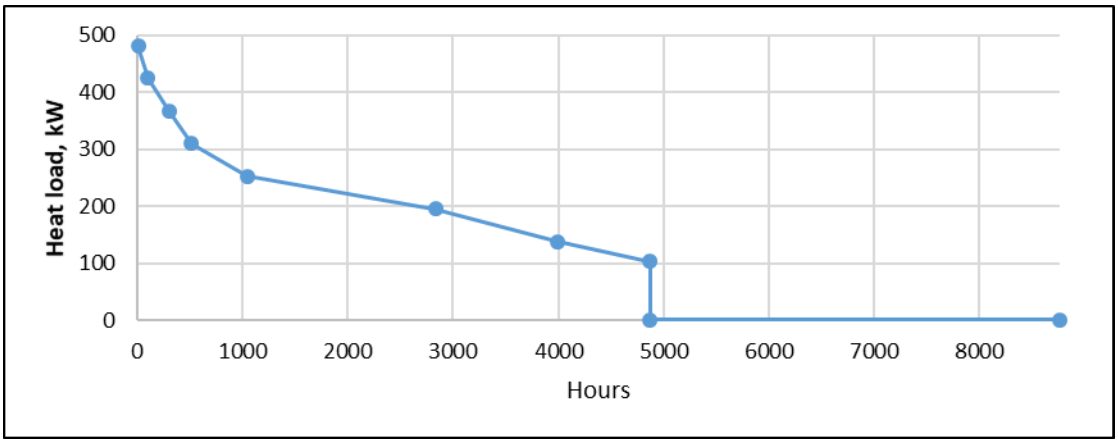


Fig. 3.2.2 Heat load graph of Stari village

The DH performance analysis uses data from the 2018/2019 heating season, which is the only period for which information on the amount of heat produced in the boiler house and consumed in each building is available. Around 900 MWh of heat was produced in the boiler house the particular heating season.

Analyzing heat carrier temperature data (Fig. 3.2.3), correlation of supply and return flow temperature with the average outdoor temperature was determined. Using the obtained regression equations, the boiler house temperature graph is constructed (Fig. 3.2.4).

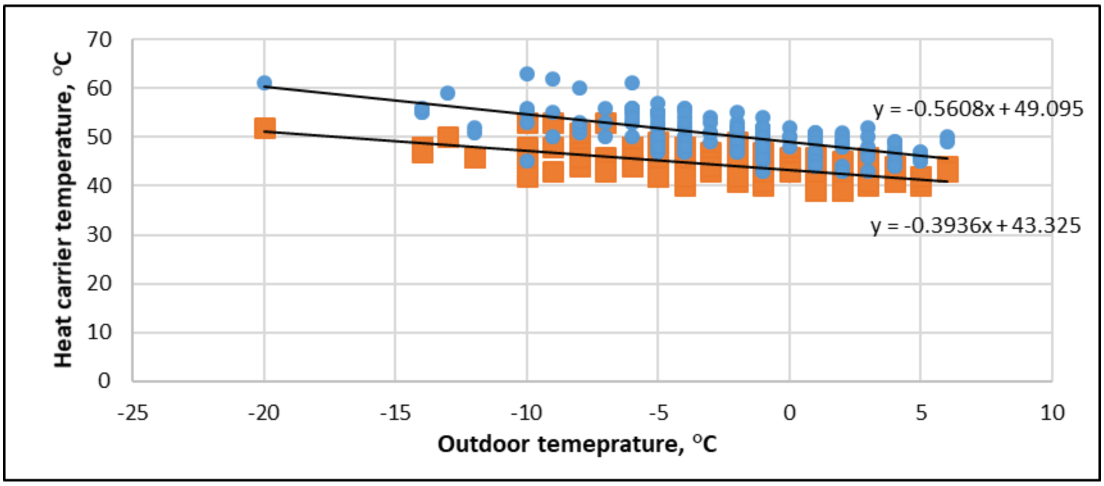


Fig. 3.2.3 Correlation of supply and return flow with outdoor air temperature

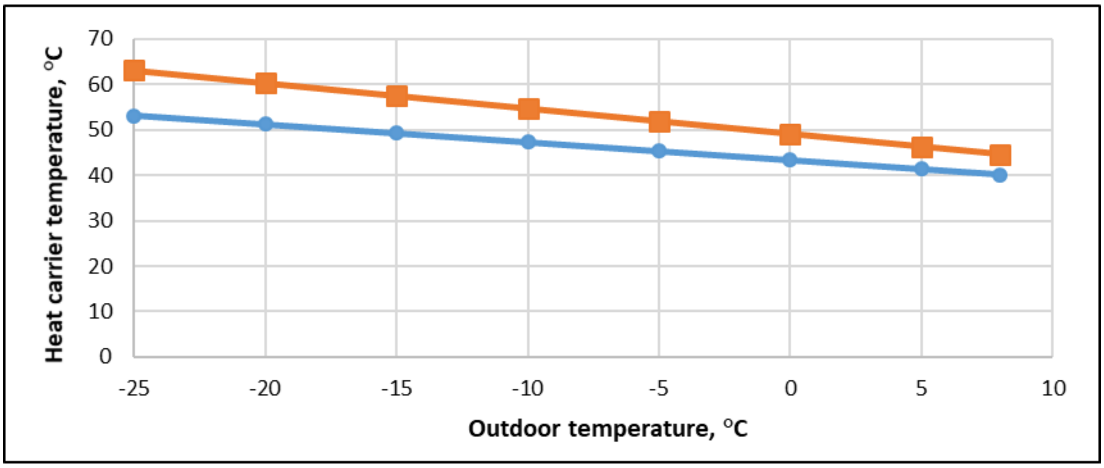


Fig. 3.2.4. Modelled boiler house temperature graph

Fig. 3.2.4 shows that the boiler house is already operating with a reduced temperature regime and the maximum flow temperature at -25 degrees reaches 63°C. It can also be seen that the difference between the flow and return temperature is very small - on average 6°C, which is mainly influenced by the configuration of the consumer heating systems and heating units. In order to improve the performance of the heating system and to transfer the maximum amount of heat to the consumers, the temperature difference between the supply and return flow should be as high as possible.

The layout of the DH heating pipeline is shown in Fig. 3.2.5. The total length of the heating pipes is 561 m (supply). The average diameter of the pipes is 85 mm. Applying the total amount of heat consumed to the length of the heating pipeline, the average heat consumption density is determined, which is 1.53 MWh/m in the Stari DH. According to the installed meters, the heat losses in the heating pipeline are insignificant - about 36 MWh per year or 4% of the heat produced.

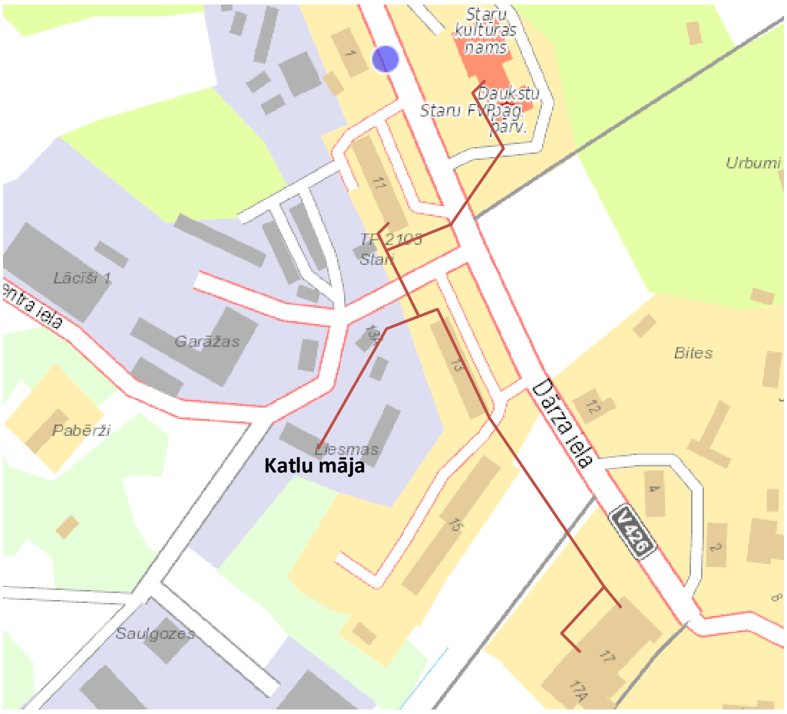


Fig. 3.2.5 The location of the heating pipes in the Stari village

An important indicator for heat production is the amount of electricity consumed for the operation of boilers and heat transfer. Fig. 3.2.6. shows that the average monthly electricity consumption is 3.3 MWh, but it is significantly influenced by the amount of heat produced. Consequently, the specific electricity consumption indicator for the amount of thermal energy produced is 25.7 kWh/MWh $_{prod.\ heat}$ per year.

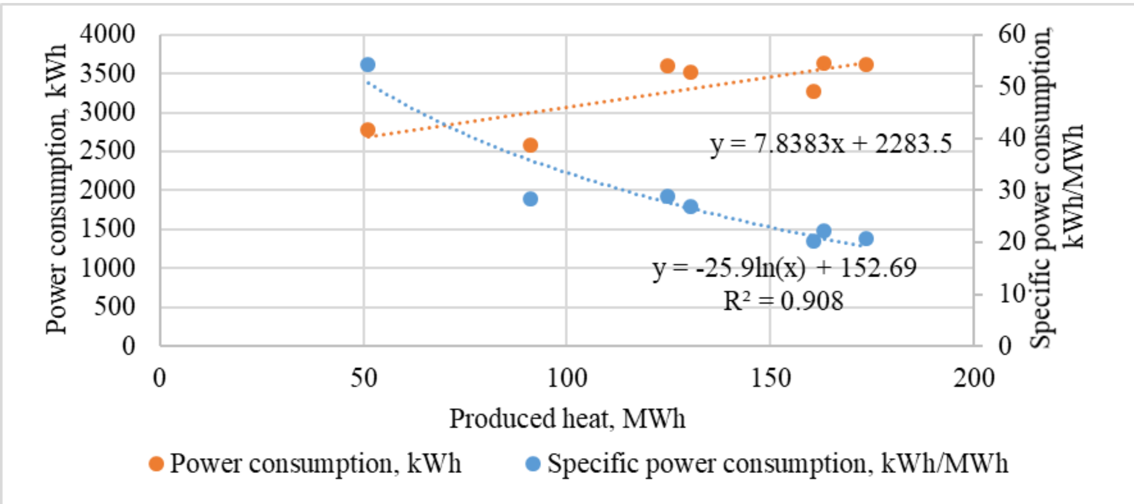


Fig. 3.2.6. Correlation of Electricity Consumption and Specific Electricity Consumption with the generated heat

Stari DH is considered to be a small system, as only 5 consumers are connected to it - three apartment buildings, the parish administration building and the cultural center. The total heated area is 5232 m². Most of the thermal energy is consumed by apartment buildings (see Fig. 3.2.7). Hot water is not prepared in this system.

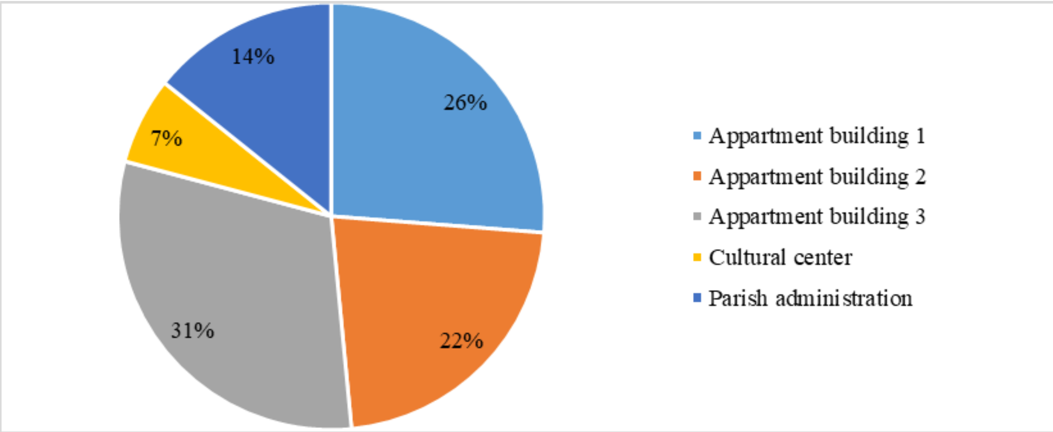


Fig. 3.2.7 Distribution of heat consumption by buildings

An important indicator for measuring consumer efficiency is the specific heat consumption per heated area. Fig. 3.2.8 shows the specific heat consumption of each building in the 2018/2019 heating season, as well as the normalized value under standard climatic conditions. The average specific heat consumption for space heating in residential buildings is 157 kWh/m² per year (adjusted 186 kWh/m² per year), while the consumption of municipal buildings is lower (average adjusted 100 kWh/m² per year). All buildings have heating units with direct connection to the boiler house heat carrier.

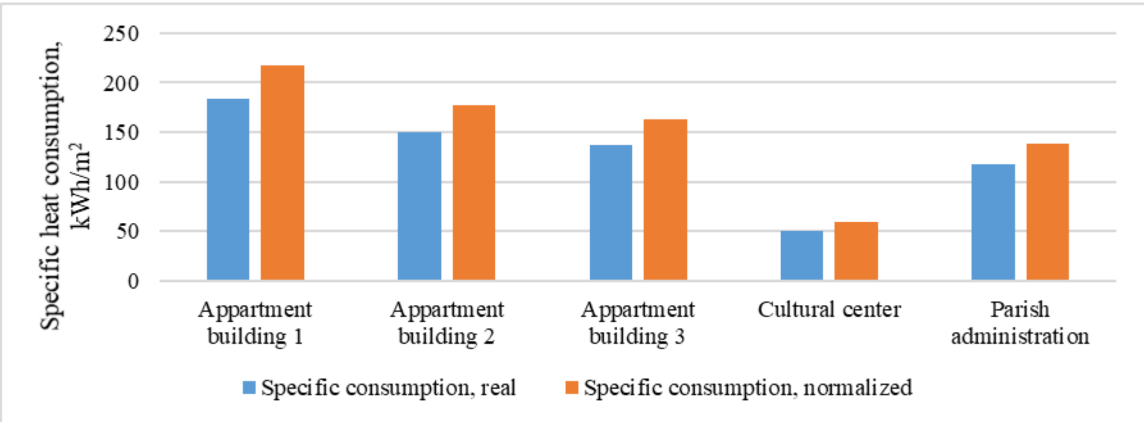


Fig. 3.2.8 Specific heat consumption of consumers (real and corrected)

Currently, the Stari DH has the highest heat tariff if comparing to other DH systems in Gulbene district 74,19 EUR/MWh without VAT. The main cost components are fuel costs (49%) and labor costs (38%).

3.2.2. Description of long-term transformation paths, consumption forecasts and technical alternatives

In order to make the Stari DH more cost and resource efficient, it is necessary to modernize the wood-fired boiler house. In order to reduce labour costs, it is recommended to install an automatically controlled boiler using wood chips or wood pellets as fuel. In order to smooth the operation of the boiler and reduce the effect of peak load, it is necessary to equip the boiler with a heat storage tank. When upgrading a boiler house, it is also necessary to install more efficient circulation pumps in order to reduce electricity consumption for heat transfer.

One of the main factors influencing the operation of the system is the heat consumption. Analyzing strategic development directions, two different development scenarios are considered - system expansion scenario when new consumers are connected and energy efficiency scenario when apartment buildings are insulated and total heat consumption is reduced. Fig. 3.2.9 shows simulated heat load graphs for different development scenarios.

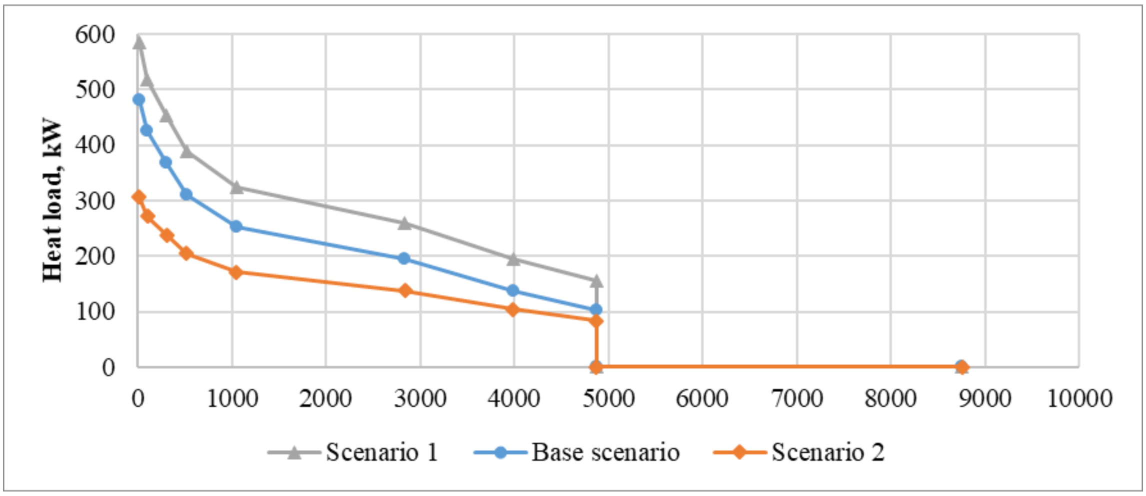


Fig. 3.2.9 Heat load graphs for analyzed scenarios

3.2.2.1. Scenario 1

In the first scenario, the consumption of heat is assumed to increase as five nearby apartment buildings are connected to the DH (see Fig. 3.2.10). The total heating area of new consumers would be 1929 m². Assuming that these buildings have a specific heating consumption of approximately 150 kWh/m², the total heat consumption of these buildings would amount to an additional 289 MWh per year.

Fig. 3.2.10 Placement of existing and potential DH users

This scenario assumes that the boiler house is equipped with an automatic wood-fired boiler with a capacity of 500 kW, equipped with moving grates, a fuel feed conveyor and an accumulation tank. To connect the buildings to the DH, it would be necessary to construct new heating pipelines with a total length of 202 m (downstream) and an average pipeline diameter of 60-50 mm. The average heat consumption density of the system would remain almost unchanged at 1.50 MWh/m. Currently, the buildings have individual wood heating, so it is necessary to build internal heating systems with heaters and heating units. Cost assumptions used for further benefit-cost analysis are summarized in Table 3.2.1.

3.2.2.2. Scenario 2

Scenario 2 assumes that three DH-connected apartment buildings will be insulated and that total heat consumption will decrease. Further calculation of benefits and costs assumes that the specific heat consumption of these buildings for heating from the existing one would decrease to 90 kWh/m^2, which is in accordance with Cabinet of Ministers Regulation No. 383 "Requirements for reconstruction and renovation of buildings". As a result, the total heat consumption in the DH would be reduced to 575 MWh. In this case, the heat consumption density would drop to 1.02 MWh/m and the maximum peak load would be 300 kW. In this scenario, it is assumed that an automatic pellet boiler with a capacity of 250 kW with an accumulation tank was installed in the boiler house.

In both scenarios, it is assumed that the current flow temperature will be maintained (65°C maximum), but as part of the optimization and management of the system, the flow and return flow temperatures would increase to at least 10-15°C on average.

Table 3.2.1 Specific cost values used in the calculations

Assumption	Costs
Building internal heating system, EUR/m²	26
Automated heating unit construction, EUR/heating unit	6000
Construction of heating network, EUR/m	250
Pellet boiler and its installation, EUR/kW	310
Automatic wood chip boiler and its installation, EUR/kW	600
Heat storage tank, EUR/m³	900

3.2.3. Cost-benefit analysis

A comparison of the defined development scenarios is given in Table 3.2.2. Potential investments, production costs (fuel and electricity costs), labour costs and other related costs are taken into account when assessing different development alternatives.

The cost analysis makes assumptions about the performance of pellets and woodchip boilers - efficiency and specific electricity consumption, based on previously implemented examples of DH modernization.

In the energy efficiency scenario, when a pellet boiler with an accumulation tank is installed, the potential investment amounts to about 112 thousand EUR. In the DH expansion scenario, additional investments result from the construction of a heating network and an automated woodchip boiler (total EUR 350 thousand). The cost analysis also includes the heating system automation, but excludes the cost of the internal heating system of new consumers. It would reach around 50,154 EUR, which would be allocated to the heat consumers and not to the heat producer.

In both of these scenarios, labour costs are significantly reduced. Scenario 2 assumes that the pellet boiler will be fully automated, requiring only one part-time worker to service it. In the case of woodchip boiler house, it is assumed that it will be necessary to employ two full-time employees. The cost-benefit analysis does not take into account the social factors involved in reducing workload. The cost analysis carried out shows that in both development scenarios, the assumptions made result in lower costs than the existing boiler house.

Table 3.2.2 Cost-benefit analysis of the proposed alternatives

	Existing DH	Scenario 1	Scenario 2
Installed boiler capacity, kW	n/a	500	250
Volume of heat storage tank, m^3	n/a	10	5
Heat produced, MWh per year	894	1244	612
Heat losses, MWh per year	37	49	37
Heat sold, MWh per year	858	1147	575
Investments, EUR	**n/a**	**293240**	**112000**
Boiler equipment and installation costs, EUR	n/a	300000	77500
Accumulation tank cost, EUR	n/a	9000	4500
Heating network construction costs, EUR	n/a	50500	n/a
Installation of automatic heating units, EUR	n/a	60000	30000
Production costs, EUR per year	**34716**	**26853**	**29483**
Type of fuel	Firewood	Wood chips	Wood pellets
Boiler efficiency	0.6	0.85	0.9
Price of fuel	27 EUR/m^3	12 EUR/m^3	182 EUR/t
Fuel consumption, MWh per year	1490	1463	680
Calorific value of fuel	1.25 MWh/m^3	0.71 MWh/m^3	4.3 MWh/t
Fuel consumption (in units)	1194 m^3	2061 m^3	158 t
Total fuel costs, EUR	32105	24734	28788
Specific power consumption, kWh/MWh_{heat}	25.7	15	10
Electricity consumed, MWh per year	23	19	6
Electricity tariff, EUR / MWh	114	114	114
Electricity costs, EUR per year	2611	2119	695
Labour costs, EUR per year	**2 47 73**	**12 387**	**30 97**
Number of employees	4	2	1
Working period, months	7	7	7
Average salary, EUR/month	885	885	442
Investment costs, EUR per year	**n/a**	**20 975**	**5 600**
Duration of equipment, years	n/a	20	20
Other costs, EUR per year	**54 18**	**54 18**	**54 18**
Total maintenance costs	**64907**	**65632**	**43598**
Specific cost of heat sold, EUR/MWh	**75.65**	**57.21**	**75.76**

3.2.4. SWOT and Risk Analysis

The main strengths of Scenario 1 are the lower fuel costs resulting in the lower heating tariff. Weaknesses, on the other hand, are related to high investments in woodchip boiler, heating network construction, as well as investments necessary for the construction of new consumer heating systems. Alternatively, municipal grants for the construction of heating systems to promote the development of a common heating system can be considered. The threat identified is the increase in woodchip costs, the reluctance of new consumers to connect DH when it requires high investment, and the lack of qualified staff.

Table 3.2.3 SWOT analysis for Scenario 1

Strengths	Weaknesses
Lower fuel costs Lower heat tariff	Higher system modernization investments Consumers need to invest in heating system construction Complicated DH and accumulation system alignment process
Opportunities	**Threats**
Attracting European Union funding Municipal support to consumers to improve the heating system Use of cheaper plastic pipes for the new heating pipeline Increases in woodchip costs	Consumers' reluctance to join DH Lack of qualified staff

The strengths of Scenario 2 are the higher overall efficiency of the heat supply system as the heat consumption is reduced and the boiler house operates with high efficiency. This scenario has relatively lower investment costs. The insulation of buildings would also improve the quality of the environment.

The weaknesses of the scenario are the high fuel costs resulting from a relatively higher heat tariff. The weaknesses include the complex heat and storage system setup process, which requires careful system monitoring. There is potential of the energy efficiency scenario to attract external funding and further lower the temperature of the heat carrier in the case of energy efficient buildings. Potential increases in pellet prices and a shortage of skilled workers are identified as threats.

Table 3.2.4. SWOT Analysis for Scenario 2

Strengths	Weaknesses
Higher energy efficiency of the overall system Reduced labour costs Lower investment costs Improved environmental quality	Higher fuel costs Higher heat tariff Complicated DH and accumulation system alignment process
Opportunities	**Threats**
Attracting external funding Further reduction of heat carrier temperature	Increase in pellet costs Lack of qualified staff

A simplified risk analysis is provided in Table 3.2.5, which analyzes 6 different risks. Risks have a different impact on each of the analyzed scenarios, which are rated high, medium or low.

Consumers' switching to individual heat supply or the reluctance of new consumers to connect to DH have been identified as high probability risks as it would result in a higher heat tariff. These risks can be mitigated by ensuring cost-effective operation of DH, reducing heat tariffs as much as possible, and informing consumers of the potential benefits of joining DH. Other high probability risks are related to the increase of wood fuel costs and lack of investments for the modernization of the boiler house. Continuous monitoring and periodic evaluation of DH performance (boiler efficiency, heat carrier temperature, heat loss, etc.) is required to prevent the risk of heat generation and transmission equipment errors and maximizing efficiency. As medium risk labor shortage is identified, which can be eliminated by maximum automation of heat production and transmission.

Table 3.2.5. Risk analyses

Risk	Probability	Impact		Actions to eliminate risk
		Scenario 2	Scenario 1	
Consumer transition to individual heat supply	High	High	Medium	Ensuring cost efficiency of DH to minimize heat tariff; Informing consumers about the operation and costs of DH;
The reluctance of new consumers to join DH	High	Low	High	Informing consumers about the operation and costs of DH; Grants for the construction of heating systems
Increase in wood fuel prices	High	High	High	Increase DH performance to minimize fuel consumption
Lack of financial resources	High	Medium	High	Mobilization of Structural Funds
Inefficient management of heat production and transmission	Medium	High	Medium	Regular monitoring of DH system performance; Continuous system performance improvement
Shortage of skilled labour	Medium	Medium	Medium	Maximum automation of heat production

Conclusions and recommendations

The DH system of Stari parish is already running at a lower temperature and there is minimal heat loss in the system. The specific heating costs of DH would be significantly reduced by automated installation of woodchip or pellet boiler and connection of new consumers, however, the estimated cost of building internal heating system is more than 50 thousand. EUR.

One of the goals for increasing energy efficiency is to increase the difference between the supply and return temperatures. This can be achieved by changing the heat regulation conditions, installing automated heating units that are adapted to the existing temperature schedule or improving the efficiency of consumer heating systems.

3.3. Litene parish

3.3.1. Assessment of the current situation

Currently, 0.5 MW pellet boiler is installed in the village of Litene to produce thermal energy and providing heat to five buildings. The doverview of the DH heating network is shown below.

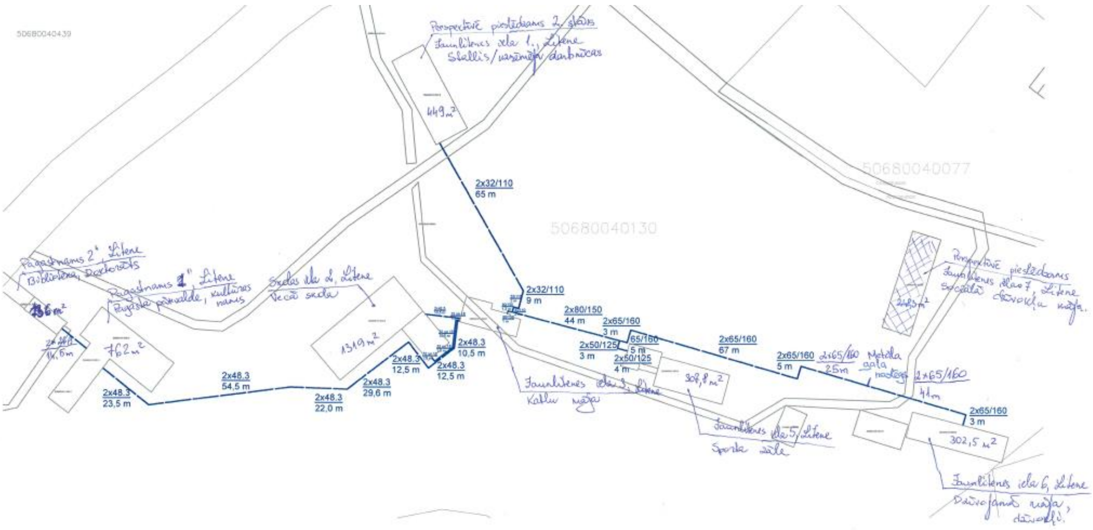


Fig. 3.3.1 DH heating network of Litene village

Litene village's DH system does not have meters installed for the accounting of heat produced and consumed. The produced thermal energy can only be determined by the consumption of fuel (pellets). The calculation of the heat produced assumes a minimum combustion heat of pellets of 4.3 kWh / kg and a boiler efficiency of 0.90. The boiler house produces heat only to cover space heat consumption. Fig. 3.3.2 shows the amount of heat produced in the period from 2014 to 2018 by month.

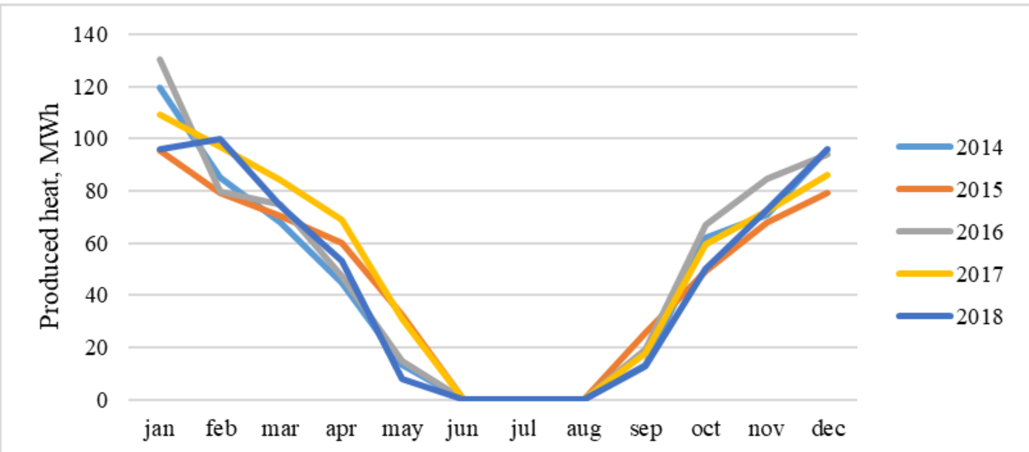


Fig. 3.3.2 Produced thermal energy in the period from 2014 to 2018

Fig. 3.3.3 compares the total amount of heat produced during the last five years. The average heat production in Litene village is 587 MWh per year.

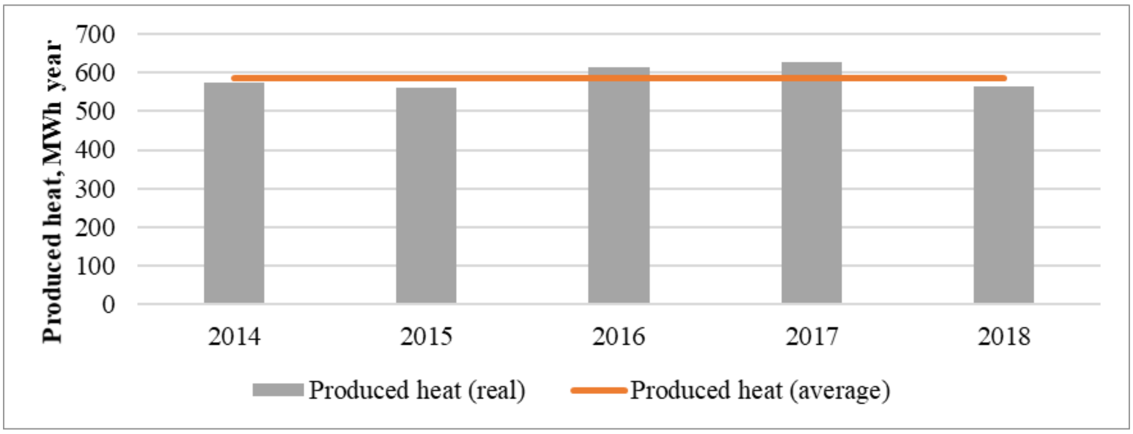


Fig. 3.3.3 Comparison of annual heat production from 2014 to 2018

Taking into account the above analysis of the heat production data and the meteorological conditions, the Litene DH heat load curve is shown in Fig. 3.3.4. It can be seen that the maximum load reaches 228 kW.

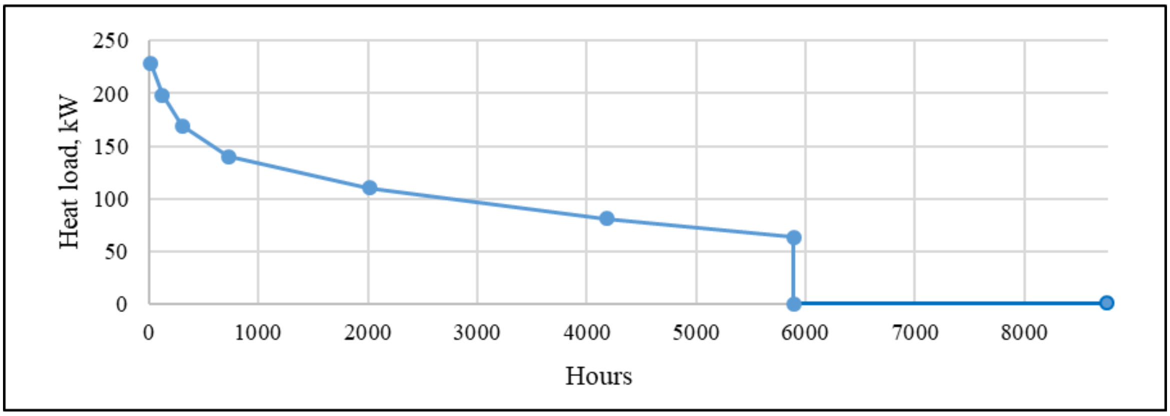


Fig. 3.3.4 Litene DH heat load graph

The heat consumption of the buildings connected to the Litene DH is not measured, therefore, it is not possible to determine the transmission heat loss. A mathematical model of heat networks has been prepared for determination of heat losses. The estimated amount of heat loss is 54 MWh or 9% of the total heat production. The flow and return temperatures of the heating networks are not recorded, so the set boiler temperature schedule 75/55 is used in the calculations.

Table 3.3.1 Input data used and calculated values

Parameter	Value
Heating area, m²	3276
Amount of thermal energy produced, MWh per year	587
Thermal losses, MWh	54
Amount of heat consumed, MWh	533
Average specific heat consumption of buildings, kWh/m² per year	163
Length of heating network, m (supply)	277
Maintained temperature curve (assumption)	75/55

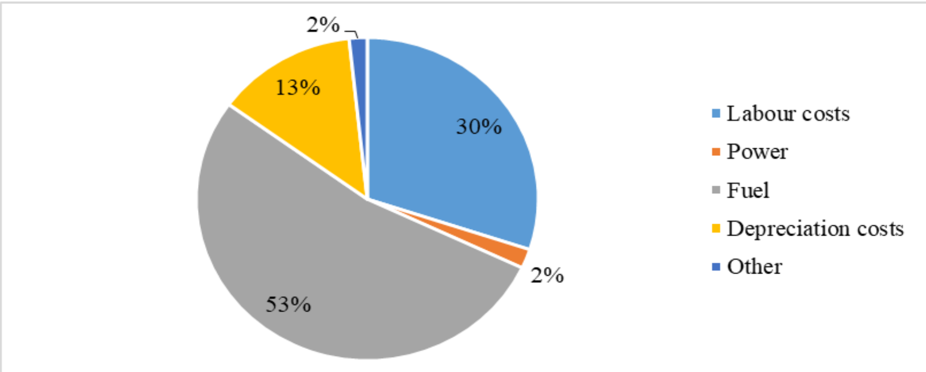


Fig. 3.3.6. DH cost allocation in Litene

The Litene DH system cost breakdown is shown in Fig. 3.3.6. It can be seen that fuel costs account for 53%, salary 30% and depreciation 13%. The heat tariff of Litene DH currently reaches 54.07 EUR/MWh excluding VAT.

3.3.2. Description of strategic development directions, forecast of changes, technical solutions and resources needed for their implementation

The main factor influencing the further development of Litene DH is the change in heat consumption. Two different heat consumption scenarios are adopted to model the future development of the system. In addition to changes in heat consumption, the reduction of heat carrier temperature is analyzed.

Scenario 1

In scenario 1, it is assumed that a nearby apartment building would be connected to the DH, which would require an additional 25 m of heating line construction, and the heating area of the stables building would be increased by 400 m². Assuming the average heating consumption of these new consumers to be similar to that of existing buildings (163 kWh/m² per year), the potential increase in heat consumption is estimated to be around 105 MWh per year.

In scenario 1, it is assumed that the flow temperature will be gradually lowered to 70°C by monitoring and optimizing the temperature of the heat carrier.

Scenario 2

Scenario 2 assumes that no new consumers are connected to the DH, but in some of the existing buildings (parish administration, doctorate, dwelling house and stable) energy efficiency measures are implemented, resulting in a specific heat consumption reduction to 90 kWh/m². In this scenario, total heat consumption is reduced by 120 MWh. A similar reduction in heat consumption would be achieved if the specific heating consumption of the school and gym is reduced from the currently adopted 163 kWh/m² to 90 kWh/m², while the consumption of other buildings remains unchanged. Scenario 2 assumes that due to increased energy efficiency of buildings it will be possible to reduce the temperature to 60°C if the internal heating systems and heaters of the buildings are not changed. The analyzed temperature graphs are shown below.

Fig. 3.3.5 shows the heat loads of the analyzed scenarios. In Scenario 1, the maximum heat load increases to almost 270 kW, but in Scenario 2 it decreases to 180 kW.

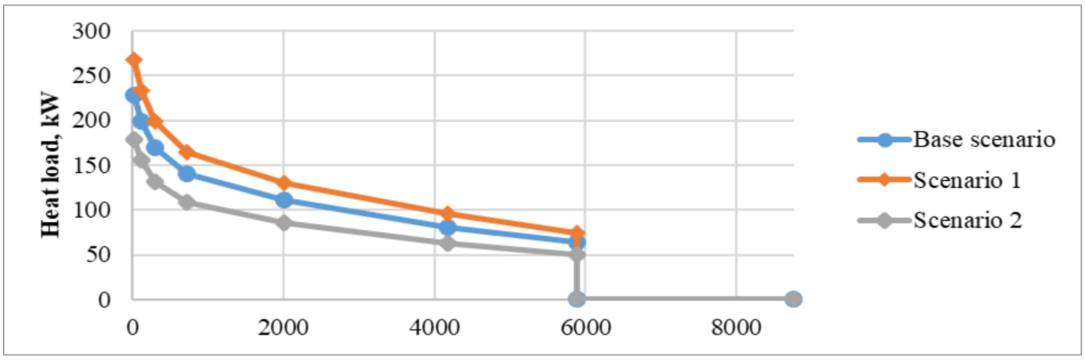


Fig.3.3.5 Differences in heat load for different scenarios

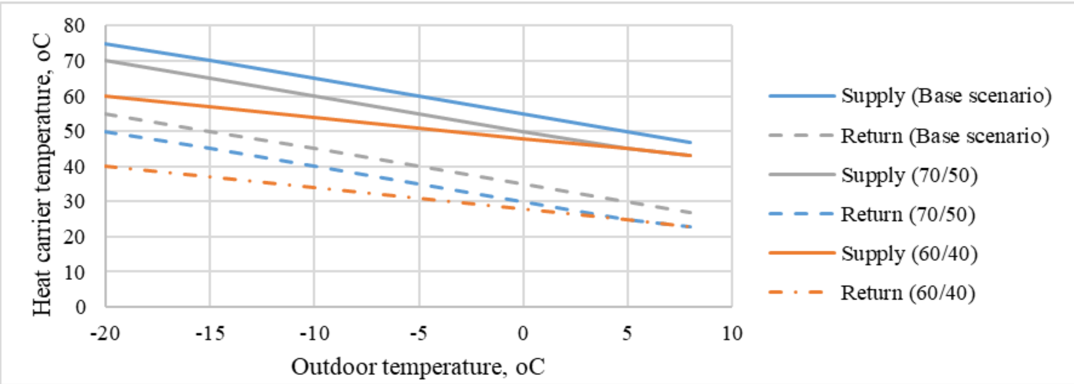


Fig. 3.3.5 Analyzed heat carrier temperature graphs

Table 3.3.2 summarizes the overview of the analyzed scenarios - input values used and calculated parameters.

Table 3.3.2 Assumptions and calculated values of the analyzed scenarios

Parameter	Base scenario	Scenario 1	Scenario 2
Temperature graph	75/55	70/50	60/40
Heating area, m²	3276	3925	3276
Average specific heat consumption, kWh/m²	163	163	126
Total consumption of buildings, MWh per year	533	639	510
Loss of thermal energy, MWh per year	54	51	45
Proportion of heat losses,%	9%	7%	8%
Total heat produced, MWh per year	587	690	556
Length of heating circuit, m	277	302	277
Consumption density of heat energy, MWh/m	2.12	2.11	1.49

Scenario analysis shows that in Scenario 2, when the heat consumption of buildings is decreasing, the density of heat energy consumption is also significantly reduced. However, the reduced heat carrier temperature allows the heat loss rate to be kept at an optimum level.

3.3.3. Cost-benefit analysis

Potential investments, production costs (fuel and electricity costs), labour costs and other related costs are taken into account when evaluating the different development alternatives, as well as the potential heat tariff. Other assumptions related to equipment costs are summarized in Table 3.3.3.

Table 3.3.3. Overview of input data and assumptions

Parameter	Value
Boiler efficiency	0.9
Automated heating unit construction, EUR heating unit	4000
Building internal heating system construction, EUR/m²	26
Heating pipeline construction, EUR/m	250
Price of pellets, EUR/t	182
Lowest combustion heat of pellets, MWh/t	4.3
Specific electricity consumption, kWh/MWh	12.2
Electricity tariff, EUR/MWh	113.55
Existing heat tariff, EUR/MWh (excluding VAT)	54.07

A cost-benefit analysis assumes that the existing boiler will be retained for heat production as it is technically in good condition and operates at optimum efficiency. In Scenario 1, the additional investment consists of constructing a new section of the heating pipeline and equipping the buildings with an internal heating system, which would in reality create costs for consumers. The main costs of Scenario 2 are related to the installation of automatic heating units. The average cost of each heating unit is 4,000 Euro. The input data values used in the calculations are summarized in Table 3.3.4. The cost-benefit analysis does not include the cost of building a consumer internal heating system of about 16.8 thousand. EUR that would be needed in Scenario 1.

Table 3.3.4. Results of a cost-benefit analysis

	Base scenario	Scenario 1	Scenario 2
Heat produced, MWh per year	587	690	458
Loss of thermal energy, MWh per year	54	51	46
Heat sold, MWh per year	533	638	413
Investments	**n/a**	**10 250**	**20 000**
Heating network construction costs, EUR	n/a	6 250	n/a
Installation of automatic heating units, EUR	n/a	4 000	20 000
Production costs, EUR per year	**28424**	**33397**	**22188**
Type of fuel	Pellets	Pellets	Pellets
Fuel consumption, MWh	652	766	509
Fuel consumption, tonnes	152	178	118
Total fuel costs, EUR	27611	32441	21554
Electricity consumed, MWh	7	8	6
Electricity tariff, EUR / MWh	114	114	114
Electricity costs	813	956	635
Staff costs, EUR per year	**1 26 21**	**1 26 21**	**1 26 21**
Number of employees	2	2	2
Working hours, months	7	7	7
Average salary, EUR/month	902	902	902
Investment costs, EUR per year	**n/a**	**513**	**10 00**
Duration of equipment, years	n/a	20	20
Other costs, EUR per year	**63 05**	**63 05**	**63 05**

Total thermal energy costs, EUR per year	47350	52835	42115
Specific cost of heat sold, EUR / MWh	88.85	82.76	102.03

Table 3.3.4 shows that in the event of a significant reduction in the heat consumption of buildings (Scenario 2), the specific heat costs increase to 102 EUR / MWh. In such a situation, it is necessary to consider the connection of new customers to the system or individual heating solutions.

3.3.4. SWOT analysis and risk analysis

The main strengths of Scenario 1 are the higher heat consumption density resulting in a lower heat tariff. Weaknesses, on the other hand, are related to investments in the construction of heating networks, as well as investments necessary for the construction of new consumer heating systems. Alternatively, municipal grants for the construction of heating systems to promote the development of a common heating system can be considered. The increase in pellet costs and the reluctance of new consumers to access DH if it requires high investments have been identified as a threat.

Table 3.3.5. SWOT analysis for Scenario 1

Strengths	**Weaknesses**
Higher heat consumption density Lower heat tariff	Consumers need to invest in heating system construction
Opportunities	**Threats**
Attracting external funding Municipal support to consumers to improve the heating system Use of cheaper plastic pipes for the new heating pipeline	Increase in pellet costs Consumers' reluctance to connect DH

The strengths of Scenario 2 are the higher overall efficiency of the heat supply system by reducing the heat consumption and heat loss of buildings. The insulation of buildings would also improve the quality of the environment. The weaknesses of the scenario are the high investment costs for installing the automated heating units, which results in a high heat tariff. The scenario has the potential to attract European Union funding and further lower the temperature of the heat carrier in the case of energy efficient buildings. Potential increases in pellet prices and lack of designers' experience in low temperature DH customization are identified as threats.

Table 3.3.6 SWOT Analysis for Scenario 2

Strengths	Weaknesses
Higher energy efficiency of the overall system Improved environmental quality	Higher heating tariff
Opportunities	**Threats**
Attracting external funding Further reducing the temperature of the heat carrier	Increase in pellet costs Lack of designers experience in low temperature DH implementation

A simplified risk analysis is provided in Table 3.3.7, which analyzes 5 different risks. Risks have a different impact on each of the analyzed scenarios, which are rated high, medium or low.

An increase in the cost of wood fuel has been identified as a high probability risk. To minimize the impact of this risk, it is necessary to ensure efficient heat production with the minimum possible fuel consumption. Consumers' switching to individual heating or the reluctance of new consumers to connect to DH has been identified as low to medium risk, as most of the connected buildings are municipal. Continuous monitoring and periodic evaluation of DH performance (boiler efficiency, heat carrier temperature, heat loss, etc.) is required to prevent the risk of heat generation and transmission equipment malfunctioning and maximizing efficiency.

Table 3.3.7 Risk analysis

Risk	Probability of risk	Impact of risk (low, medium, high)		Operational risk prevention
		Scenario 1	Scenario 2	
Consumer transition to individual heat supply	Low	High	High	Ensuring cost efficiency of DH to minimize heat tariff; Informing consumers about the operation and costs of DH;
New consumers' hesitation to join DH	Medium	Medium	Low	Informing consumers about the operation and costs of DH; Grants for the construction of heating systems
Increase in wood fuel prices	High	High	Medium	Increase DH performance to minimize fuel consumption

Investment shortage	Low	Low	Medium	Mobilization of external funds
Inefficient management of heat production and transmission	Low	Low	Medium	Regular monitoring of DH system performance; Continuous system performance improvement

Conclusions and recommendations

The future development of the Litene DH is mainly influenced by the heat consumption of existing buildings and the attraction of new consumers. In the case of a significant reduction in the thermal energy consumption of buildings, the specific heat cost increases to 102 EUR/MWh. In such a situation, it is necessary to consider the connection of new customers to the system or individual heating solutions.

Litene DH should improve the monitoring system and continuously evaluate the most important performance indicators, because at the moment it is not possible to accurately assess the supply and return flow temperature, the amount of heat produced and consumed. In order to evaluate whether it is possible to lower the flow temperature, it is necessary to evaluate the existing temperature regime, to monitor the indoor temperature of the connected buildings and to evaluate the existing heating elements.

3.4. Lejasciems parish

3.4.1. Assessment of the current situation

Currently, two wood-fired boilers with a capacity of 1 and 1.5 MW are installed in the Lejasciems DH for thermal energy production (see Fig. 3.4.1). During the heating season one of the boilers is mainly operated. The heat load graph (Fig. 3.4.2) also shows that the maximum output is close to 0.7 MW.

Fig. 3.4.1 Wood boilers with capacity of 1 and 1.5 MW installed in Lejasciems boiler house

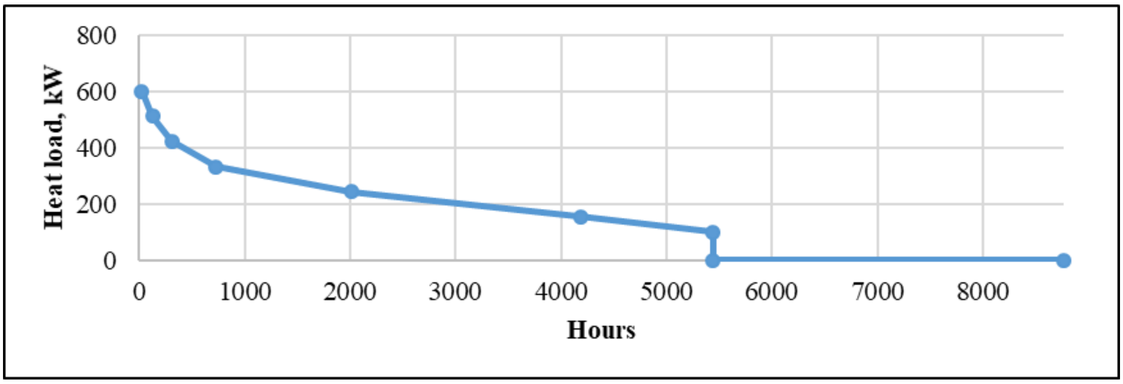


Fig. 3.4.3 Heat load of Lejasciems boiler house

The DH performance analysis uses data from the heating season 2018/2019, which is the only period for which information on the amount of heat consumed in each building is available. The amount of heat produced is determined by the fuel consumption data. During this heating season the boiler house produced about 1656 MWh of heat. Fig. 3.4.3 shows the distribution of consumed heat and heat losses by month. The main reason for the differences in the rate of heat loss could be the uncertainty in the fuel efficiency of the fuel used and the boiler.

11 buildings with a total heated area of 9587 m^2 are connected to the Lejasciems DH. Most of the heat is consumed in apartment buildings at Sakses Street and Rigas Street (42% in total), 15% is

used in kindergarten and 13% is used for heating school and gym. Hot water is not prepared in this system.

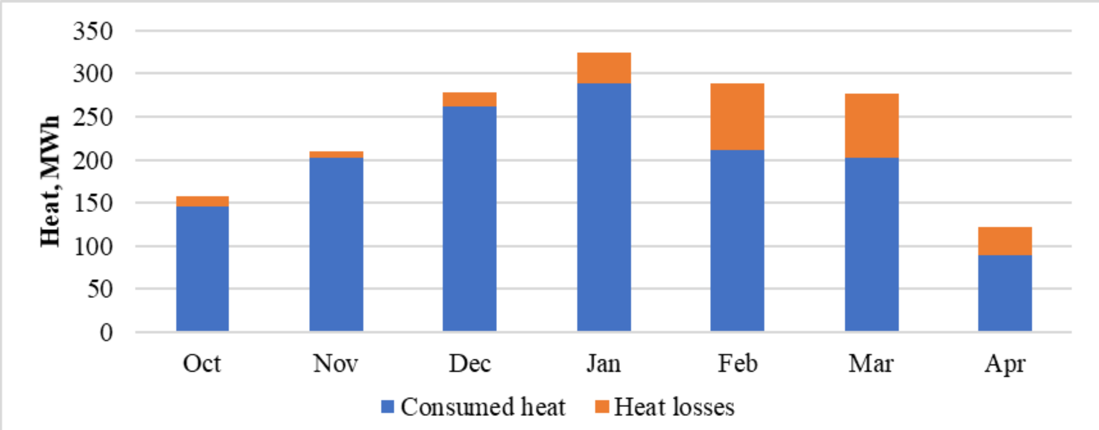


Fig. 3.4.3 Consumed heat and heat losses in the 2018/2019 heating season

Fig. 3.4.4 shows the specific heat consumption of each building in the 2018/2019 heating season, as well as the corrected value under standard climatic conditions. The average specific heat consumption of buildings for heating is 150 kWh/m² per year (normalized 178 kWh/m² per year). All buildings have heating units with direct connection to the boiler house heat carrier.

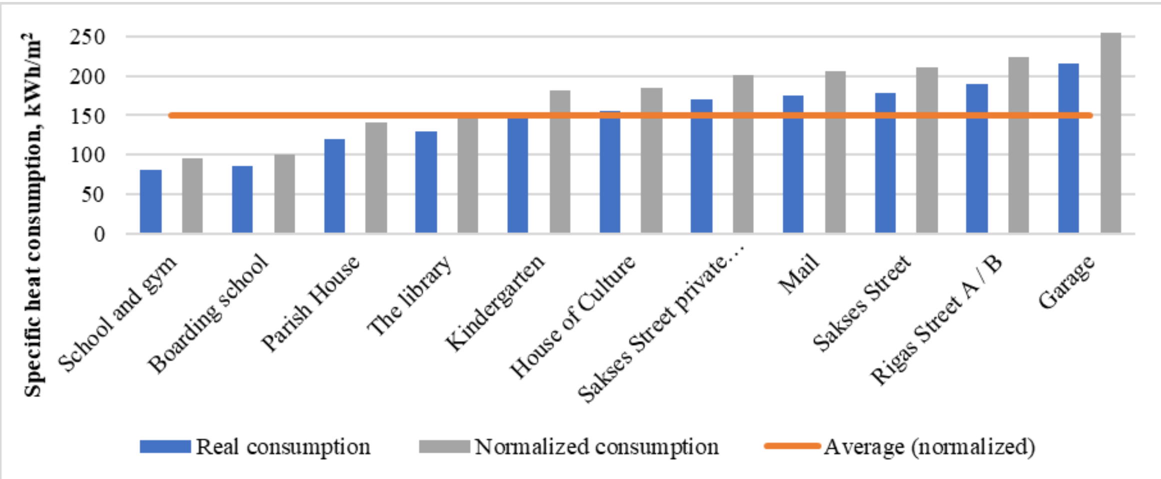


Fig. 3.4.4 Specific heat consumption for heating of DH connected buildings (actual consumption in the 2018/2019 heating season and normalized values)

The layout of the DH heating pipeline is shown in Fig. 3.4.5. The total length of the heating route is 974 m. The average diameter of the pipes is 95 mm. The average heat density in Lejasciems DH is 1.7 MWh/m. The estimated heat loss, based on the available information on fuel consumption and heat consumption in buildings, is approximately 253 MWh, or 15% of the heat generated.

Table 3.4.1 Diameter and length of Lejasciems heat networks

Diameter, mm	Heat pipe length
150	227
125	203
100	92
80	82
48	247
42	123

Fig. 3.4.5 Lejasciems DH heating circuit diagram

Analyzing heat carrier temperature data (Fig. 3.4.6.), correlation of flow and return flow temperature with the average outdoor air temperature of the respective period was determined. Using the obtained regression equations, the boiler house temperature graph is constructed (Fig. 3.4.7.). As can be seen, Lejasciems boiler house is already operating with a reduced temperature schedule 66/55.

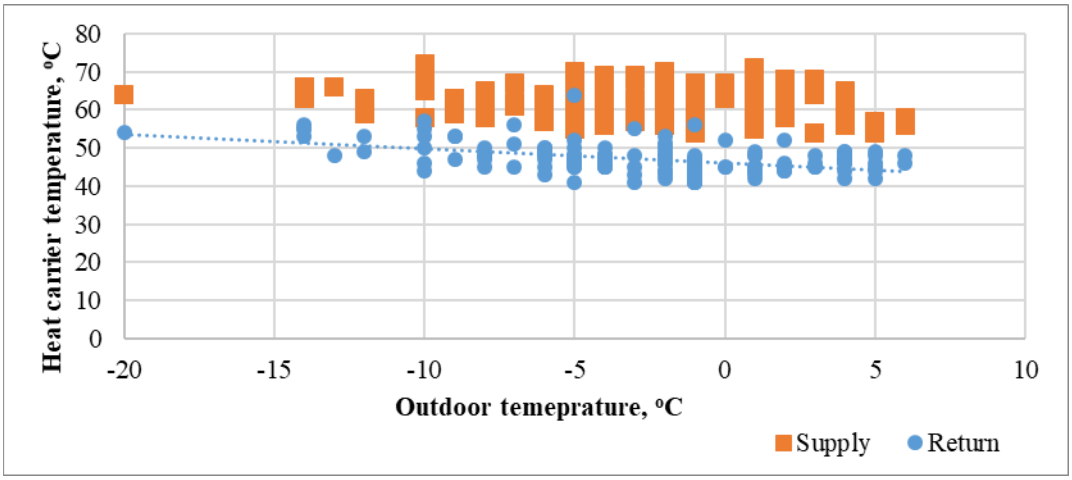


Fig. 3.4.6 Correlation of flow and return flow with outdoor air temperature

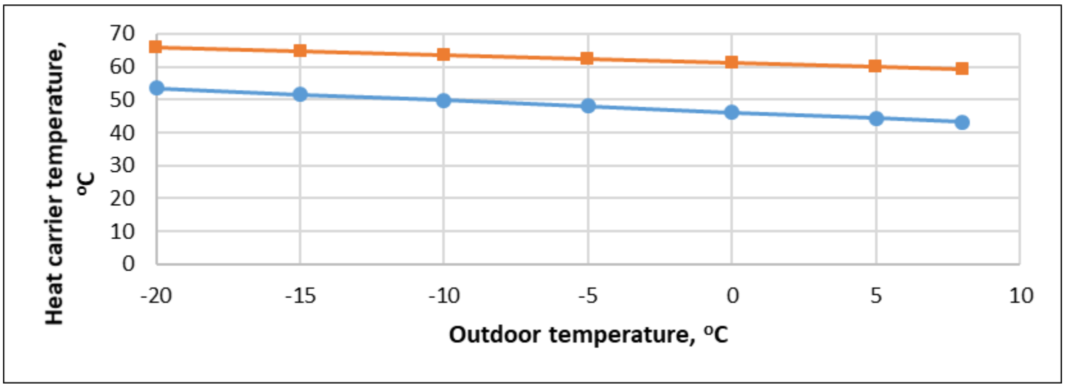


Fig. 3.4.7 Modeled boiler house temperature graph

Fig. 3.4.8 shows that the average monthly electricity consumption ranges from 3 to 7.8 MWh depending on the amount of heat produced. The specific electricity consumption is determined on the basis of the amount of heat produced, which is 23.5 kWh/MWh of average heat per heating season.

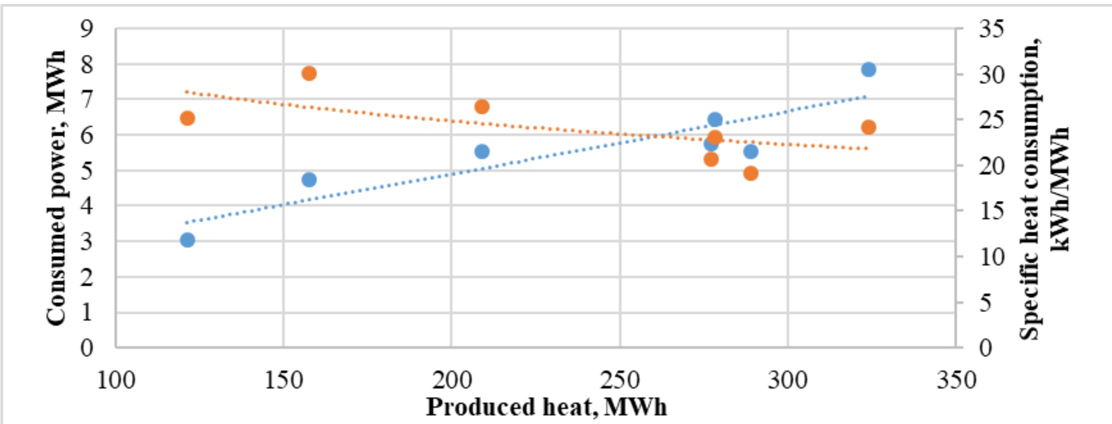


Fig. 3.4.8 Correlation of Electricity Consumption and Specific Electricity Consumption with the Heat Generated

Lejasciems heat tariff is currently 59.58 EUR / MWh excluding VAT. The main cost items are fuel costs (50%) and labor costs (41%).

3.4.2. Description of strategic development directions, forecast of changes, technical solutions and resources required for their implementation

In order to make Lejasciems DH more cost-effective and resource efficient, it is necessary to modernize the wood-fired boiler house. In order to reduce labour costs, it is recommended to install an automatically controlled boiler using wood chips or wood pellets as fuel.

One of the main factors influencing the operation of the system is the heat consumption. Analyzing the strategic development pathways, the scenario with the existing heat consumption and the energy efficiency scenario when part of the buildings are insulated is considered. Fig. 3.4.9 shows simulated heat load graphs for different development scenarios.

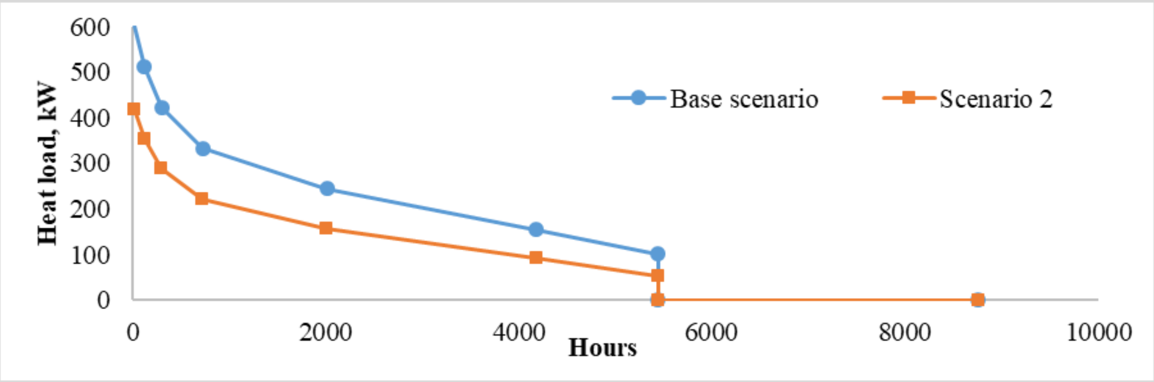


Fig. 3.4.9 Heat load graphs for analyzed scenarios

Scenario 1

In the first scenario, an automated woodchip boiler with a capacity of 600 kW is installed in the existing boiler house instead of the existing boilers. In order to smooth the operation of the boiler and reduce the effect of peak load, it is necessary to equip the boiler with a heat storage tank. When upgrading a boiler house, it is also necessary to install more efficient circulation pumps in order to reduce electricity consumption for heat transfer. The first scenario assumes that heat consumption will remain at current levels.

Scenario 2

Scenario 2 assumes that buildings with a specific heat consumption of more than 150 kWh/m^2 (cultural center, post office, kindergarten and apartment buildings) are insulated. It is assumed that the specific heat consumption of each building after thermal insulation decreases to 90 kWh/m^2 and the total heat consumption decreases by almost 500 MWh per year. In this case, the heat consumption density would drop to 1.1 MWh/m and the maximum peak load would be 418 kW.

Scenario 2 assumes that it is possible to further reduce the temperature of the heating network (temperature curve 60/45) due to increased energy efficiency of buildings and modernization of heating units.

Lejasciems boiler house is located far from the heat load load center. The boiler house and the nearest consumer are connected by a 227 m long DN150 pipeline, which is poorly insulated and generates about 70 MWh of heat a year. Thus, as a second alternative, the placement of a new container-type pellet boiler house closer to heat consumers, for example, in the area near Lejasciems secondary school or boarding school, is being considered. The calculation assumes that about 100 m of new heating section should be built to connect the boiler house to an existing section of the appropriate size.

Table 3.4.2 summarizes the information on the analyzed development scenarios. It can be seen that in the 2nd scenario, even with the lower temperature curve and smaller heating network length, the specific loss amount reaches 18%, because the amount of heat produced and consumed significantly decreases. It should be noted that with the current boiler house location and current temperature graph, the specific heat loss in the energy efficiency scenario would reach up to 30%.

Table 3.4.2 Raw data, assumptions and calculated values of the analyzed scenarios

Parameter	Base scenario	Scenario 1	Scenario 2
Fuel used	Firewood	Wood chips	Pellets
Installed boiler power, kW	2500	600	400
Heat network temperature graph	66/53	66/53	60/45
Length of heating network, m	974	974	847
Volume of accumulation tank, m^3	n/a	10	5
Heat produced, MWh per year	1656	1656	1063
Loss of thermal energy, MWh per year	253	253	150
Heat sold, MWh per year	1404	1404	913
Heat consumption density, MWh/m	1.7	1.7	1.1
Specific heat losses,%	15%	15%	18%

3.4.3. Cost-benefit analysis

Potential investments, production costs (fuel and electricity costs), labour costs are taken into account when evaluating different development alternatives. The cost analysis makes assumptions about the performance of pellets and woodchip boilers - efficiency and specific electricity consumption, based on previously implemented examples of DH modernization. Other assumptions related to equipment costs are summarized in Table 3.4.3.

Table 3.4.3 Assumptions used in the cost-benefit analyses

Assumption	Costs
Heating pipeline construction, EUR /m	250
Pellet boiler, EUR/kW	310
Container type boiler house, EUR/kW	116
Woodchip boiler with automatic supply, EUR/kW	600
Cost of accumulation tank, EUR/m³	900
Electricity tariff, EUR/MWh	114

In both of these scenarios, reductions in labor costs are significant. The energy efficiency scenario assumes that the pellet boiler will be fully automated, requiring only one employee to service it. In the case of woodchip boiler house, it is assumed that it will be necessary to employ two full-time employees.

Table 3.4.3 Results of a cost-benefit analysis

Parameter	Base scenario	Scenario 1	Scenario 2
Fuel used	Firewood	Wood chips	Pellets
Installed boiler power, kW	2500	600	400
Volume of accumulation tank, m³	n/a	10	8
Investments	**n/a**	**389000**	**202600**
Boiler equipment and installation costs, EUR	n/a	360000	124000
Boiler house reconstruction/container type boiler house construction, EUR	n/a	20000	46400
Accumulation tank cost, EUR	n/a	9000	7200
Heating network construction costs, EUR	n/a	n/a	25000
Production costs, EUR per year	**43009**	**35772**	**51205**
Boiler efficiency	0.7	0.85	0.9
Price of fuel	24.5 EUR/m³	12 EUR/m³	182 EUR/t
Fuel consumption, MWh per year	2366	1949	1181
Lowest heat of combustion	1.50 MWh/m³	0.71 MWh/m³	4.3 MWh/t
Annual fuel consumption	1578 m³	2745 m³	275 t
Total fuel costs, EUR per year	38572	32937	49992

Specific electricity consumption, kWh/MWh	23.5	15	10
Electricity consumed, MWh per year	39	25	11
Electricity costs, EUR per year	4437	2835	1213
Staff costs, EUR per year	3 12 13	1 24 85	62 43
Number of employees	5	2	1
Working hours, months	7	7	7
Average salary, EUR/month	892	892	892
Investment costs, EUR per year	**n/a**	**1 94 50**	**1 01 30**
Duration of equipment, years	n/a	20	20
Other costs, EUR per year	**26 38**	**26 38**	**26 38**
Total maintenance costs, EUR per year	**76859**	**70345**	**70215**
Specific cost of heat sold, EUR/MWh	**54.75**	**50.11**	**76.87**

The cost analysis carried out shows that, in the case of Scenario 1, the costs are lower than for the existing boiler house. In Scenario 2, fuel costs will increase significantly and revenue from heat sold will decrease, resulting in much higher specific heat costs.

3.4.4. SWOT and risk analysis

The main strengths of Scenario 1 are lower fuel and labour costs. Weaknesses, on the other hand, are associated with higher heat losses. Alternatively, municipal grants for the construction of heating systems to promote the development of a common heating system can be considered. Increased woodchip costs and shortage of skilled workers have been identified as threats.

Table 3.4.4. SWOT analysis for Scenario 1

Strengths	Weaknesses
Higher heat consumption density Lower heat tariff	Higher transmission heat losses
Opportunities	**Threats**
Attracting external funding	Increase in wood chip costs Lack of qualified stuff

The strengths of Scenario 2 are reduced heat transmission losses and lower total investment. The weaknesses of the scenario are higher fuel costs and lower heat consumption density, which results in a higher heat tariff. The possibilities of the scenario are to attract European Union funding, further lowering the temperature of the heat carrier in the case of energy efficient buildings. Potential increase in fuel prices and lack of designers' experience in low temperature DH system integration are identified as threats.

Table 3.4.5. SWOT Analysis for Scenario 2

Strengths	Weaknesses
Reduced transmission heat losses Higher overall system efficiency	Higher specific costs of heat production and transmission
Opportunities	**Threats**
Attracting external funding Further reduction of heat carrier temperature Use of cheaper plastic pipes for the new heating pipeline	Increase in pellet costs Lack of experience in designing low temperature DH systems Lack of qualified staff

A simplified risk analysis is provided in Table 3.4.6, which analyzes 5 different risks. Risks have a different impact on each of the analyzed scenarios, which are rated as high, medium or low.

Consumer switching to individual heat supply, promoted by high heat tariffs, has been identified as high risk. This risk can be reduced by ensuring cost-effective operation of DH to reduce heat tariff as much as possible and by informing consumers of the potential benefits of joining DH. Other high probability risks are related to the increase of wood fuel costs and lack of investments for the modernization of the boiler house. A medium risk is identified as the lack of skilled labor, which can be eliminated by maximum automation of heat generation and transmission.

Table 3.4.6 Risk analysis

Risk	Probability of risk	Impact of risk	Operational risk prevention
Consumer transition to individual heat supply	Scenario 1 -medium Scenario 2-high	High	Ensuring cost efficiency of DH to minimize heat tariff; Informing consumers about the operation and costs of DH;
Increase in wood fuel prices	High	High	Increase DH performance to minimize fuel consumption
Investment shortage	Scenario 1 -high Scenario 2-medium	High	Mobilization of external funds
Inefficient management of heat production and transmission	Low	High	Regular monitoring of DH system performance; Continuous system performance improvement
Lack of qualified stuff	Medium	Medium	Maximum automation of heat production

Conclusions and recommendations

In order to make DH of Lejasciems parish more cost-effective and resource efficient, it is necessary to modernize the wood-fired boiler house, maintaining the existing reduced heat carrier temperature schedule. In order to reduce labor costs, it is recommended to install an automatically controlled boiler using wood chips or wood pellets as energy source. Alternative evaluation also analyzed moving the boiler house closer to the heat consumption center to reduce heat loss through the main pipeline.

The DH systems of Lejasciems already operate with a reduced temperature regime, but one of the goals for increasing energy efficiency is to increase the difference between the supply and return temperatures. This can be achieved by changing the heat regulation conditions, installing automated heating units that are adapted to the existing temperature schedule or improving the efficiency of consumer heating systems.

Lejasciems DH needs to improve its monitoring system to accurately determine the amount of heat produced and consumed and the amount of heat loss.

3.5. Lizums parish

3.5.1. Assessment of the current situation

In Lizums Parish the DH heat is purchased from a nearby wood cogeneration plant Ltd "Eko NRG". Gulbene Municipality provides heat transfer via circulation pumps located in Lizums boiler house. The previous Orion-3H1 boiler, which was manufactured in 2007 and has the capacity of 1.5 MW, is also preserved in the boiler house. The DH performance analysis uses data on purchased and consumed heat for 2018, which is the only full period for which the necessary information is available.

Fig. 3.5.1 Lizums DH heating network and nearby industrial companies

The total amount of purchased heat in 2018 was 2094 MWh. There are 17 buildings connected to DH, for 14 of which heat meters are installed. Therefore, it is not possible to calculate the exact amount of heat consumed. Fig. 3.5.2 shows the specific heat consumption of buildings in 2018 for which metering is performed and the adjusted consumption according to the regulatory climatic conditions. It can be seen that the specific consumption of two buildings is below 100 kWh/m^2 (the pharmacy building has an insulated roof), but the higher Fig. is in apartment buildings - on average 190 kWh/m^2 (adjusted 225 kwh/m^2). The average specific heat consumption for heating of all buildings is 166 kWh/m^2 per year (normalized 196 kWh/m^2 per year).

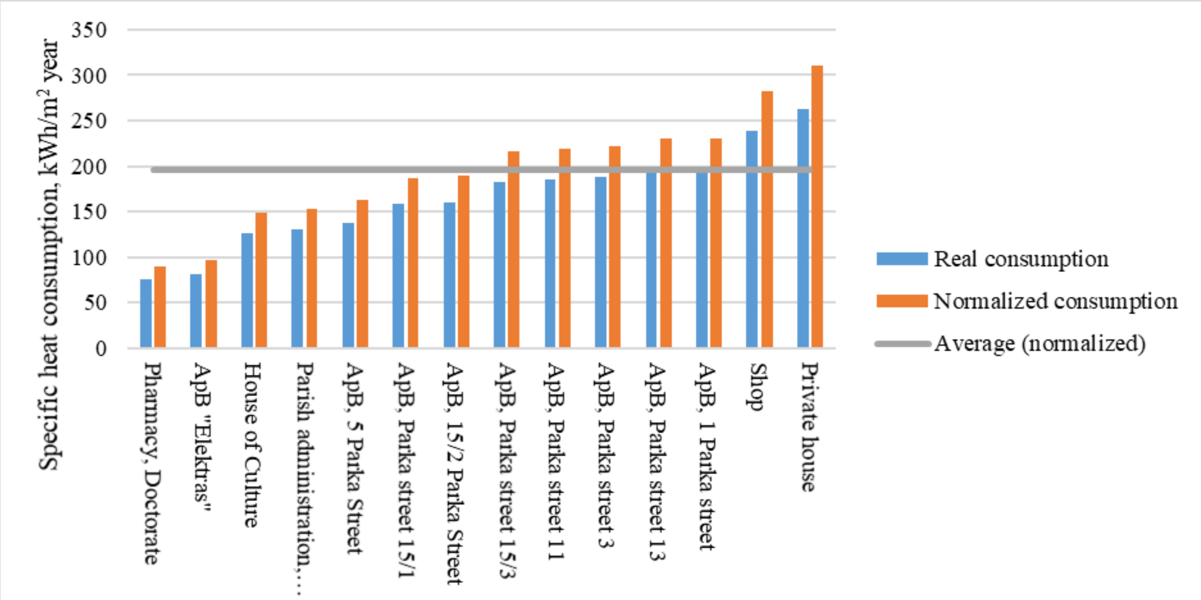


Fig. 3.5.2 Specific heat consumption (real and normalized) of DH connected buildings in Lizums

Based on the information on the amount of purchased heat, the heat load of Lizums DH is shown in Fig. 3.5.3. It can be seen that the maximum heat load reaches 860 MW.

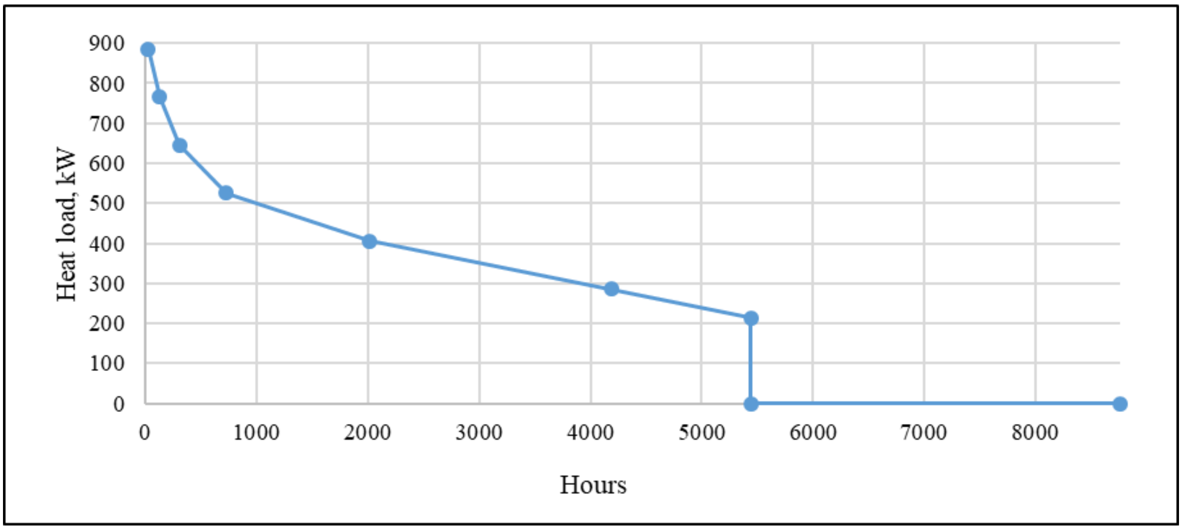


Fig.3.5.3 Lizums DH thermal load

The amount of purchased heat in 2018 by month and the corresponding electricity consumption for transmission is shown in Fig. 3.5.4. The total annual electricity consumption is 88 MWh, and the specific electricity consumption per delivered heat amount is 42.22 kWh/MWh.

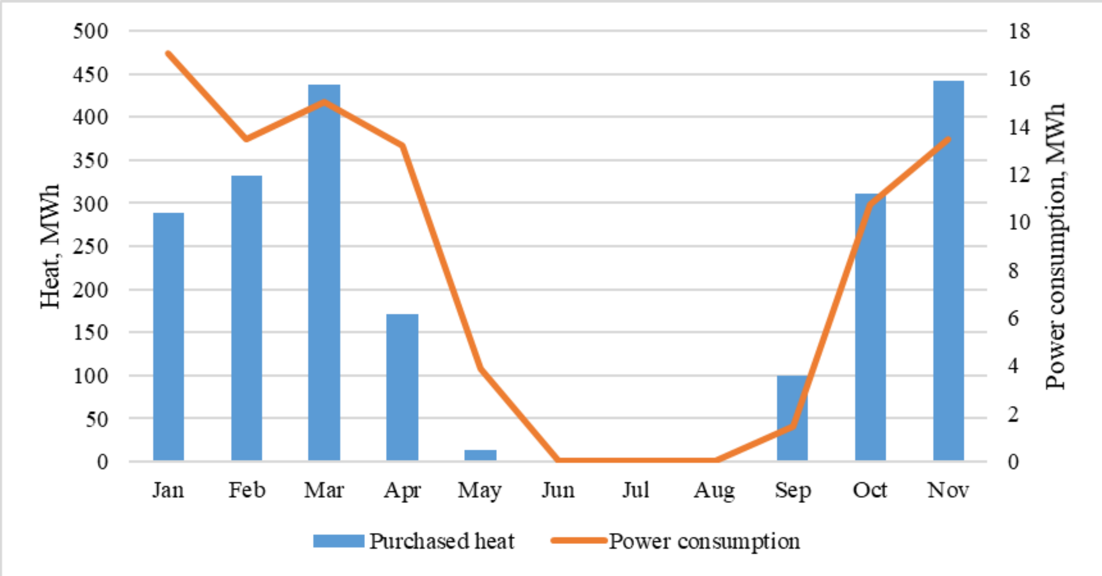


Fig. 3.5.4 Quantity of heat purchased in 2018, electricity consumed for heat transmission

Analyzing heat carrier temperature data (Fig. 3.5.5), correlation of flow and return flow temperature with the average outdoor temperature of the respective period was determined. The picture shows that at the moment the flow temperature of Lizuma DH is kept almost constant around 80°C. In order to refine the temperature graph, it is necessary to monitor the flow temperature on the secondary side of the heat exchanger.

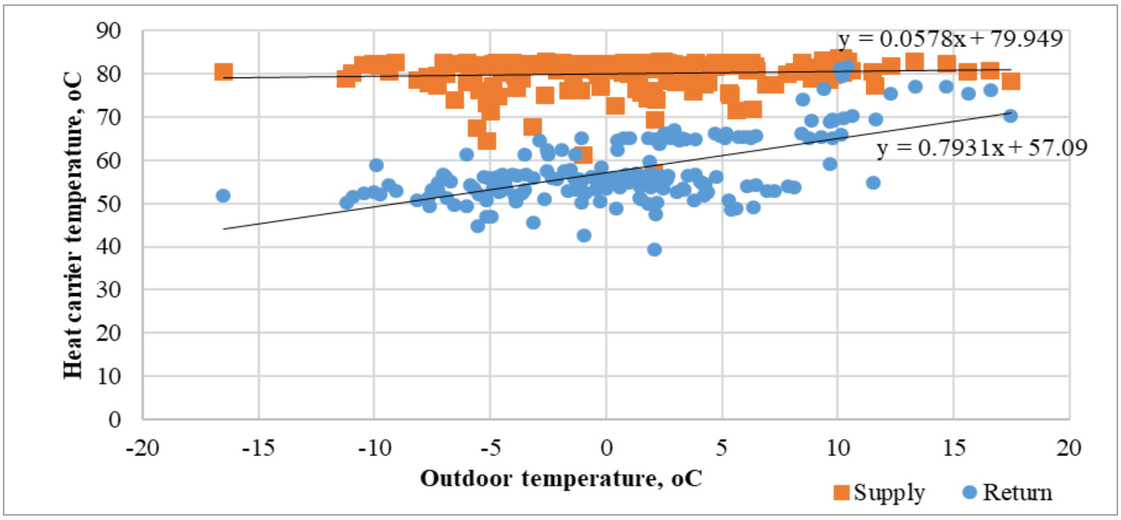


Fig. 3.5.5 Correlation of flow and return flow with outdoor air temperature

The total length of the Lizums heating pipes is 1.523 m, excluding the pipeline connecting the CHP plant and the boiler house, which is owned by SIA "Eko NRG". Pipes weighted average diameter is 71 mm. The average heat consumption density in Lizums DH is 1.1 MWh/m. The modeled heat loss, taking into account the available information on the technical condition, lengths and diameters of the heat networks (see Table 3.5.1), is approximately 479 MWh or 23% of the heat generated.

Table 3.5.1 Diameters and lengths of pipelines

Pipeline diameters, mm	Pipeline length, m
DN139	177
DN114	136
DN89	130
DN76	183
DN60	243
DN48	163
DN42	454
DN33	37

The heat tariff in Lizums DH is currently 41.33 EUR/MWh excluding VAT, which is the lowest among all analyzed Gulbene district heat tariffs.

3.5.2. Description of strategic development directions, forecast of changes, technical solutions and resources required for their implementation

Currently, Lizum's DH is cost-effective due to the low cost of purchased heat. Heat production in cogeneration mode is one of the most efficient ways of producing heat, as it allows to save fuel compared to separate production of heat and electricity. Therefore, no other heat production alternatives are considered for further development of the Lizums DH system, assuming that the "Eko NRG" cogeneration plant will continue to operate for the next 10-15 years.

Scenario 1

In the village of Lizums two industrial buildings of Ltd. "Dimdiņi" are located. Currently, the company uses liquefied petroleum gas (LPG) for heat production. Steam is produced for production processes, and water is used as the heat carrier for heating buildings. The heating area of one building is 1210 m², while for the other building it is almost 200 m². In 2018, the company consumed 229 tons of LPG at both plants. Assuming a minimum fuel heat of combustion of 12.87 MWh/ton and a boiler efficiency of 0.9, it is estimated that both buildings of the company consume approximately 2654 MWh of thermal energy.

One of the alternatives for the development of Lizums DH is the connection of these buildings to district heating to cover the space heating consumption of the buildings. At present, the company does not separately account the amount of fuel consumed for steam production and heating of buildings. To determine the potential consumption, the average specific heat consumption of the heating of buildings is assumed to be about 120 kWh/m² (taking into account the heat gain from the production process). The estimated heat consumption of the first building would be 145 MWh for heating and 24 MWh for other. In order to connect the buildings to the DH, it would be necessary to construct new sections of the heating pipeline - up to 270 m to the first building and 150 m to the second building. It is estimated that heat losses from this pipeline would result in heat losses of approximately 53 MWh at a temperature schedule of 75/55.

In order to increase the overall efficiency of the heating system, it is necessary to ensure the flow temperature control according to the outdoor air temperature. Scenario 1 assumes that the boiler house will operate at temperature graph 75/55.

Scenario 2

Another alternative analyses the option without new consumers, but assumes that part of the buildings will be renovated and the total heat consumption decreases. Potential energy efficiency measures could be implemented in five apartment buildings and a cultural center owned by municipality. In this scenario, the existing heat consumption of the buildings is assumed to be reduced to 90 kWh/m². The resulting reduction in heat consumption is estimated at 534 MWh per year. In Scenario 2, when energy efficiency measures are taken in part of the buildings, a step-by-step temperature curve of 60/45 may be introduced.

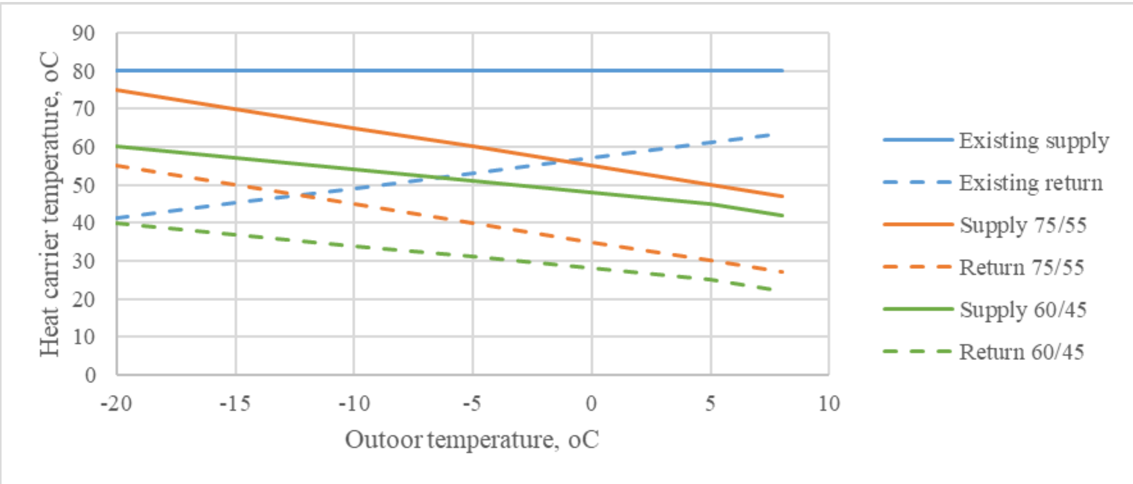


Fig. 3.5.6. Modelled temperature graphs

Fig. 3.5.7 shows the heat load graphs for different scenarios. It can be seen that in the Scenario 1 the maximum heat load increases slightly - up to 957 kW, but in the Scenario 2 the maximum heat load decreases significantly - up to 650 kW.

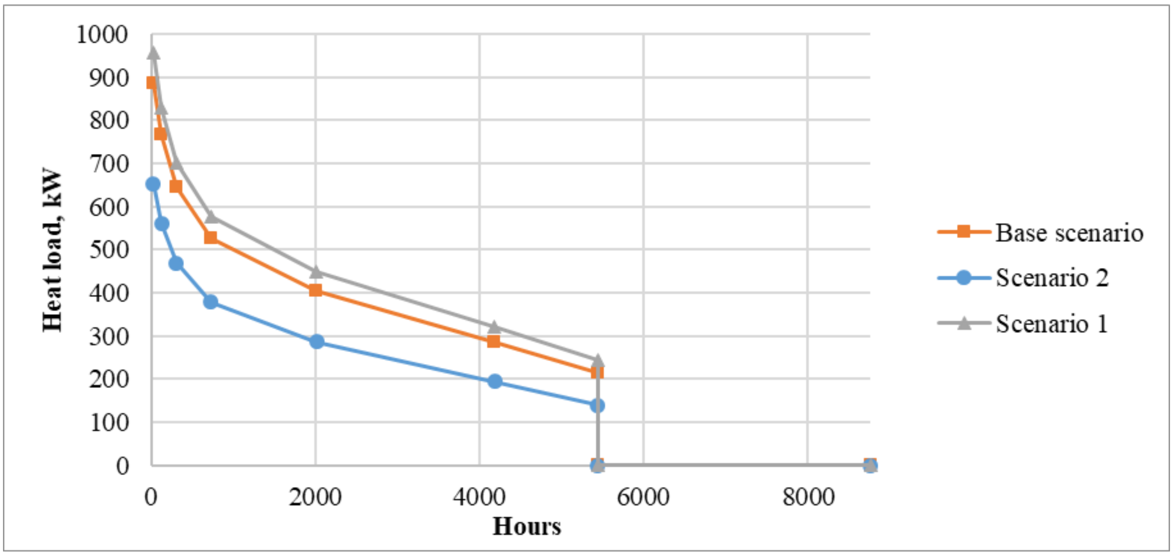


Fig. 3.5.7 Simulated heat load graphs for each of the analyzed scenarios

Fig. 3.5.8 shows modeled heat losses and specific heat losses in different scenarios. With the implementation of the temperature graph 75/55, losses in transmission networks will be reduced to 333 MWh and account for 14% of the produced heat. This scenario takes into account that additional heating pipelines are being built to connect new customers. In Scenario 2, the heat loss at the reduced temperature schedule is 254 MWh. However, due to the significantly reduced heat consumption, the specific heat loss rate is high and reaches 21% of the produced heat.

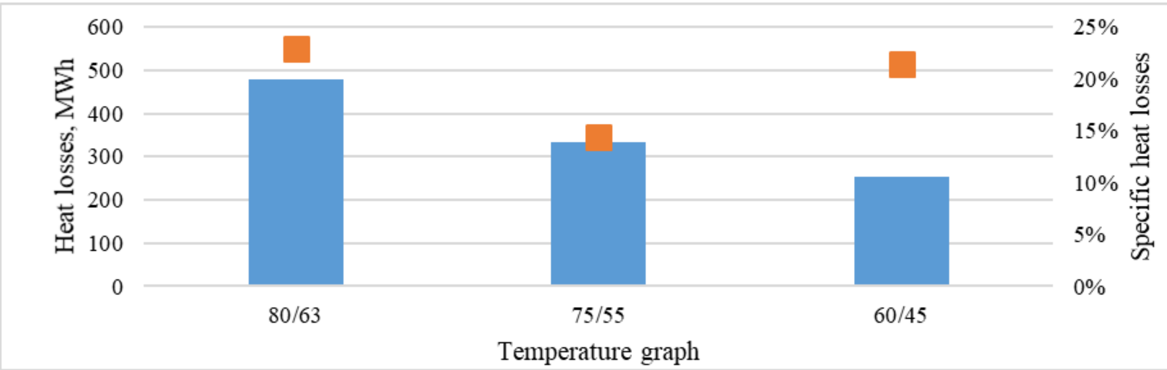


Fig. 3.5.8 Estimated heat losses

Table 3.5.2 summarizes the information on the analyzed development scenarios. It can be seen that in the Scenario 2 even with the lower temperature curve and smaller heating network length, the specific losses amount reaches 21%, because the amount of heat produced and consumed significantly decreases.

Table 3.5.2 Input data, assumptions and calculated values for the analyzed scenarios

Parameter	Base scenario	Scenario 1	Scenario 2
Energy source	Purchased heat from CHP		
Heating network temperature graph	80/40	75/55	60/45
Length of heating network, m	1523	1843	1523
Purchased heat, MWh per year	2095	2312	1186
Heat losses, MWh per year	479	333	254
Consumed heat, MWh per year	1615	1980	932
Heat density, MWh/m	1.1	1.1	0.6
Proportion of heat losses,%	23%	14%	21%

3.5.3. Cost-benefit analysis

The main investments arise in Scenario 2 for the construction of the heating pipeline and heating units. In addition, the costs of new circulation pumps are included to reduce the power consumption for transmission. The cost of a new circulation pump with installation is estimated at about 3000 EUR. In total 4 pumps operates in the boiler house for heat transfer.

Table 3.5.3 Assumptions used in the cost- benefit analyses

Parameter	Value
Purchased heat tariff, EUR/MWh	26.26
Electricity tariff, EUR/MWh	105.97
Automated heating unit construction, EUR/heating unit	6000
Heating pipeline construction, ER /m	250

The cost-benefit analysis shows that in Scenario 1, the connection of new consumers provides a significant reduction in the specific costs of heat. In the Scenario 2, when the building insulation is done, the specific costs increase. If the heat carrier temperature is not lowered in the case of Scenario 2 and the losses remain at the current level, the specific cost increases to 54.20 EUR / MWh.

Table 3.5.4 Results of a cost-benefit analysis

Parameter	Base scenario	Scenario 1	Scenario 2
Investments	**n/a**	**92000**	**30000**
Construction of automated heating units, EUR	n/a	12000	30000
Heating network construction costs, EUR	n/a	80000	n/a
Circulation pump replacement, EUR	n/a	12000	12000
Production costs, EUR per year	**65861**	**65624**	**33660**
Cost of purchased thermal energy in EUR per year	55003	60725	31147
Specific electricity consumption, kWh/MWh	49	20	20
Electricity consumed, MWh	103	46	24
Electricity costs	10859	4899	2513
Labour costs, EUR per year	**77 94**	**77 94**	**77 94**
Number of employees	1.5	1.5	1.5
Working hours, months	6	6	6
Average salary, EUR/month	866	866	866
Investment costs, EUR per year	**n/a**	**4600**	**15 00**
Duration of equipment, years	n/a	20	20
Other costs, EUR per year	**75 86**	**75 86**	**75 86**
Total maintenance costs, EUR per year	**81241**	**85604**	**50540**
Specific cost of heat sold, EUR/MWh	**50.31**	**41.33**	**54.20**

3.5.4. SWOT and risk analysis

The main strengths of Scenario 1 are lower specific heat production costs and higher total heat consumption density. Weaknesses, on the other hand, are related to higher heat losses and necessary investments in the construction of new heat pipelines.

Table 3.5.5 SWOT analysis for Scenario 1

Strengths	Weaknesses
Higher heat consumption density Lower heat tariff	Higher transmission heat losses Higher investments
Opportunities	**Threats**
Use of extra heat in a manufacturing plant for production processes Recovery of excess heat from the production plant	Decommissioning of a cogeneration unit Increase in the purchased heat tariff

The construction of heat pipeline to the production buildings of Ltd "Dimdiņi" offers several opportunities for the development of the DH system, for example, increasing the heat consumption, if the DH heat is also used in the production process where possible. If the company identifies excess heat, a two-way system can be set up, where part of the heat is returned to the DH and used for heating other buildings. The identified threats are related to the operation of the CHP plant and the increase in the purchased heat tariff.

The strengths of Scenario 2 are reduced heat transmission losses and lower total investment. The weaknesses of the scenario are the lower heat consumption density, which results in a higher heat tariff. The scenario offers the possibility of further lowering the temperature of the heat carrier in the case of energy efficient buildings and attracting new consumers. The threats are identified the same as in Scenario 1.

Table 3.5.6. SWOT Analysis for Scenario 2

Strengths	Weaknesses
Reduced transmission heat losses Higher overall system efficiency	Lower heat density Higher specific costs of heat production and transmission
Opportunities	**Threats**
Attracting new consumers Further reduction of heat carrier temperature	Decommissioning of a cogeneration unit Increase in the purchased heat tariff

A simplified risk analysis is provided in Table 3.5.7, which analyzes 5 different risks.

Table 3.5.7 Risk analysis

Risk	Probability of risk	Impact of risk	Operational risk prevention
Consumer transition to individual heat supply	Low	Medium	Ensuring cost efficiency of DH to minimize heat tariff; Informing consumers about the operation and costs of DH;
New consumers' hesitation to join DH	Scenario 1-medium Scenario 2- high	Medium	Informing consumers about the operation and costs of DH; Grants for the construction of internal heating systems
Increase in purchased heat tariff	High	High	Fixing of purchased heat tariff in DH contract
Investment shortage	Scenario 1-medium Scenario 2- low	Scenario 1-medium Scenario 2- low	Mobilization of external funds
Inefficient management of heat production and transmission	Medium	High	Regular monitoring of DH system performance; Continuous system performance improvement

The high probability risk is related to the increase of the purchased heat tariff, which would significantly affect both scenarios analyzed. Consumers' reluctance to connect DH would result by a high heat tariff and has been identified as a high risk. This risk can be reduced by ensuring cost-effective operation of DH system, reduction of heat tariff as much as possible and by informing consumers of the potential benefits of DH. Continuous monitoring and periodic evaluation of DH performance (boiler efficiency, heat carrier temperature, heat loss, etc.) is required to prevent the risk of heat generation and transmission equipment malfunctioning and maximizing efficiency.

Conclusions and recommendations

The economically justified scenario for the development of DH operation in Lizums Parish is the connection of industrial buildings to the system and provision of heating of the buildings. The low cost of thermal energy purchased from a cogeneration unit allows to keep DH costs at an optimum level even in a scenario of increased energy efficiency in buildings.

The DH of Lizums should primarily improve the regulation of the existing flow depending on the outdoor temperature. Lizums DH needs to improve its monitoring system to accurately determine the amount of heat produced and consumed and the amount of heat loss. Lowering the temperature should be done in the long term by gradually identifying branches of energy efficient buildings that do not require such high heat carrier temperatures. Reducing the temperature of the DH should be taken into account when renovating existing buildings and their heating systems so that their heating surface is suitable for a reduced flow temperature.

3.6. Galgauska parish

3.6.1. Assessment of the current situation

There is currently no district heating system in Galgauska village. There are 5 buildings close to each other in the village - the culture house, the primary school, the parish administration, the gym (sport hall) and the apartment building (see the layout plan in Figure 3.6.1). Currently, heating in the buildings is provided individually with wood-fired boilers (see Figure 3.6.2). Each building is equipped with a wood-fired boiler with a capacity of 240 kW. Accumulation tanks with a volume of 4 m^3 have been installed in the cultural center and the municipal building. The House of Culture has historically also installed a ground source heat pump with an electric capacity of 4.5 kW, but it is currently not in operation. The total heating area of the buildings is 5673.5 m^2. Hot water preparation in buildings is done locally with installed electric boilers.

Figure 3.6.1. The layout of buildings in Galgauska parish

Figure 3.6.2. Boilers installed in the parish administration building

Currently, the heat produced and consumed in the particular buildings is not accounted for. Average fire wood consumption data for the period from 2014 to 2018 were used to determine the heat consumption of buildings (see Figure 3.6.3).

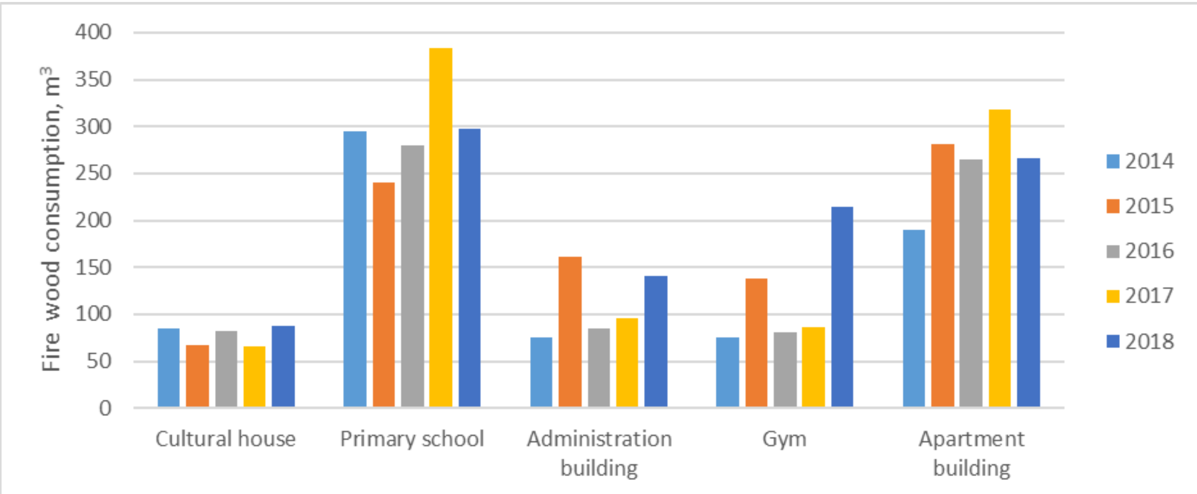


Figure 3.6.3. Comparison of fire wood used in buildings

To determine the amount of thermal energy produced, assumptions were made about the efficiency of the boiler (0.75) and the lowest heat of combustion of the wood (1.3 MWh / m^3). Figure 3.6.4 shows the calculated specific heat consumption for heating of each building.

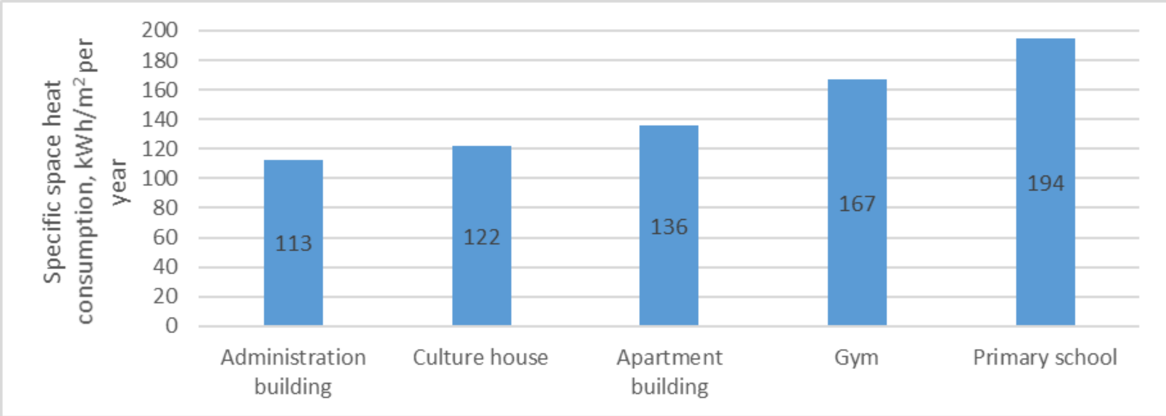


Figure 3.6.3. Specific heat consumption for space heating

It can be seen that the highest specific heat consumption is for the Galgauska Primary School building 194 kWh/m² on average, but the lowest for the parish administration building. The average specific heat consumption of buildings is 146 kWh/m².

Based on the monthly fuel consumption of buildings, the total heat output is determined in relation to the average monthly outdoor air temperature. The regression equation shown in Figure 3.6.4 is used to model the heat load curve of the buildings.

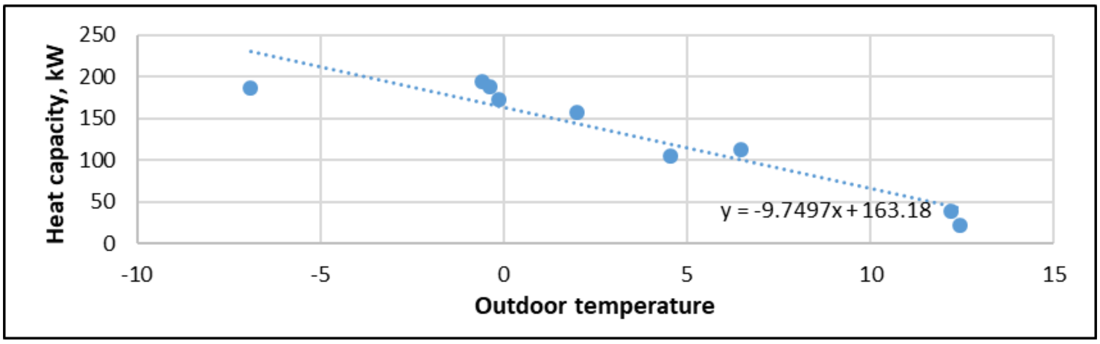


Figure 3.6.4 Correlation between Galgauska buildings thermal capacity and outdoor air temperature

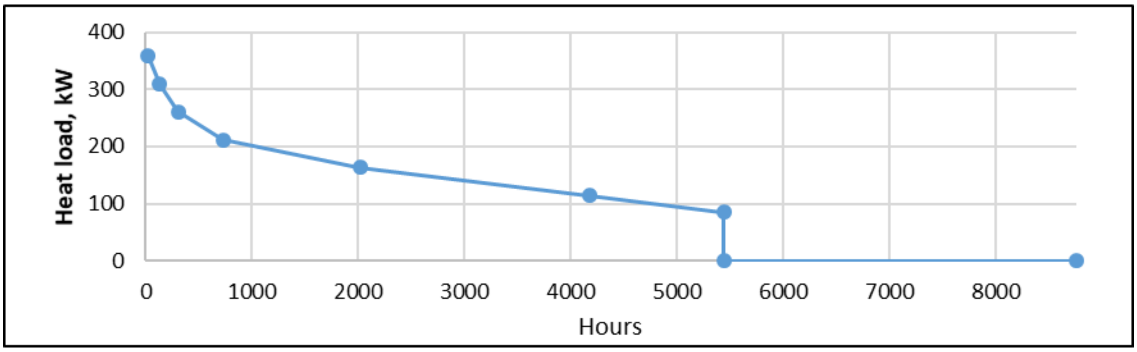


Figure 3.6.5 Potential heat load curve of Galgauska buildings

The heat load curve in Figure 3.6.5 shows that the total heat load of the buildings reaches 358 kW, which is several times less than the total amount of boilers installed in the buildings (1.2 MW)

3.6.2. Description of strategic development directions, forecast of changes, technical solutions and resources required for their implementation

In the comparison of development alternatives, two different heat production technologies are considered - the use of existing wood-fired boilers for district heating (Scenario 1) and the installation of a new pellet boiler in a container boiler house (Scenario 2). Two different temperature graphs have been analyzed for the development of Galgauska DH.

Scenario 1

Scenario 1 represents the development of DH system and centralized heat production for the 5 buildings by assuming the existing heat consumption. Scenario 1 assumes that existing boilers will be used for heating, adapting their operation to centralized heat production, for example by using boilers located in a school building. In order to supply heat, it is necessary to construct heating networks with a total length of 460 m and an average diameter of 60 mm. Consumption density of Galgauska DH is determined to be 1.8 MWh/m. Scenario 1 assumes a 75/55 temperature schedule for the heating networks.

Scenario 2

Scenario 2 represents the development of DH and centralized heat production for the 5 buildings with reduced heat consumption due to the closure of the school. The construction of heat networks is assumed to be the same as described in Scenario 1.

The Galgauska`s Primary School will no longer continue to operate from September 2019. Therefore, it is expected that there will be no need to maintain high indoor temperatures in the school building and the gym and total heat consumption will be significantly reduced. The calculation assumes that the specific heat consumption of both buildings would decrease to 100 kWh/m². As a result, the total heat consumption of buildings is reduced by almost 200 MWh per year. Figure 3.6.6 shows the changes in heat load curve under the assumption that the heat consumption of the school and gym would decrease. In this scenario the maximum heat load reaches 284 kW.

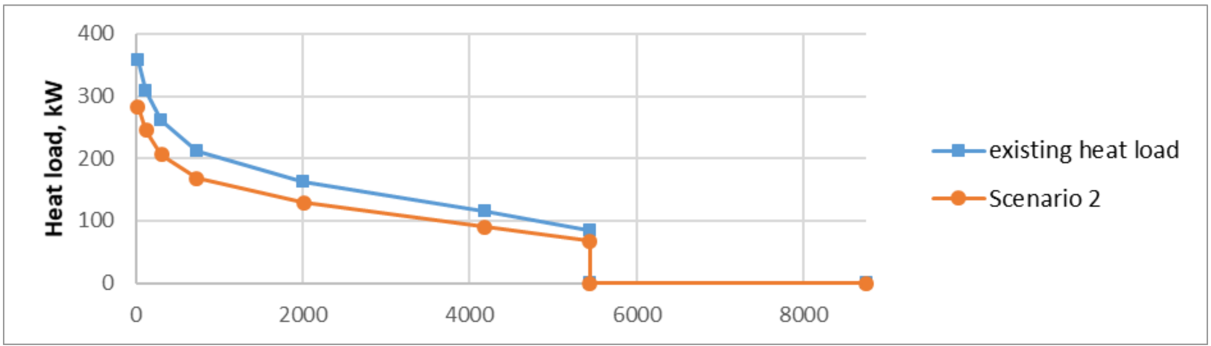


Figure 3.6.6. Changes in heat load curve

It is assumed that in the Scenario 2 a reduced temperature curve 60/40 will be used. Taking into account the assumptions about the location of the heating networks and the temperature graphs, it is estimated that the heat losses in Scenario 1 would be 76.4 MWh or 7% of the produced heat, but in Scenario 2, 66.5 MWh or 9% of the produced heat. Table 3.6.1 summarizes the information on the raw data, assumptions and calculated values of the analyzed scenarios.

Table 3.6.1 Raw data, assumptions and calculated values of the analyzed scenarios

Parameter	Existing situation	Scenario 1	Scenario 2
Fuel used	Fire wood	Fire wood	Pellets
Installed boiler capacity, kW	1200	350	250
Heat network temperature graph	n/a	75/55	60/40
Length of heating network, m	n/a	460	460
Volume of accumulation tank, m³	n/a	10	4
Heat produced, MWh per year	850	926	728
Loss of thermal energy, MWh per year	n/a	76	67
Heat consumed, MWh per year	850	850	661
Heat consumption density, MWh / m	1.7	1.7	1.4
Proportion of heat losses,%	n/a	8%	9%

3.6.3. Cost-benefit analysis

The assumptions about the performance of pellet boilers - efficiency and specific electricity consumption within the cost analysis are based on previously implemented examples of DH modernization. In both scenarios, accumulation tanks are assumed. Other assumptions related to equipment costs are summarized in Table 3.6.2.

Table 3.6.2 Assumptions used in the cost-benefit analyses

Assumption	Costs
Heating pipeline construction, EUR/m	250
Pellet boiler, EUR/kW	310
Automated heating unit construction, EUR/heating unit	6000
Container type boiler house, EUR/kW	116
Accumulation tank cost, EUR/m3	900
Electricity tariff, EUR/MWh	114

Table 3.6.3. Results of cost-benefit analyses

Parameter	Existing situation	Scenario 1	Scenario 2
Investments	n/a	155400	251500
Boiler equipment and installation costs, EUR	n/a	5400	77500
Boiler room reconstruction/container boiler house construction, EUR	n/a	5000	29000
Heating network construction costs, EUR	n/a	115000	115000
Installation of automatic heating units, EUR	n/a	30000	30000
Production costs, EUR per year	22176	24 803	35 472
Type of fuel	Fire wood	Fire wood	Pellets
Boiler efficiency	0.75	0.75	0.9
Price of fuel	24.5 EUR/m³	24.5 EUR/m³	182 EUR/t
Fuel consumption, MWh	1133	1235	809
Lowest combustion heat	1.30 MWh/m³	1.30 MWh/m³	4.3 MWh/t
Fuel consumption (in units)	871 m³	950 m³	188 t
Total fuel costs, EUR	21303	23218	34226
Specific power consumption, kWh/MWh	9.0	15	15
Electricity consumed, MWh	8	14	11
Electricity costs, EUR	872	1585	1246
Staff costs, EUR per year	2 49 70	1 24 85	62 43
Number of employees	4	2	1
Working hours, months	7	7	7
Average salary, EUR/month	892	892	892
Investment costs, EUR per year	n/a	7770	12575
Duration of equipment, years	n/a	20	20
Other costs, EUR per year	20 00	30 00	30 00
Total maintenance costs	49 146	48 058	57 290
Specific cost of heat sold, EUR / MWh	57.85	56.57	86.64

The cost-benefit analysis in Table 3.6.3 shows that in a Scenario 1 where the existing wood-fired boilers are used and the heat consumption is constant, the specific heat costs for a centralized system are slightly lower than for individual heat supply, mostly due to reduced labor costs. In Scenario 2, when reduced heat consumption of buildings and high investments in the construction of a heat source are assumed, the specific heat costs exceed those determined in the current situation.

3.6.4. SWOT and Risk Analysis

The main strengths of Scenario 1 are lower investments and higher density of heat consumption resulting in lower specific heat costs. Weaknesses, on the other hand, are related to higher heat losses and necessary investments in the construction of heating networks. In order to increase the total heat consumption, it is possible to install combined hot water boilers and to centralize hot water during the heating season. The biggest threat is seen as the depreciation of existing boilers and the need to purchase a new boiler, which would significantly increase the cost of heat production.

Table 3.6.4 SWOT analysis for Scenario 1

Strengths	Weaknesses
Lower specific costs of heat production Higher heat consumption density	Higher heat losses
Opportunities	**Treats**
Using heat to prepare hot water Attracting external funding	Depletion of boilers and thermal storage tanks

Table 3.6.5. SWOT Analysis for Scenario 2

Strengths	Weaknesses
Reduced heat transmission losses Higher energy efficiency of the overall system	Lower heat consumption density Higher specific costs of heat production
Opportunities	**Treats**
Use of existing heat pump and boiler equipment Further reduction of heat carrier temperature Use of cheaper plastic pipes in heating networks	Increase in fuel prices Apartment building reluctance to connect DH Lack of experience in designing low temperature systems Lack of qualified staff

The strengths of Scenario 2 are reduced heat losses and higher overall system efficiency. The weaknesses of the scenario are the lower heat consumption density, which results in a higher heat tariff.

Scenario opportunities are further lowering the temperature of the heat carrier in the case of energy efficient buildings and the use of a heat pump installed in the culture house. Increased fuel prices and the reluctance of the apartment building to connect to DH have been identified as threats.

Risk analysis

A simplified risk analysis is provided in Table 3.6.6, which analyzes various risks. Risks have a different impact on each of the analyzed scenarios, which are rated high, medium or low.

The reluctance of the apartment building to connect to the DH, which would be promoted by a high heat tariff, has been identified as a high risk. This risk can be mitigated by ensuring cost-effective operation of DH, reducing heat tariff as much as possible, and informing consumers of the potential benefits of connecting to DH. Increased fuel costs would also pose a high risk. Continuous monitoring and periodic evaluation of DH performance (boiler efficiency, heat carrier temperature, heat loss, etc.) is required to prevent the risk of heat generation and transmission equipment malfunctioning and operating at peak efficiency.

Table 3.6.6. Risk analysis

Risk	Possibility	Impact	Actions to avoid the risk
New consumers' hesitation to join DH	High	High	Informing consumers about the operation and costs of DH; Grants for the construction of internal heating systems
Increase in fuel costs	High	Average	Increase the efficiency of DH to minimize fuel consumption
Insufficient investments	Scen 1 -low Scen 2- high	Scen 1 -low Scen 2- high	Attraction of external funds
Inefficient management of heat production and transmission	Medium	High	Monitoring of DH system performance; Continuous system performance improvement

Conclusions and recommendations

In the villages of Galgauska the transition from individual heat supply to district heating system was analyzed. Establishment of DH system in Galgauska village is economically justified on condition that 5 analyzed buildings (municipalities and apartment buildings) are connected to DH, existing boilers are used and heat consumption of the buildings does not change. The risk for optimum system design would be the reluctance of consumers to switch DH system.

It is recommended to develop the DH in Galgauska village building (apartment buildings, cultural center, school, parish administration and gym) only if the school and gym are used and it is necessary to maintain optimum indoor temperature. In order to evaluate whether it is possible to reduce the flow temperature, it is necessary to evaluate the temperature of the outgoing and incoming flows of the existing boilers, to monitor the indoor temperatures of the connected buildings, and to evaluate the existing heating elements.

3.7. Ranka parish

3.7.1. Assessment of the current situation

There is currently no district heating system in Ranka parish. There are 10 apartment buildings close to each other in the parish (see layout plan in Figure 3.7.1). Currently, heating in the buildings is provided individually with wood-fired boilers (6 buildings) or local furnaces (4 buildings). The total heating area of the buildings is 7 240 m². Hot water preparation in buildings is done locally with installed electric boilers.

Fig. 3.7.1 The layout of Ranka village buildings and one of the apartment buildings

Information on the amount of heat consumed in buildings is not recorded and the data is not available. The specific heat consumption of the buildings is assumed to be 150 kWh/m² per year in order to determine the potential heat load in the village. As a result, each building consumes an average of 109 MWh, while the total heating consumption of all 10 buildings is approximately 1086 MWh.

3.7.2. Description of strategic development directions, forecast of changes, technical solutions and resources required for their implementation

The development of DH and centralized heat production for the buildings were considered as development alternative. Two different types of heat production are considered - use of woodchip boiler (Scenario 1) and installation of pellet boiler in container boiler house (Scenario 2). In Scenario 1, it is assumed that all apartment buildings are connected to the heating system, but in Scenario 2, only a part (6 buildings with heating boilers) are connected to DH. Figure 3.7.2 shows the heat load graphs of the two analyzed DH scenarios. It can be seen that in the Scenario 1 the maximum heat load reaches 430 kW, but in the second scenario - 300 kW.

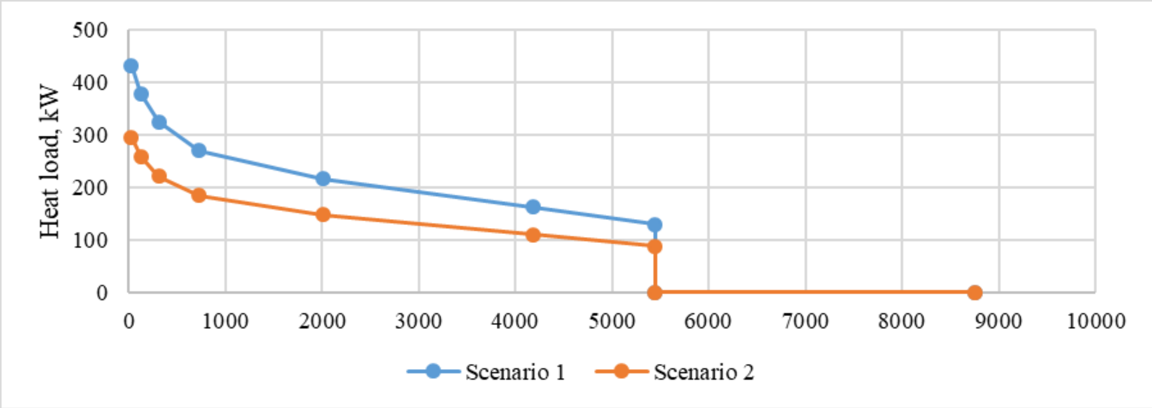


Fig. 3.7.2 Heat load graph in the analyzed scenarios

The supply of heat requires the construction of heating networks. Table 3.7.1 summarizes the information on potential heating networks in each of the scenarios. The first scenario would require the construction of heating networks with a total length of approximately 440 m, while the second would reduce the total length to 221 m. It has been determined that the potential consumption density of Ranka DH in Scenario 1 would be 2.5 MWh/m, but in the second scenario - 3.3 MWh/m.

Table 3.7.1 Potential heating pipe diameters and lengths

Diameter, m	Length, m	
	Scenario 1	Scenario 2
DN100	60	54
DN60	120	244
DN48	260	144
Total	440	221

Two different temperature graphs have been analyzed for Ranka`s DH. Scenario 1 assumes a 75/55 temperature schedule for heating networks and 60/40 for Scenario 2 if the building's internal heating systems and heating units are adjusted accordingly. With the respective configuration of heating networks, it is determined that the heat losses in Scenario 1 would be about 73 MWh or 6% of the produced heat energy, but in Scenario 2, 68 MWh or 8% of the produced heat energy. Table 3.7.2 summarizes information about the input data, assumptions and calculated values of the analyzed scenarios.

Table 3.7.2 Assumptions used in the CBA

Parameter	Existing situation	Scenario 1	Scenario 2
Fuel used	Fire wood	Wood chips	Pellets
Installed boiler power, kW	n/a	430	300
Heat network temperature graph	n/a	75/55	60/40
Length of heating network, m	n/a	440	221
Heat consumption density, MWh / m	2.5	2.5	3.3
Proportion of heat losses,%	n/a	6%	8%

3.7.3. Cost-benefit analysis

The assumptions regarding the performance of the boiler - efficiency and specific electricity consumption are based on previous examples of DH modernization. Other assumptions related to equipment costs are summarized in Table 3.7.3.

Table 3.7.3 Assumptions used in the CBA

Assumption	Costs
Automated heating unit construction, EUR/heating unit	6000
Heating pipeline construction, EUR/m	250
Pellet boiler, EUR/kW	310
Container type boiler house, EUR/kW	116
Woodchip boiler with automatic supply, EUR/kW	600
Accumulation tank cost, EUR / m^3	900
Electricity tariff, EUR/MWh	114

The cost analysis assumes that in the case of Scenario 1, the construction of a woodchip boiler house would be necessary, whereas in Scenario 2, a container-type pellet boiler house would be installed. Investments also include the construction of heating networks and automatic heating units in each building.

Table 3.7.4. Cost-benefit analyses

Parameter	Existing situation	Scenario 1	Scenario 2
Fuel used	Fire wood	Wood chips	Pellets
Installed boiler capacity, kW	n/a	430	300
Volume of accumulation tank, m^3	n/a	5	4
Heat produced, MWh per year	1086	1159	807
Loss of thermal energy, MWh per year	n/a	73	68
Heat consumed, MWh per year	1086	1086	739
Investments	**n/a**	**482500**	**222650**
Boiler house construction/container type boiler house construction, EUR	n/a	50000	34800
Boiler equipment and installation costs, EUR	n/a	258000	93000
Accumulation tank cost, EUR	n/a	60169	n/a
Heating network construction costs, EUR	n/a	4500	3600
Installation of automatic heating units, EUR	n/a	110000	55250
Production costs, EUR per year	**26154**	**25020**	**38873**
Boiler efficiency	0.7	0.85	0.9
Price of fuel	24.5 EUR/m^3	12.0 EUR/m^3	182 EUR/t
Fuel consumption, MWh per year	1551	1363	897
Lowest calorific value	1.50 MWh/m^3	0.71 MWh/m^3	4.3 MWh/t
Fuel consumption (in units)	1034 m^3	1920 m^3	209 t
Total fuel costs, EUR	25287	23039	37953
Specific electricity consumption, kWh / MWh	7.0	15	10
Electricity consumed, MWh per year	8	17	8
Electricity costs	867	1981	920
Staff costs, EUR per year	**3 12 13**	**1 24 85**	**62 43**
Number of employees	10	2	1
Working hours, months	3.5	7	7
Average salary, EUR / month	892	892	892

Investment costs, EUR per year	**n/a**	**2 41 25**	**1 11 33**
Duration of equipment, years	n/a	20	20
Other costs, EUR per year	**20 00**	**30 00**	**30 00**
Total maintenance costs, EUR per year	**59367**	**64630**	**59248**
Specific cost of heat sold, EUR / MWh	**54.67**	**59.51**	**80.19**

In Scenario 1, additional investments would be made by residents of 4 apartment buildings for the construction of an internal heating system, as currently stoves are used for heating. Assuming a specific cost for the internal heating system of around 26 EUR/m², the total investment for consumers would be around 60.169 EUR.

As the cost-benefit analysis shows, the specific heat costs in both scenarios are higher than the corresponding assumptions of the current situation. Although the heat consumption density is higher in Scenario 2, the specific cost of heat is increasing due to the decrease in investment and total consumption. In its turn, if pellets are used under the heat consumption conditions of Scenario 1 and the container-type boiler house is built accordingly, the specific heat costs are higher than in Scenario 1 (76.37 EUR/MWh)

3.7.4. SWOT and risk analyses

The main strengths of Scenario 1 are lower fuel costs compared to Scenario 2 and higher heat consumption resulting in lower specific heat costs. Weaknesses, on the other hand, are related to higher heat losses and necessary investments in the construction of heating networks, as well as the construction of an internal heating system in four apartment buildings. In order to increase the total heat consumption, it is possible to install combined hot water boilers and to centralize hot water during the heating season. The main threat to the development of the DH system would be the reluctance of consumers to connect to the heating system.

Table 3.7.5 SWOT analysis for Scenario 1

Strengths	Weaknesses
Lower fuel costs Lower labour costs Lower specific costs of heat production	Higher heat losses High investment for consumers heating system
Opportunities	**Treats**
Using heat to prepare hot water Attracting external funding	Consumers' reluctance to join DH

The strengths of Scenario 2 are reduced heat transmission losses, lower investments, higher overall system efficiency and higher heat consumption density resulting in a higher heat tariff. However, the main weakness is the higher specific heat costs. Scenario options include further lowering the temperature of the heat carrier in the case of energy efficient buildings or choosing a cheaper fuel. Increased fuel prices and the reluctance of apartment buildings to connect to DH have been identified as threats.

Table 3.7.6. SWOT Analysis for Scenario 2

Strengths	Weaknesses
Reduced heat transmission losses Higher energy efficiency of the overall system Lower investments Higher heat density	Higher costs of energy source Higher specific costs of heat production
Opportunities	**Treats**
Further reduction of heat carrier temperature Use of cheaper plastic pipes in heating networks Attraction of external funding	Increase in fuel prices Reluctance to connect DH Lack of experience in designing low temperature systems

Risk analysis

A simplified risk analysis is provided in Table 3.7.7, which analyzes various risks. Risks have a different impact on each of the analyzed scenarios and those are rated high, medium or low.

Table 3.7.7. Risk analysis

Risk	Possibility	Impact	Actions to avoid the risk
New consumers' hesitation to join DH	High	High	Informing consumers about the operation and costs of DH; Grants for the construction of internal heating systems
Increase in fuel costs	High	Medium	Increase the efficiency of DH to minimize fuel consumption
Insufficient investments	High	High	Attraction of external funds
Inefficient management of heat production and transmission	Medium	High	Monitoring of DH system performance; Continuous system performance improvement

The reluctance of apartment buildings to connect to the DH has been identified as a high probability risk. It would be encouraged by a high heat tariff and other reasons. This risk can be mitigated by ensuring cost-effective operation of DH system, reducing heat tariff as much as possible, and informing consumers about the potential benefits of connecting to DH. As large investments are needed to build a new DH system, a lack of these investments would be a high risk. Increased fuel costs would also pose a high risk. Continuous monitoring and periodic evaluation of DH performance (boiler efficiency, heat carrier temperature, heat loss, etc.) is required to prevent the risk of heat generation and transmission equipment malfunctioning and operating at low efficiency.

Conclusions and recommendations

In the village of Ranka the transition from individual heat supply to district heating system was analyzed. With the relevant investment, consumption and heating route assumptions, the development of DH in a residential area is not economically viable. The risk for optimum system design would be the reluctance of consumers to switch DH system.

It is not economically feasible to combine the 10 apartment buildings of Ranka village with the existing investment, fuel cost and consumption assumptions for the DH system. The development of low-temperature DH can be re-evaluated with other alternatives, for example, if existing municipal heat production facilities are used, a cheaper heat source is identified nearby, etc.

4. District cooling systems

Future energy supply systems are designed to combine both heat and cooling to achieve maximum energy efficiency when aligned. In Latvia, including Gulbene, there is currently no district cooling system installed, however, as the building's cooling energy consumption increases, it is possible to implement such a solution.

There are different solutions to cover the cooling load - individual solutions for a room or building, a set of buildings or a district. Individual solutions are usually split air conditioning systems or more precisely air-to-air heat pumps. In warm climates, to meet the general cooling requirements of buildings, individual air conditioning units reach a coefficient of performance (COP) of between 2.5 and 3.25, electrical refrigeration units have a COP of 3.5 to 5, and electrical refrigeration units with wet cooling towers achieve a COP of up to 6-10. Absorption or electrical refrigerators can achieve much greater efficiency than individual air cooling systems. [41]

Various resources and technologies are used for the production of cold - natural cold energy (water bodies, geothermal energy) or residual cold energy from industrial processes through heat exchangers, excess heat energy used to operate the absorption refrigerator (with or without heat recovery) and cooling. Renewable energy sources such as solar energy, biomass, geothermal energy are widely used in district heating, but the use of these resources in cooling is not widespread. One of the main reasons is that heat production from the above mentioned energy sources is highly efficient. However, in order to produce cold energy, these resources must first be converted into thermal energy and then to electricity or cold through an absorption cooler. This results in relatively higher energy losses.

Cold energy is transmitted with a small temperature difference between the flow and return flow. Consequently, the diameters of the refrigeration pipelines are usually much larger than those of the heat supply network at the same power input. The loss of cold energy in European systems is very small as the ground temperature is almost the same as the flow temperature. The supply of cold energy is provided through an individual substation with or without a heat exchanger. Because of the small differences in temperature, heat exchangers with a larger surface area are used in order not to reduce the transmission capacity of the cooling networks. [42]

The specific cooling consumption differs significantly between different types of buildings. In the service sector buildings (office, educational, hotel, healthcare, retail, sports, etc.) it is much higher than in residential buildings. However, the cold load in these buildings is not the same, as the requirements for the microclimate differ. [43] An analysis of cooling loads in Sweden shows that almost half of the delivered cold energy is consumed in service buildings, while the remainder is consumed in other types of buildings such as technological processes. Average cold power consumption is estimated to be about 45 kWh/m^2 when using district cooling. [42]

From the analyses of building consumption, allocation and usage it has been conclude that currently the development of district cooling system in Gulbene city is not relevant as there are mainly buildings with low cooling demand (municipality buildings, residential buildings, retail buildings etc.).

5. Monitoring of implemented projects and evaluation of results

In the summer of 2018, the Belava DH system reconstruction project was implemented, within which heat networks were rebuilt and optimized, reducing the total length of the heating pipeline and increasing the heat consumption density (see Fig. 5.1.1). The new heating networks use industrially insulated heating lines. Within the framework of the system reconstruction, two insulated buildings from a total of 5 connected buildings have been provided with reduced flow and return temperatures. A new pellet container boiler house with an accumulation tank was installed at DH in Beļava, replacing the technically out-dated wood boiler plant. The buildings are equipped with individual heating units, adapted to the temperature schedule. One of the tasks of the pilot project was to develop a detailed monitoring system to assess the results achieved and identify potential improvements.

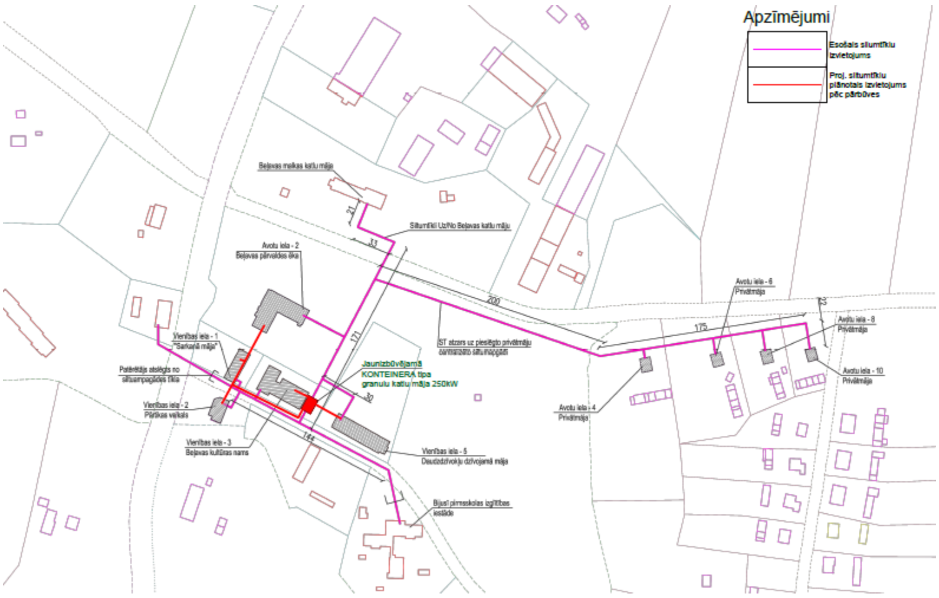


Fig. 5.1.1. Beļava heating network before and after reconstruction

Prior to the reconstruction of the Belava DH, the heat consumption and the amount of heat produced by all connected buildings were not counted, thus it is not possible to accurately estimate the reduction of heat loss.

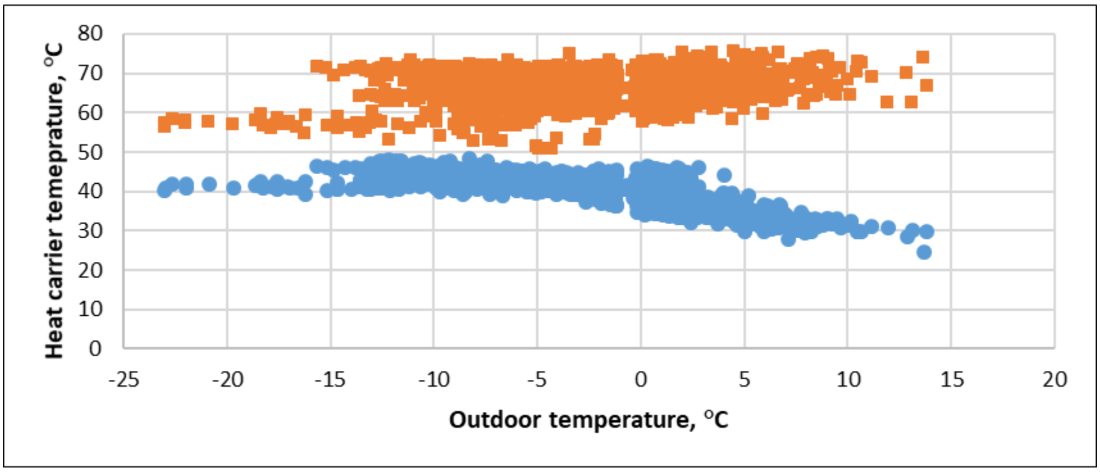


Fig. 5.1.2 Correlation between heat carrier temperature and outdoor air temperature

Fig. 5.1.2 analyzed the supply and return flow temperatures of the boiler house heat carrier depending on the outdoor air temperature. It can be seen that the correlation is weak and the flow temperature is not controlled by the outdoor air temperature.

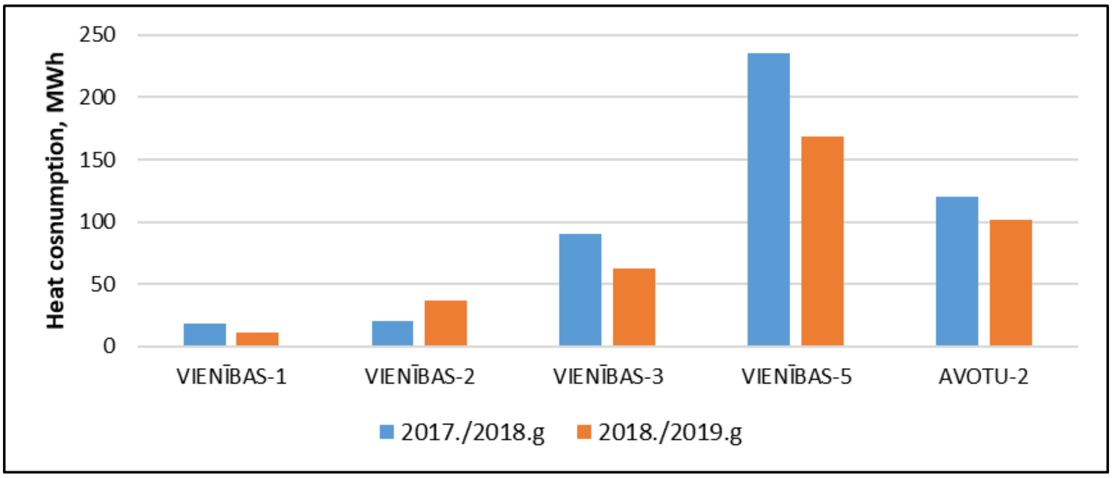


Fig. 5.1.3 Heat consumption of buildings connected to the Beļava DH

Fig. 5.1.3 shows a comparison of heat consumption of buildings before and after reconstruction. It can be seen that the consumption of an apartment building on Vienibas Street 5 has significantly decreased.

In the 2018/2019 heating season, 97.69 tons of wood pellets were consumed and the total amount of heat produced was 398 MWh. The total heat loss during the heating season was 18 MWh or 5% of the produced heat.

There are several main conclusions drawn from the pilot case system in Beļava:

- The pilot case study showed the important role of careful monitoring system. Due to several technical problems it was not possible to obtain precise building heat consumption, supply and return water temperatures for several periods.

- Data shows that the supply flow temperature is not controlled by the outdoor air temperature therefore, the operation of boiler should be improved.
- The modernisation of Beļava DH system did not included the use of cheaper plastic pipes which would reduce the total installation costs. However, it should be considered for other low temperature pilot projects.
- The internal heating system of buildings play crucial role in overall DH system performance. In the rooms with impropriate heating elements (old, unbalanced elements) there were insufficient indoor temperature. However, in the majority of rooms provided with low temperature heating the indoor temperature were above 18°C during the heating season.

Conclusions and recommendations

- The information gathered during the development of the low temperature district heating development strategy, the object surveys carried out and the results of the implemented projects show that the Gulbene Municipality is resolutely moving towards renewable energy-efficient heat supply, which exceeds the average indicators of the Latvian municipalities.
- The main strategic directions for further development of the district heating system (DH) in Gulbene municipality are the gradual lowering of heat carrier temperatures to reduce transmission losses, the efficient use of renewable energy sources and the integration of local surplus heat to increase overall heat efficiency.
- When constructing new heat pipelines, it is necessary to carefully choose the optimum pipeline diameter, because unjustifiably enlarged pipeline diameters are one of the main causes of high heat loss. The average diameter of the pipelines in Gulbene is 146 mm.
- All DH systems should monitor the correlation between heat carrier temperature and outdoor air temperature to optimize supply and return flow temperatures and to provide maximum temperature difference.
- When planning the reconstruction of existing DH systems or the construction of new DH, it is necessary to carefully evaluate the capacity of the heat source to be installed in order to operate it in optimal load mode. When forecasting the future heating load, it is necessary to take into consideration such factors as the potential of new heat consumers, increase of energy efficiency of buildings, changes in the load of buildings, etc.
- The specific heat costs of DH are significantly reduced by the connection of new heat consumers, but consumers are often discouraged by the high investment costs and prejudice against district heating. In order to attract new consumers and increase the overall cost efficiency of the system, it is necessary to carry out information campaigns on the main aspects, costs and development opportunities of DH, as well as to attract external sources of financing for the reconstruction of internal heating systems
- In order to better evaluate the existing heating system, it is necessary to improve the monitoring system. The most important DH indicators that need to be automatically and manually recorded and stored are fuel consumption, produced heat, heat supplied to consumers, heat carrier temperatures, electricity consumption for heat production and transmission.
- The Gulbene city DH shall improve the monitoring system and continuously evaluate the key performance indicators (including supply and return temperatures). Lowering the temperature in Gulbene should be done in the long term - gradually identifying small districts where low temperature DH divisions can be created. Reducing the temperature of the DH should be taken into account when renovating buildings and their heating systems so that their heating surface is suitable for a reduced flow temperature.
- The DH systems of Stari and Lejasciems already operate with a reduced temperature regime, but one of the goals for increasing energy efficiency is to increase the difference between the supply and return temperatures. This can be achieved by changing the heat regulation condi-

tions, installing automated heating units that are adapted to the existing temperature schedule or improving the efficiency of consumer heating systems. Lejasciems DH needs to improve its monitoring system to accurately determine the amount of heat produced and consumed and the amount of heat loss.

- Litene DH should improve the monitoring system and continuously evaluate the most important performance indicators, because at the moment it is not possible to accurately assess the supply and return flow temperature, the amount of heat produced and consumed. In order to evaluate whether it is possible to lower the flow temperature, it is necessary to evaluate the existing temperature regime, to monitor the indoor temperature of the connected buildings and to evaluate the existing heating elements.
- The DH of Lizums should primarily improve the regulation of the existing flow depending on the outdoor temperature. Lizums DH needs to improve its monitoring system to accurately determine the amount of heat produced and consumed and the amount of heat loss. Lowering the temperature should be done in the long term by gradually identifying branches of energy efficient buildings that do not require such high heat carrier temperatures. Reducing the temperature of the DH should be taken into account when renovating existing buildings and their heating systems so that their heating surface is suitable for a reduced flow temperature.
- It is recommended to develop the DH in Galgauska village building (apartment buildings, cultural center, school, parish administration and gym) only if the school and gym are used and it is necessary to maintain optimum indoor temperature. In order to evaluate whether it is possible to reduce the flow temperature, it is necessary to evaluate the temperature of the outgoing and incoming flows of the existing boilers, to monitor the indoor temperatures of the connected buildings, and to evaluate the existing heating elements.
- It is not economically feasible to combine the 10 apartment buildings of Ranka village with the existing investment, fuel cost and consumption assumptions for the DH system. The development of low-temperature DH can be re-evaluated with other alternatives, for example, if existing municipal heat production facilities are used, a cheaper heat source is identified nearby, etc.

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Appendix 1 - The main aspects of flue gas condenser use

The return water from the district heating network is used as heat carrier in the economizer. Upon entering the economiser sections, the water warms up by "picking up" the physical and condensing heat of the flue gas and returns to the total return of the heating network, which combines the return water of the entire heating network [4].

In addition, the flue gas cooling process reduces particulate emissions. The flue gas condenser improves the technic-economic performance in the following directions:

- increases the efficiency of the heat production system;
- increases the purity of the flue gas from particulate matter (reduces emissions);
- reduces the cost price of the heat produced.

The limiting factor that determines the capacity of the flue gas condenser is the heat exchanger supplied and the cross-sectional area of the flue. The capacity of the flue gas condenser depends on several factors:

- return temperatures - the lower the more efficient the capacitor
- fuel moisture - the higher the more efficient the condenser
- flue gas temperatures - the higher the more efficient the condenser

The operating costs are related to the purchase of NaOH injected into the system and the power consumption to operate the additional pumps installed.

The operation of the flue gas condenser would be significantly affected by lowering the temperature regime. The Fig. below shows the relationship between the return temperature of the water in the network and the amount of heat produced by the economizer at a specific boiler house. The equation in the Fig., which describes the increase in efficiency depending on the return temperature, can be used to evaluate the performance of heating systems at different return temperatures.

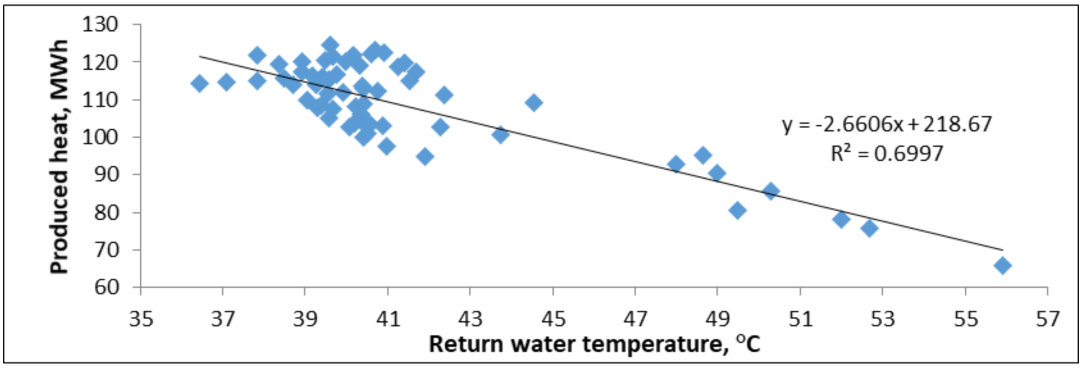

Fig. 3.1.14 Example of flue gas condenser operation depending on return temperature

Appendix 2 –Evaluation of solar energy use for power production in boiler house

Fig. 1 shows the monthly electricity consumption of the boiler house over the last three years. It can be seen that electricity consumption drops significantly in April, May, September and October, when the boiler house is down and most of the heat is purchased.

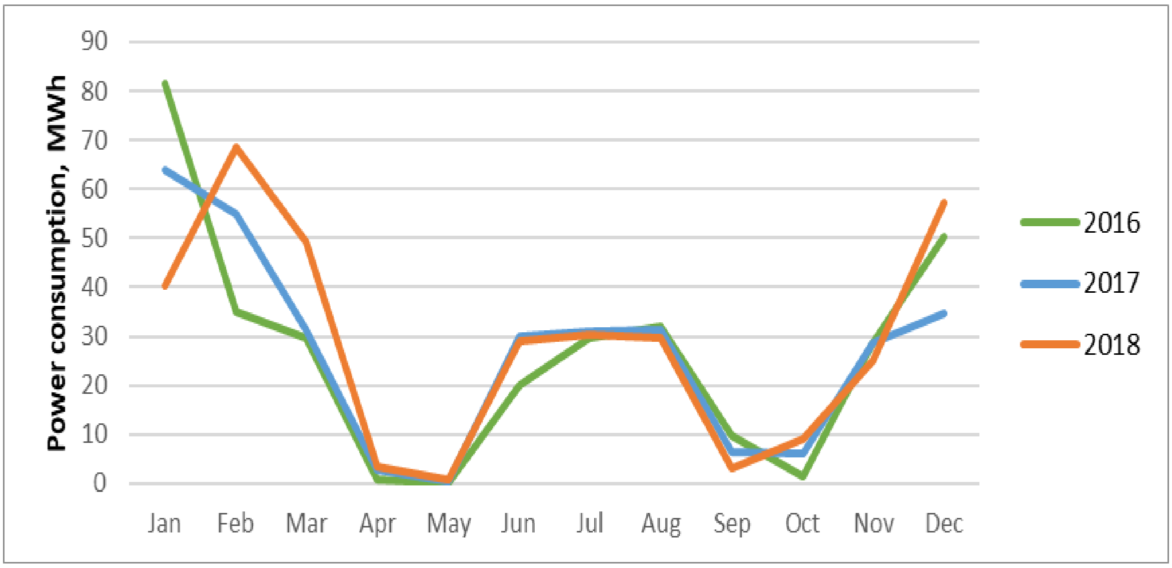

Fig.1 Electricity consumption of Nākotnes Street boiler house

The required solar panel area is calculated based on the monthly consumption of summer boiler house electricity and global solar radiation in the Vidzeme region, which has been determined according to meteorological observations. The optimal output of the solar power plant would be 170 kW, provided by the installation of an effective area of 1000 m^2 panels. Such an area of solar panels with average solar radiation and total efficiency of 17%, could produce 168 MWh of electricity per year. However, as shown in Fig.2, a part (58 MWh) of the electricity produced would be generated as a surplus when the boiler house is closed during spring and autumn. This "surplus" power can be converted into thermal energy to cover the heat load by using an electric boiler or heat pump at a higher cost. Installation of a solar power plant is more cost effective, provided that the boiler house operates continuously without any interruption.

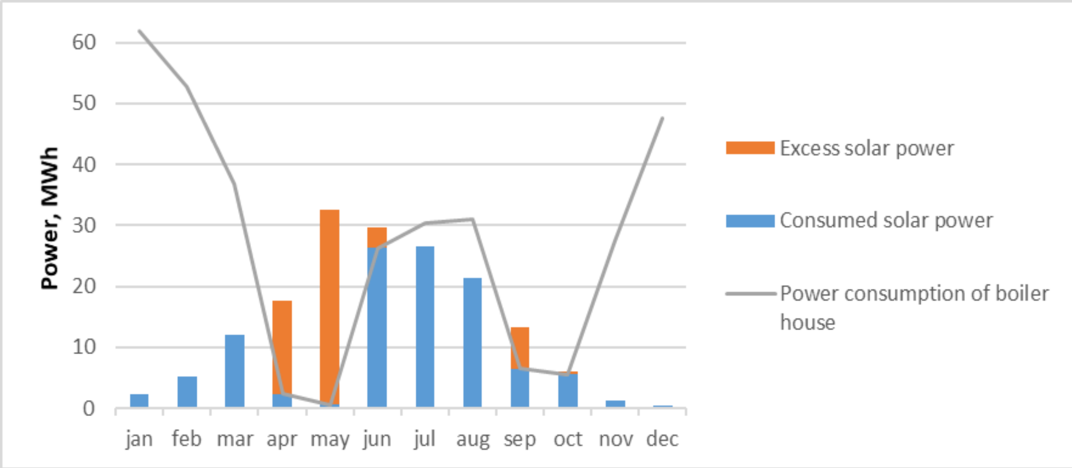

Fig.2 Average Electricity Consumption Boiler House (green line), Solar Electricity Consumption (blue) and surplus solar power (red)