15.07.2020, Riga

Low Temperature District Heating System Technologies for the Baltic Sea Region

Low temperature district heating system implementation options: development of recommendations in addition to the existing energy documents of the Vidzeme Planning Region

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Agreement No.: 1.15/61
Version: 1

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About LowTEMP project:

Within the framework of the Interreg Baltic Sea Region Programme 2014–2020, the Vidzeme Planning Region with partners from nine countries of the Baltic Sea Region, including Riga Technical University's Institute of Energy Systems and Environment and Gulbene Municipality Council, are implementing the project "Low Temperature District Heating System Technologies for the Baltic Sea Region" with the support from the European Regional Development Fund and the European Neighbourhood Instrument. The objective of LowTEMP is to increase energy efficiency by improving knowledge and know-how among stakeholders in the public and private sectors about the planning, installation and management of low temperature district heating systems. Find out more about the project on http://www.vidzeme.lv or http://www.lowtemp.eu/. This document represents only the author's opinion, and the Interreg Baltic Sea Region Programme assumes no responsibility for it, irrespective of the use of information included therein.

CONTENTS

1 Summary

District heating systems are being planned in long-term at the national, regional and municipal levels. In most planning documents, energy efficiency and renewable energy sources (RES) in district heating systems are identified as priorities, with more detailed measures, such as replacement of old boilers, renovation of DHS pipes, etc. However, no specific objectives for the transition to the 4th generation low temperature district heating system (DHS) have been specified, except for the ones indicated in the 3.4 Roadmap to a Sustainable, Low Carbon Economy 2050.

Data on the existing DHS in Vidzeme show that the systems become more efficient, but there is still a low level of energy efficiency in both DHS with RES and with fossil fuels. According to a study [8], the efficiency of the heat source was below 70 % in two DHS systems and below 80 % in four of the 10 systems considered, indicating the need to renew the existing heat sources. According to the Central Statistical Bureau [7], losses in heating networks are generally decreasing. However, a study conducted in Vidzeme [8] found that in most of the examined DHS heat losses were higher than in statistics — in six DHSs out of eight, for which the data were available, losses were above 15 %. This indicates the need for improvements in heating networks.

The pilot projects carried out in Vidzeme, implementing low temperature district heating systems (LTDHS), show significant benefits for consumers. With the long-term implementation of LTDHS, the transition to RES and consumers becoming more energy efficient, total payments of consumers will decrease.

A detailed feasibility study has been performed in Palsmane village. In the last five years, the average losses in heating networks have been 16.32–21.00 %, and the average efficiency factor of heat sources has been approx. 70 %. The study showed a large dispersion of supply and return flow temperatures depending on the outdoor air temperature, which indicates that the automatic controllers are not able to provide the set temperature regime. In the last heating season of 2019/2020, the actual thermal energy consumption in Palsmane was about 20 % lower due to the warmer heating season. After adjusting the data for normal year conditions, it is evident that consumption has been similar.

Existing consumers in Palsmane Village have E and F energy efficiency classes. By increasing the energy efficiency of the consumers' premises, it is expected that the thermal energy tariff will increase significantly, as the heat flux will decrease.

The evaluation considers three strategic scenarios for the implementation of the 4th generation heat supply system. Actions have been specified for both the consumers and the heat sources, with the gradual implementation of low temperature DHSs. The calculations show that the renovation of the old heat source and transmission pipes and adaptation to the 4th generation DHS do not increase the costs compared to the scenario in which the heating would be provided using the existing outdated boilers and pipes.

The main recommendations for the improvement of the regulatory framework are discussed in section 6.1, describing the need to set requirements for internal heating networks of buildings after renovation in order to be compatible with LTDHS. In addition, the transition to a three-part tariff is recommended, which would motivate consumers to renovate buildings faster and switch to lower temperatures. Although most laws and regulations outline the promotion of energy efficiency and the transition to RES, it is necessary to define LTDHS as an achievable goal in planning documents.

In order to implement an LTDHS, it is necessary to revamp systematically the entire DHS, which includes not only technical solutions but also complex DHS energy planning. Transition to the 4th generation district heating system takes place gradually, together with renovation of buildings and transition to RES.

2 Introduction

The Vidzeme Planning Region is participating in the Interreg Baltic Sea Regions project "Low Temperature District Heating System Technologies for the Baltic Sea Region" (LowTEMP). The period of project implementation is 01.10.2017–30.09.2020.

One of the project's LowTEMP activities — "3.4 Development or Improvement of Regional Energy Strategies" — provides for promotion of the use of energy efficient technologies in the construction and renovation of new and existing district heating systems of buildings to ensure reduction of heat losses and economy of resources. District heating systems (DHS) are indispensable. However, these days they often fail to meet energy efficiency standards and are technically obsolete. To reduce heat losses and economise resources, innovative solutions must be integrated in the district heating of new and existing buildings. A work assignment has been made as part of the implementation of the activity:

1. Following the instructions of the Vidzeme Planning Region, to draft a study document: "Low temperature district heating system (LTDHS) implementation options: development of recommendations in addition to the existing energy documents of the Vidzeme Planning Region". Information to be included in this document:

    a. summary of the present situation of district heating systems and evaluation of problems, with description of energy sources included;

    b. evaluation of present and potential availability of district heating system production and alternative energy sources in the sector of public buildings in the Vidzeme Planning Region (VPR);

    c. preparation of recommendations for the district heating energy efficiency improvement measures and betterment of heating service quality;

    d. considering the collected information, preparation of recommendations and potential scenarios for transitioning to the implementation system of low temperature district heating.

2. To present one specific and detailed example of LTDHS in Palsmane, Smiltene Municipality. Potential for public buildings to transition to LTDHS using the existing DHS network:

    a. to describe the evaluation and perform the analysis of risks and benefits;

    b. to forecast changes;

    c. to describe technical solutions and resources required for their implementation;

    d. to give other important information that may have an effect on the heat tariff, heating system management and provision of services in a long term, environment and its protection;

    e. to make proposals for improvement of the heating service.

    f. During the course of work, the Client may update the information that must be included in the strategy.

3 Existing Energy Planning Documents of the Region

District heating systems are being planned in the long term. Different binding planning documents apply to these systems — from national level planning documents (National Energy and Climate Plan — NECP) to regional planning documents of Vidzeme and local municipalities. Documents with the most binding force have been described to consider the existing plans and to prepare recommendations for more successful transitioning to the 4th generation district heating systems (hereinafter, DHS).

3.1 National Energy and Climate Plan 2021–2030 [1]

The ultimate national planning document in the energy sector, also pertaining to heating systems, is the National Energy and Climate Plan. The long-term vision of the plan is to facilitate the development of a sustainable national economy in a sustainable, competitive and safe manner. The long-term goal of the plan is to facilitate the development of a climate-neutral national economy in a sustainable, competitive, cost-efficient and safe manner based on market principles, by improving energy safety and welfare of the society. Implementation of the goal requires:

- Facilitation of efficient use of resources and their self-sufficiency and diversity;
- Significant reduction in the consumption of resources, especially fossil and unsustainable resources, and concurrent transition to the use of sustainable, renewable and innovative resources, ensuring equal access to energy sources for all groups of the society;
- Stimulation of research and innovation that facilitate the development of the sustainable energy sector and mitigation of climate changes.

The directions for action established for achieving the goals of the plan are as follows:

- Improvement of energy efficiency of buildings;
- Improvement of energy efficiency and facilitation of the use of RES technologies in heating and cooling and in industry;
- Facilitation of using zero-emission technologies in electricity production;
- Facilitation of economically justified self-production and self-consumption of energy;
- Improvement of energy efficiency and facilitation of the use of alternative fuels and RES technologies in transportation;
- Energy safety, reduction of energy dependence, complete integration of energy markets and infrastructure upgrade;
- Improvement of solid waste and waste water management efficiency and reduction of GHG emissions;
- Efficient use of resources and reduction of GHG emissions in agriculture;
- Sustainable use of resources and reduction of GHG emissions, and increase of CO_2 capture in the land use, change of land use and forestry sector;
- Facilitation of reduction in the use of fluorinated greenhouse gases (F-gases);
- Tax system greening and improvement of its friendliness towards energy efficiency and RES technologies;
- Information, education and awareness raising for the society.

The main actions and measures in relation to the district heating systems are as follows:

- ensuring reduction of energy consumption and an increase in the use of RES in DHS, ensuring attractiveness of DHS;
- ensuring the use of the most efficient heating system and applied technologies, enhancement of the thermal energy market.

In general, the plan does not specifically define the measures for implementation or support of low temperature DHS, instead aiming at common measures that are like pre-conditions for implementation of the 4th generation and measures for increasing the overall efficiency of DHS, including transition to low temperature DHS.

3.2 Vidzeme Planning Region's Sustainable Development Strategy 2030 [2]

The strategy is a long-term spatial planning document of the Vidzeme Planning Region that includes the long-term development vision of the region, strategic objectives, spatial development perspective and development priorities. The Vidzeme Planning Region's Sustainable Development Strategy 2030 takes into account such planning documents as the Europe 2020 Strategy, EU Strategy for the Baltic Sea Region, Sustainable Development Strategy of Latvia and sustainable development strategies prepared by the Vidzeme Planning Region municipalities, as well as the previously drafted regional planning documents. Municipalities have included the following measures in their development strategies for the area of energy and energy efficiency:

- Energy planning and energy availability — municipalities have mostly emphasised the need for increasing the energy efficiency of public and multi-apartment buildings and revamping of public utility services. To a lesser extent, transition to renewable energy sources has also been emphasised;
- More efficient and repeated use of local resources — municipalities in most cases have emphasised preservation of natural resources and sustainable management of the environment. Only a few municipalities have reflected adaptation to climate changes in their priorities.

The vision of the Vidzeme Planning Region is that the number of businesses efficiently using local resources in a sustainable manner and acting in an environmentally friendly and socially responsible manner will have increased by 2030. Businesses, municipalities and population of the region will be energy-efficient. Diversity of renewable energy sources will have increased, as well as the options of their use and production, and searching for new alternative sources will be ongoing. The region's ability to react to climate changes will have increased.

- The following items that may be constituents of low temperature DHS have been included in the vision's adaptation solutions:
- increase in the energy efficiency of public and private buildings and businesses;
- efficient and repeated use of local resources;

The strategy also outlines solutions required for ensuring the availability of energy sources and sufficiency of capacity for populated areas in Vidzeme, which include the use of alternative energy sources and development of renewable energy sources. These two solutions may become integral constituents in creating low temperature DHSs.

The following priority long-term directions in the field of energy and energy efficiency must be included in the Vidzeme Planning Region's strategy: Economics — IAS4: Sustainable, Energy-efficient Economics. The following objectives have been defined for this long-term direction:

- 4.1 Increase in energy efficiency and use of renewable energy sources
- 4.2 Sustainable management of the endowment of natural resources.

Achievement of the objectives is envisioned with the following solutions:

- Efficient energy planning in the region by improving coordination of the energy planning and management, informing the public and involving it in the energy planning and implementation of EE and RES solutions;
- Promotion of energy efficiency increase in public and private buildings and businesses;
- Promotion of efficient and repeated use of local resources (incl. by developing waste recycling solutions and promoting cooperation between educational and research institutions and entrepreneurs with regard to implementation of solutions of re-use of resources in the region);
- Promotion of efficient use of wood and biomass resources (incl. by promoting cooperation between educational and research institutions and entrepreneurs with regard to development of clean technologies in the region and by promoting the development of smart specialisation potential in the field of wood and biomass use).

Similarly to the National Energy and Climate Plan 2021–2030, also the Vidzeme Planning Region's Sustainable Development Strategy 2030 does not directly stipulate the transition to the 4th generation heating systems. However, the strategy includes preconditions for the implementation of the 4th generation, such as renovation of buildings, overhaul of heating systems, transition to renewable energy sources.

3.3 Vidzeme Planning Region's Energy Vision [3]

The VPR's Energy Vision 2050 envisions that by 2050 the region will use all available RES and have implemented energy efficiency measures, economics will be based on circular economy principles, maintaining competitiveness and the increase in welfare. CO_2 emissions will have been reduced by approx. 70 % compared to 2015, and the reduction will be effective in all national economy sectors. The local government will be implementing an efficient management policy, ensuring sustainable management of the endowment of natural resources and ability to react to climate changes.

To ensure reduction in CO_2 emissions, energy consumption will have to be reduced by at least 25 % compared to the reference scenario, and thermal energy and electricity will be generated almost exclusively from RES. Obstacles and challenges to achieving the objectives are policy and planning, regulatory and legal framework, infrastructure, social and economic factors, communication with the society and target groups. Development of a comprehensive and high-quality energy information system and cross-sectoral cooperation networks that cover all kinds of energy-related information is required, so that to enable management of planned measures and facilitate cooperation among the stakeholders. The vision conforms to the national and EU objectives and promotes reduction of impact on climate.

The vision provides for reduction in energy consumption by at least 25 %, which goes hand in hand with low temperature district heating systems. To achieve the objectives of the Vidzeme Planning Region's Energy Vision, the Roadmap to a Sustainable, Low Carbon Economy 2050 has been prepared, with priority directions and objectives outlined in detail.

3.4 Roadmap to a Sustainable, Low Carbon Economy 2050 [4]

The roadmap has been developed under the PANEL 2050 project. Initially, a vision of the development of the energy sector in the VPR was created and objectives for 2050 were set based on the analysis of the current situation and definition of alternative scenarios. In the result, the following priority directions for action were considered:

- regional energy information and communication system;
- energy efficiency: public buildings;
- energy efficiency: residential buildings;
- bioenergy.

The alternative scenarios are the following:

- Base Scenario, in which the CO_2 reduction set forth by the region is not achieved;
- Energy Efficiency Scenario, in which energy efficiency measures are applied more than in the Base Scenario;
- Target Scenario, in which RES are used more than in the Energy Efficiency Scenario.

Among the considered scenarios, the Target Scenario is the most important one, since it will help achieve the 70 % reduction of CO_2 emissions envisioned for 2050. The following conditions have been determined for achieving the results set forth in the Target Scenario:

- urban heating employs both efficient district heating and decentralised heating technologies;
- thermal energy systems employ high efficiency bioenergy technologies;
- buildings conform to nearly zero-energy consumption by using smart technologies;
- urban residential and public buildings employ high efficiency district heating systems with integrated feedback;
- buildings combine different efficient energy-saving technologies, energy production micro-technologies and energy accumulation technologies and solutions;
- buildings employ decentralised solar energy and heat pump technologies;
- smart technologies and solutions implemented in the buildings present a leading example;
- energy management system meets the demand and the life style of residents.

The following measures that must be applied to ensure the consumption of bioenergy sources are related to the heat supply system:

- merging of boiler houses in a unified bioenergy heating network and closing of small boiler houses, where possible, is required;
- efficient transmission of obtained thermal energy, which requires replacement heating mains to reduce thermal energy loss;

- connection of new consumers to the networks;
- in the event of producing decentralised thermal energy, inefficient boilers must be replaced with efficient ones.

The roadmap envisions transition to the 4th generation and more advanced heating systems by 2050. The roadmap indicates that already now the district heating system shows a tendency of transitioning to the use the heat-transfer agent (water) at a lower temperature in the network, which will become more popular in the future. However, new ways to ensure the necessary heating without combustion of fuels and by preferring decentralised use of local RES should also be sought. Noteworthy, the roadmap also defines steps prior to the implementation of the 4th generation heating systems, including high heat endurance standards and high efficiency for buildings. The roadmap provides for partial DHS transition to the 4th generation systems, allowing for the 3rd generation DHS in places where renovation and heat insulation of buildings is economically unjustified.

3.5 Guidelines: Promotion of Sustainable Energy in Central and Eastern Europe [5]

Sustainable energy is an important item on the EU agenda, as it reduces carbon emission levels and impact on climate and has a beneficial impact also in other areas. In order to achieve sustainable energy objectives, inter-sectoral cooperation and development of comprehensive and coordinated policy instruments are required. Awareness and actions on the levels of both the states and the society are important. Special attention must be drawn to promotion of the public awareness, because the Baltic States have a high risk of poverty and social exclusion (Eurostat, 2017), and, after the collapse of the Soviet economy, consumer culture and way of thinking have developed, and people are interested in acquiring everything as cheap and fast as possible, and they may not be able to appreciate the long-term benefits. Presenting the existing positive examples to people and governments is important.

The guidelines Promotion of Sustainable Energy in Central and Eastern Europe provide instructions for organisations on how to implement efficient energy promotion activities, attract stakeholders, develop roadmaps, energy visions and action plans, create appropriate advertisements and communications and attract funds.

The guidelines give recommendations for local energy roadmaps, where household heating systems must be among the considered aspects. Local governments are the decision-makers on heating solutions. Therefore, their detailed consideration in roadmaps, development programmes and strategies is advisable.

4 District Heating Systems in Vidzeme Planning Region

District heating system is very extensively used in the municipalities of the Vidzeme Planning Region. The largest district heating systems (>1–5 MW) are in cities/towns, and the smallest (e.g., some multi-apartment and municipality buildings) — in smaller populated areas [6]. In most cases, public buildings are connected to the city/town district heating systems. Public buildings are included in the section "other consumers" indicated in Figure 4.1.

According to the data of the Central Statistical Bureau, the produced quantity of thermal energy has increased on annual basis (see Fig. 4.1).

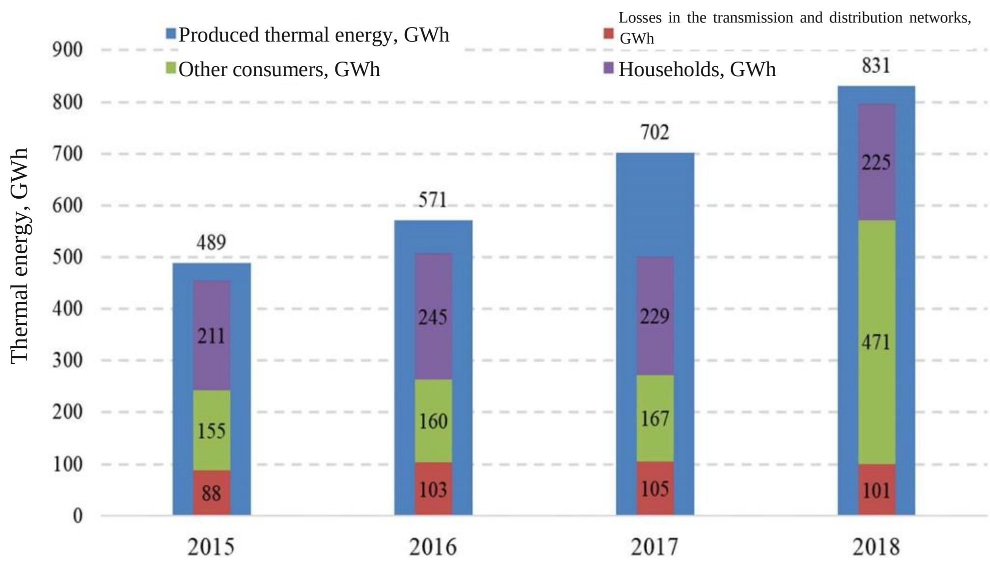


Fig. 4.1. Thermal energy balance in Vidzeme Region [7]

Data present shortage in 2017, where individual consumers together do not constitute 100 % of the total specified quantity of produced thermal energy. Significant increase for other consumers was observed in 2018.

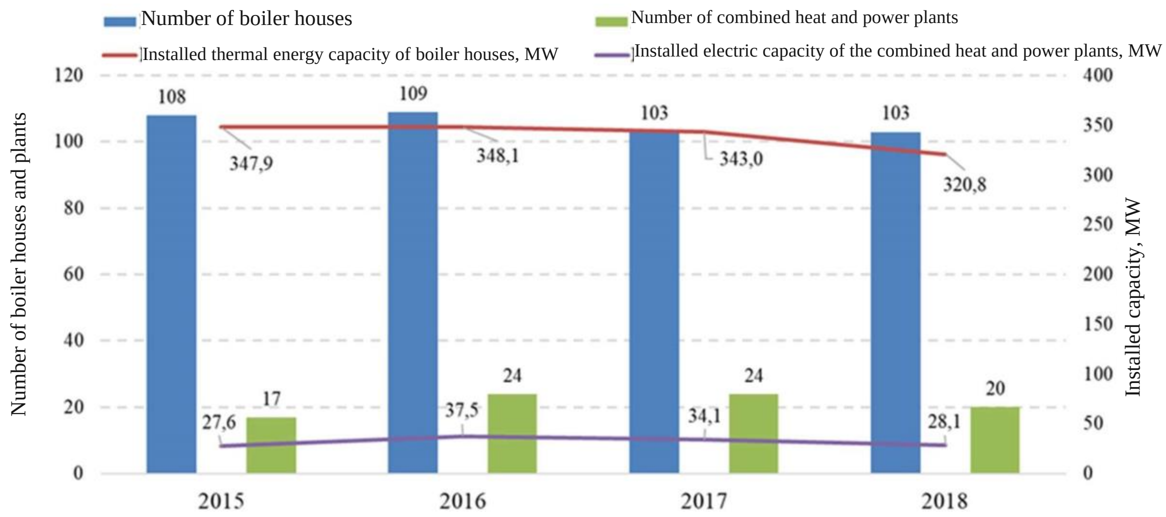


Fig. 4.2. Number and capacity of boiler houses and combined heat and power plants in Vidzeme Region [7]

Figure 4.2 shows that the installed capacity of boiler houses and combined heat and power plants in the Vidzeme Region has decreased in 2018, constituting 320.8 MW and 28.1 MW, respectively. Considering the increasing amounts of the produced thermal energy, the conclusion is that the installed capacity is being used more efficiently — the number of working hours at full capacity has increased.

The data of the Central Statistical Bureau of 2015 allow observing a significant reduction of transmission and distribution losses in heating mains [7]. Established heat losses in the region dropped from 18.0 % to 12.2 % (see Fig. 4.3).

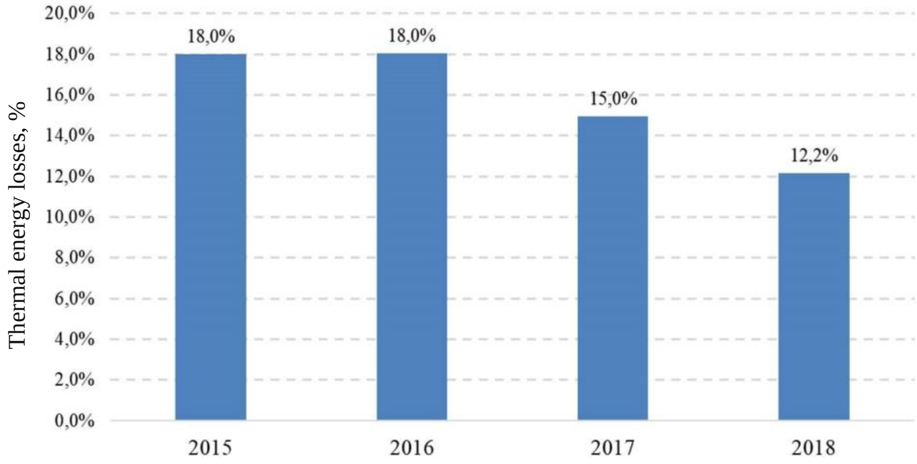
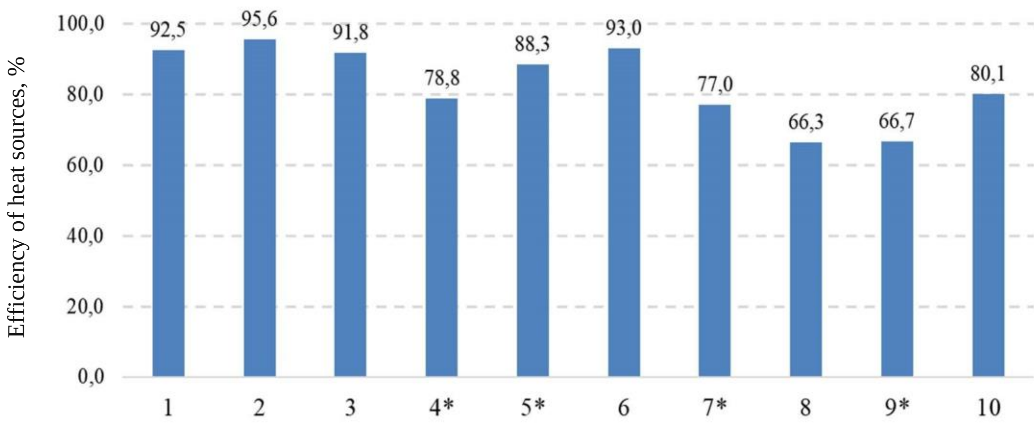


Fig. 4.3. Thermal energy losses in Vidzeme Region [7]

Although statistical data may not be fully describing the current situation, they indicate important tendencies in the region, namely, that heat losses in heating networks decrease significantly. The study of the Vidzeme Planning Region shows heat losses varying from 9.05 % to 21.24 % in the region's DHSs. The largest heat loss is in the system with the lowest heat load, i.e. 21.24 % and 0.79 kW/m, respectively, whereas the smallest heat loss of 9.05 % is in the DHS with one of the highest heat loads — 1.66 kW/m [8].

According to the regional data collection and analysis, a large share of DHSs does not achieve the increasing energy efficiency standards and often are technically obsolete. This is also supported by the fuel use efficiency of the studied heat sources, as presented in Figure 4.4 [8].



combined heat and power plants marked with *

Fig. 4.4. Efficiency of the use of fuels of heat sources [8]

The study concludes that the studied DHSs do not show a clear correlation between the type of the used fuel and the efficiency of the plant. Two plants (3rd and 4th) using biofuel and natural gas in similar proportions (approx. 50/50 and 40/60) have considerably different efficiency factors, i.e. 91.77 % and 78.78 %, respectively. Biofuel is also being used in the DHSs with the highest and the lowest efficiencies. The study examined 10 district heating systems about which information was received. Among the examined DHSs, 74 % use renewable energy sources, while 26 % use natural gas [8].

Overall, the distribution may differ in the Vidzeme Region, because the aforementioned study acquired information about 10 DHSs. Still, it is evident that the majority of heat sources use renewable energy sources. The study also considers the consumers of thermal energy of each DHS, showing that the percentage of renovated multi-apartment buildings in most of the systems is low. In the DHSs covered by the study, the percentage fluctuates between 1 % and 19.6 %. The study analysed the readiness of the 10 DHSs of the Vidzeme Region for the implementation of low temperature DHS and found an average readiness [8].

Taking into account the high proportion of renewable energy sources and availability of DHS, solar energy with prior detailed evaluation of each building would be the most suitable additional renewable source for public buildings in the Vidzeme Planning Region.

5 Low Temperature District Heating Systems in Vidzeme Planning Region

The Vidzeme Planning Region has approved 4th generation heating systems within the scope of the project "Low Temperature District Heating System Technologies for the Baltic Sea Region". They are being used both in Gulbene and Aluksne (*Alūksne*).

5.1 Low Temperature Heating System Reconstruction in Belava (*Beļava*) Village, Gulbene Municipality

The boiler house constructed in 1969 in Belava Village, Gulbene Municipality, was operated as long as until spring 2018. The boiler house and the more than 40 years old heating mains were unable to ensure heat supply meeting the current requirements. Equipment was old, outdated and with a low efficiency factor. In addition, heat loss in the heating mains constituted approx. 40 %, also affecting the thermal energy tariff. The boiler house operated a firewood boiler with a 1 MW capacity without meters for the thermal energy produced and transmitted to the network. The boiler's efficiency was 50–60 %. The boiler house provided heating to five buildings, two of which had thermal insulation. The thermal energy tariff for all buildings was calculated based on area m^2, which meant that some residents had their payments higher or lower than the actual consumption [9, 10].

Implementation of the project "Low Temperature District Heating System Technologies for the Baltic Sea Region" (LowTEMP) begun in 2017. Within the project, a five times smaller in size but much more efficient boiler house was installed in Belava Village before the heating season of 2018/2019. Compared to the old boiler house, the efficiency of the new boiler is 90 %. The reconstruction resulted in a fully automated pellet/woodchip boiler with a capacity of 199 kW installed. Reconstruction of the heating mains using new pre-insulated pipes considerably reduced the heat losses. The total length of constructed district heating system networks: 230 m, of which 111 m is the LowTEMP main [9, 10].

Low temperature district heating is provided to the administration building and the community house of Belava Civil Parish. Both buildings have thermal insulation, which is an important precondition for ensuring district heating with a low temperature of the heat-transfer agent, conforming to the 4th generation heating systems. Reconstruction of the heating mains using new pre-insulated pipes considerably reduced the heat losses. After implementation of the project, the heat loss is approx. 3–7 % [9, 10].

The DHS system provides heat for Belava Village buildings in the total area of 4,067 m^2, of which 2,337 m^2 are heated with low temperature. Each consumer has their own heating unit where they can set the desired temperature using an electronic controller. The system has remote data reading. Thermal energy production costs have been reduced by 40 %. The tariff has been reduced from 82.94 EUR/MWh excl. VAT (season 2017/2018) to 69.07 EUR/MWh excl. VAT (season 2019/2020). According to the information from the local government of Gulbene Municipality, the total costs of the project constitute EUR 160,335.01 excl. VAT, which have been allocated as follows:

- works and materials related to heating mains — EUR 59,524.23 excl. VAT;
- works and materials related to the boiler and individual heating units (IHU) — EUR 100,810.78 excl. VAT.

Investments in the DHS improved the overall efficiency of the system and enabled replacement of the obsolete equipment, which would be required anyway. Additional investments for transition to the 4th generation heating system contributed to ensuring lower heat losses in the heating mains and significantly reduced the electricity consumption for circulating the heat-transfer agent. Electricity consumption dropped to 10.4 kWh/MWh. In similar boiler houses, this rate usually constitutes approx. 20–25 kWh/MWh [9, 10].

5.2 Low Temperature District Heating System Technologies in Pre-school Educational Institution Pienenite (*Pienenīte*) in Aluksne (*Alūksne*), Aluksne Municipality

In the Vidzeme Region, low temperature technologies have been tested also in Aluksne, where construction works were carried out in the pre-school educational institution's heating unit room in summer 2019, which resulted in ensuring heating for several groups of premises in the low temperature mode since the beginning of the heating season. Instead of 70/50 degrees, 46/36 degrees are now circulating in the radiators. During the heating system upgrade, a data monitoring system was installed to collect data of the indoor temperature and humidity level and the consumption of thermal energy, electricity and water in the building. The new heating unit and monitoring system allows lowering of the indoor temperature at night. The collected data show that the energy consumption, in comparison with the same heating period in 2018, dropped by 35.3 % [11]. The reduction is expressed as actual reduction without data adjustment according to climate conditions.

5.3 Evaluation of Low Temperature DHS Implementation in Palsmane, Smiltene Municipality

Subject to the assignment of the Client, Palsmane Village was used as an example of district heating system in the Vidzeme Region, where thermal energy balance includes both renewable and fossil fuel energy sources. Recommendations for implementation of low temperature DHS in the Vidzeme Planning Region will be based on an alternative evaluation carried out in Palsmane Village. Evaluation of Palsmane Village has been carried out as reflected in Figure 5.1.

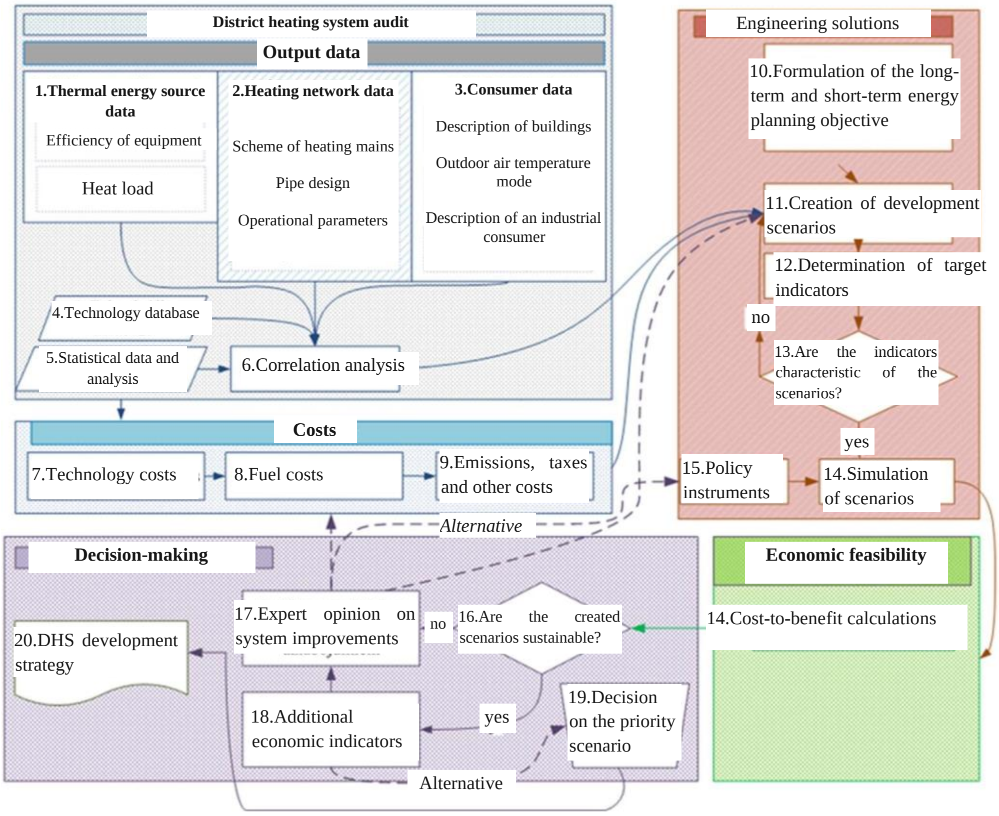


Figure 5.3. Methodology of evaluation of Palsmane Village — adapted from the doctoral thesis of J. Ziemele [27].

5.3.1 Evaluation of the Present Situation

Palsmane is located in Smiltene Municipality, approx. 17 km from Smiltene Town Centre. According to the data of the Office of Citizenship and Migration Affairs, the population of Palsmane Civil Parish constituted 861 residents as of 01.01.2020. Until March 2020, two boiler houses were used to produce thermal energy in Palsmane Village:

- boiler house of Palsmane Village;
- boiler house of Smiltene Municipality Special Primary School (Figure 5.3.1).

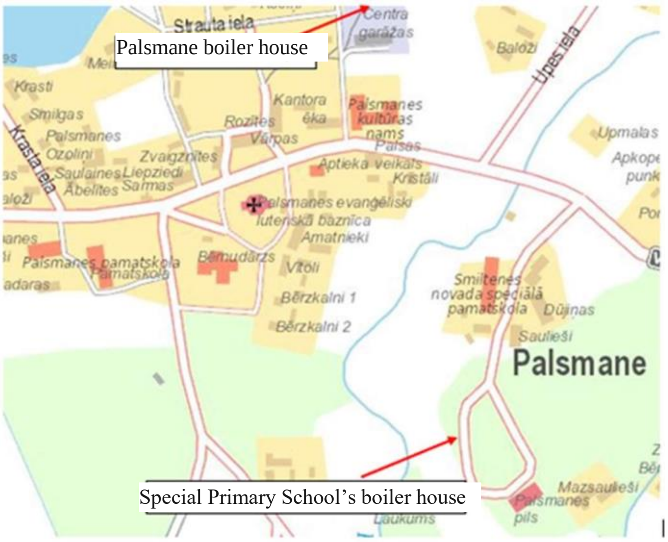


Figure 5.3.1. Locations of boiler houses in Palsmane Village

Three boilers have been installed in the Palsmane Village boiler house for production of thermal energy, and the used fuels are natural gas and wood (firewood). Table 5.3.1 summarises data about the boilers installed in the boiler house.

Table 5.3.1

List of boilers in the Palsmane boiler house

No.	Boiler series and/or manufacturer	Boiler capacity, kW	Fuel type
1	GUILLOT YGNIS (France)	540	natural gas
2	AK-1000, Komforts JSC (*AS*)	1,000	firewood
3	AK – 600, Komforts JSC (*AS*)	600	firewood

Usually, heating is ensured by operating one boiler, while the other two are kept in reserve. In the coldest winter days, two boilers are used. During the audit of the boiler house, it was established that the boiler house manager has been keeping regular records of the fuels and the produced thermal energy. Natural gas is measured using a meter (Figure 5.3.2), and wood — by the calculated consumption. Firewood is stored outdoors, uncovered in open air (Figure 5.3.2).

Figure 5.3.2. Fuels used in the Palsmane Village boiler house: natural gas and wood

The analysis of district heating (DH) operation used data from the last five heating seasons. Table 5.3.2 summarises the main thermal energy production data of the Palsmane Central Boiler House from the last five heating seasons. Table 5.3.2.

Data of the Palsmane Central Boiler House from the last five heating seasons

Parameter	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020
Thermal energy produced, MWh per year	1,271.30	1,399.70	1,370.60	1,218.30	1,099.40
Thermal energy delivered to consumers, MWh per year	1,045.60	1,105.80	1,097.90	970.60	920.0
Distribution heat losses, MWh per year	225.70	293.90	272.7	247.7	179.40
Specific distribution heat losses, %	17.75	21.00	19.90	20.33	16.32
Firewood consumption, densely stacked, m^3 per year	914.21	863.5	773.00	666.85	706.02
Natural gas consumption, MWh per year	208.72	170.79	176.91	168.22	223.52

Due to different firewood quality, the energy produced by fuel cannot be determined precisely. The calculations show that the average efficiency factor of the boiler house is approx. 70 %, which is below the standard required by Cabinet Regulation No. 243 regarding the Energy Efficiency Requirements for Centralised Heating Supply Systems in the Possession of a Licenced or Registered Energy Supply Merchant, and the Procedures for Conformity Inspection Thereof (75 % must be ensured if the facility uses solid fuel) [12]. Considering the wear and tear of the equipment and also that the Palsmane Central Boiler House does not have a licence for thermal energy production, the current efficiency factor may be considered appropriate for the equipment installed in the boiler house.

Data regarding the thermal energy produced in the last five heating seasons are compared in Figure 5.3.3.

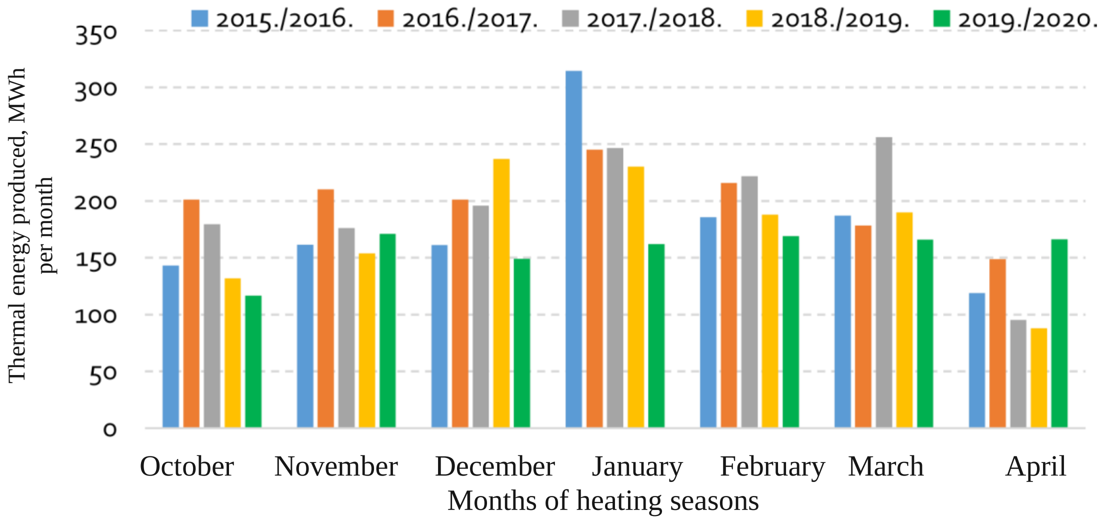


Figure 5.3.3. Thermal energy produced during the last five heating seasons

The average quantity of thermal energy produced by the Palsmane Village boiler house during the last five heating seasons is 1,257.9 MWh per year (Figure 5.3.4). The Palsmane boiler house provides consumers with heating only, no hot water supply is provided.

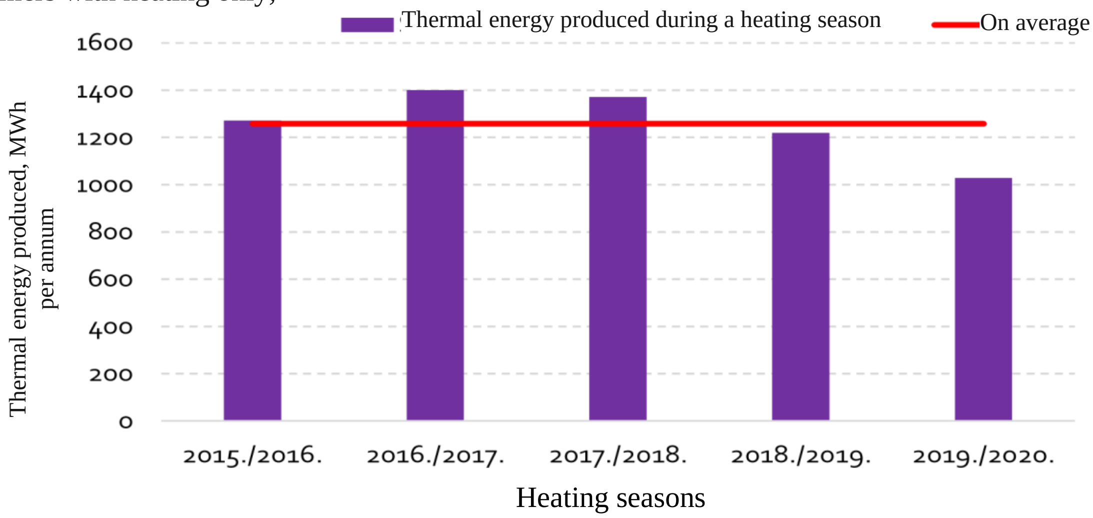


Figure 5.3.4. Thermal energy annually produced during the last five heating seasons

In recent years, a tendency of reduction in the quantity of thermal energy produced has been observed, and it is due to several factors. Firstly, three private houses were disconnected from the DH in spring 2019 — Gravas, Kastanas (*Kastaņas*) and Zemites (*Zemītes*), Secondly, an automated data reading system was installed in Palsmane Village to allow the energy manager to monitor both thermal energy production (boiler house meter data) and the largest thermal energy consumers, which are three: Palsmane kindergarten, culture centre and Palsmane school (Figure 5.3.5).

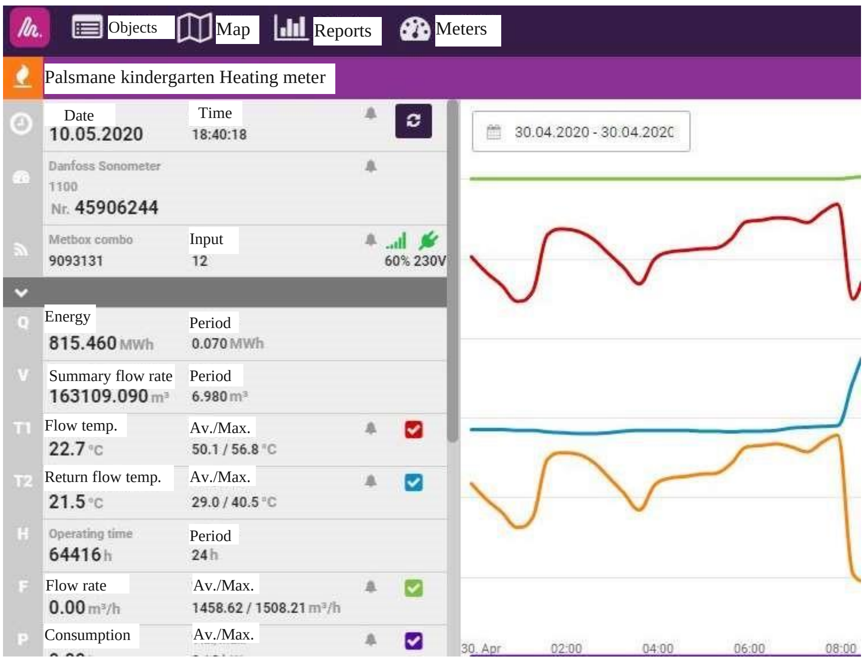


Figure 5.3.5. Remote heating meter reading system

As a result, the energy manager can analyse correlations among several system parameters:

- thermal energy consumption or thermal energy produced, MWh;
- total heat-transfer agent flow, m^3/h;
- heat-transfer agent's supply temperature, °C;
- heat-transfer agent's return temperature, °C;
- and other parameters.

The Palsmane Village strategic development direction for heating envisions a gradual reduction of heating network temperature. Several low temperature regimes have been used in pilot projects implemented globally as described in the scientific literature [13-16]. The heat-transfer agent's supply temperature in heating systems may range between 70 °C and 50 °C, and the return temperature — between 40 °C and 25 °C. Dalla Rosa et al. [13], when modelling a DH system in Canada, compared in detail different temperature regimes and concluded that a reduction of the supply temperature below 70 °C should necessitate a cost/benefit analysis.

Temperature regime in a distribution network

In the Palsmane boiler house, the supply temperature of the approved temperature regime ranges between 95 °C with the outdoor air temperature of -20 °C and 46 °C with the outdoor air temperature of +8 °C. The supply temperature is adjusted depending on the outdoor air temperature and without factoring in the changes in thermal energy consumption over a day. The temperature regime 2019/2020 was different and complied with the low 70/60 temperature regime.

Figure 5.3.6 presents both graphs and additionally the 65/50 low temperature regime, which is possible in Palsmane. The difference between both low temperature regimes is due to the differences between the supply and the return flows. During the heating season 2019/2020, Δt of the Palsmane boiler house was 7 °C, while the examples found in literature present higher Δt.

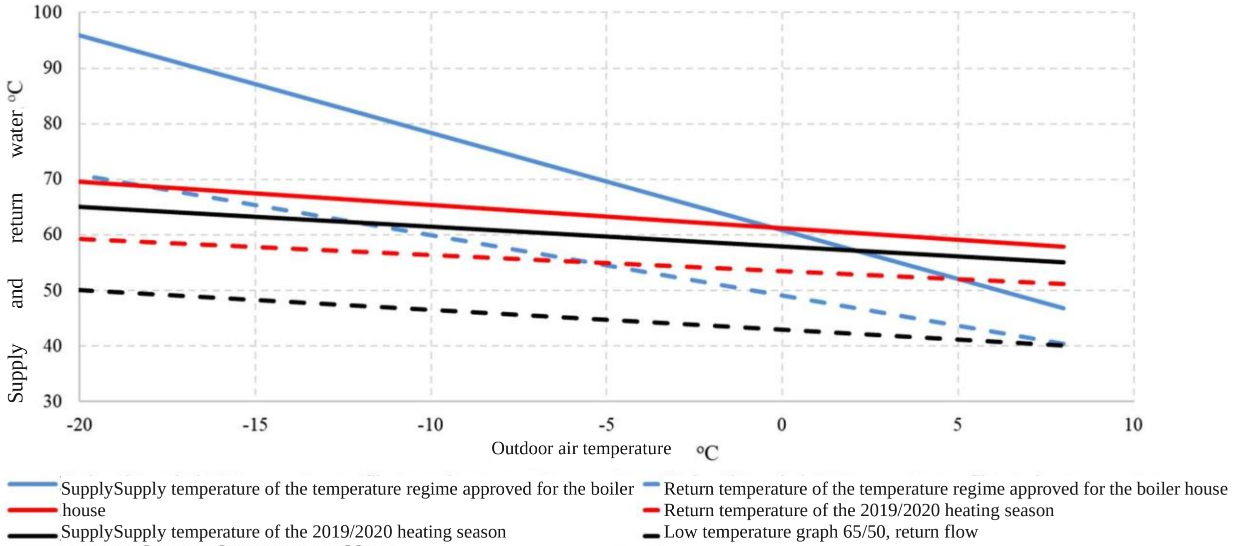


Figure 5.3.6. Temperature regimes of the boiler house in the 2019/2020 heating season as compared to the low-temperature regime

Correlation of the heat-transfer agent's supply and return temperatures with the outdoor air temperature in the 2019/2020 heating season is presented in Figure 5.3.7.

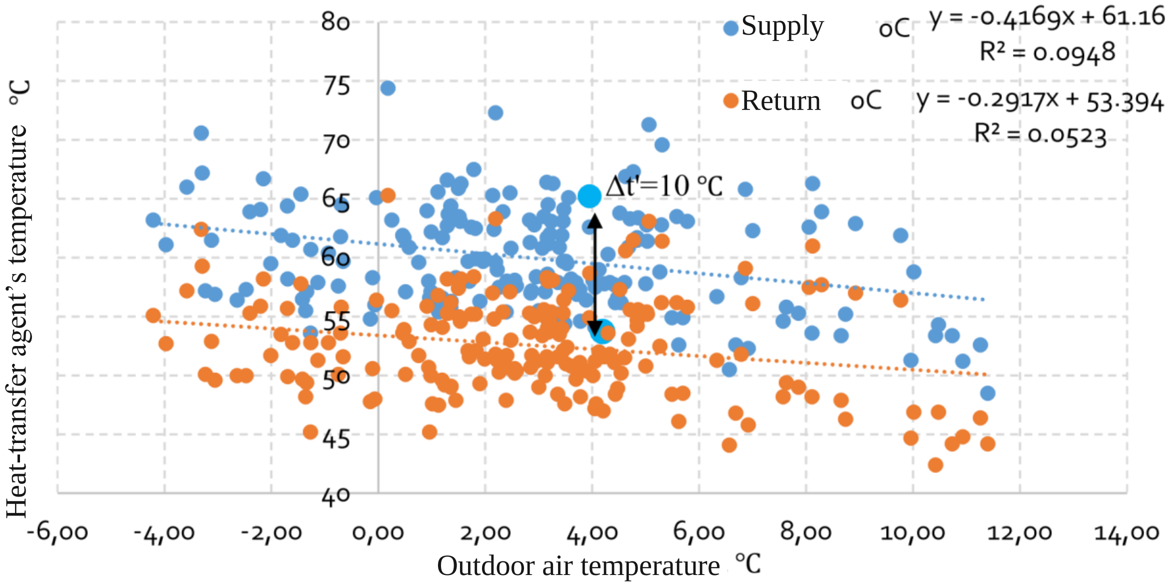
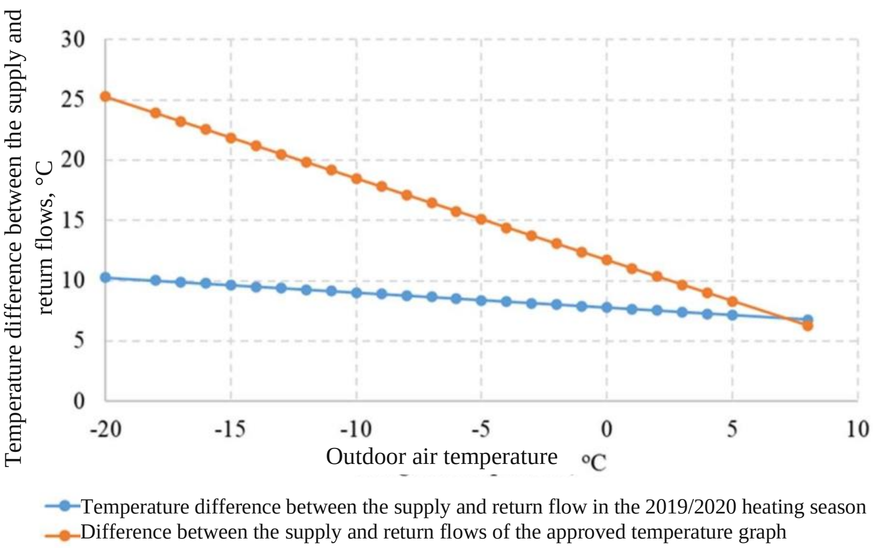


Figure 5.3.7. Correlation of the supply and return temperatures with the outdoor air temperature in the 2019/2020 heating season

The correlation factor's square value R^2 presents the degree of how precisely the obtained correlation equation describes the analysed variables. The obtained correlation equations have low R^2 values, which means that the distribution of supply and return temperatures is significant. Considering that both supply and return temperature fluctuations of the heat-transfer agent at the same outdoor air temperatures are significant (e.g., in Figure 5.3.7, Δt' = 10 °C at the outdoor air temperature of +4 °C), it must be concluded that **the automation does not work properly** in the boiler house failing to ensure conformity of the supply temperature of the heat-transfer agent to the outdoor air temperature. The cause of this is the firewood combustion boilers AK – 1000 and AK – 600 installed in the boiler house. Their technology does not allow for sufficient control of the combustion process. A comparison of the approved temperature regime of the Palsmane boiler house



and the lowered temperature regime Δt of the 2019/2020 heating season is presented in Figure 5.3.8.

Figure 5.3.8. Comparison of the approved temperature regime of the Palsmane boiler house and the lowered temperature regime Δt of the 2019/2020 heating season

The volume of consumed thermal energy (Q_{con}) is determined using the equation (1), where the heat-transfer agent's flow rate G [m^3/h] may be reduced by increasing the temperature difference between the supply and return Δt, on condition that Q_{con} remains unchanged [6]:

$$Q_{con} = G \downarrow c\Delta t \uparrow \quad (1)$$

As a result, it would be profitable for the producer of heating if the consumer turned down heat more and cooled down the return flow more. Pumping of the heat-transfer agent consumes electricity. The equation (1) clearly shows that an increase in the temperature Δt difference would require consuming less electricity, since the flow rate of the heat-transfer agent would reduce. And vice versa, because a higher flow rate of the heat-transfer agent means larger electricity consumption. Therefore, optimum costs may be determined for each heating system, taking into account heat loss and electricity costs. The optimum solution depends on several parameters:

- temperature regime in networks;
- heating solutions on the consumer side, which affect the temperature difference (connection type, IHU equipment, heating elements, etc.);
- fuel costs and heat tariff;
- electricity costs;
- heating network configuration and length.

Analysing the data from the Palsmane boiler house and assuming the electricity cost to be 149.3 EUR/MWh excl. VAT and the heat tariff 47.01 EUR/MWh excl. VAT, the optimum solution was evaluated (Figure 5.3.9).

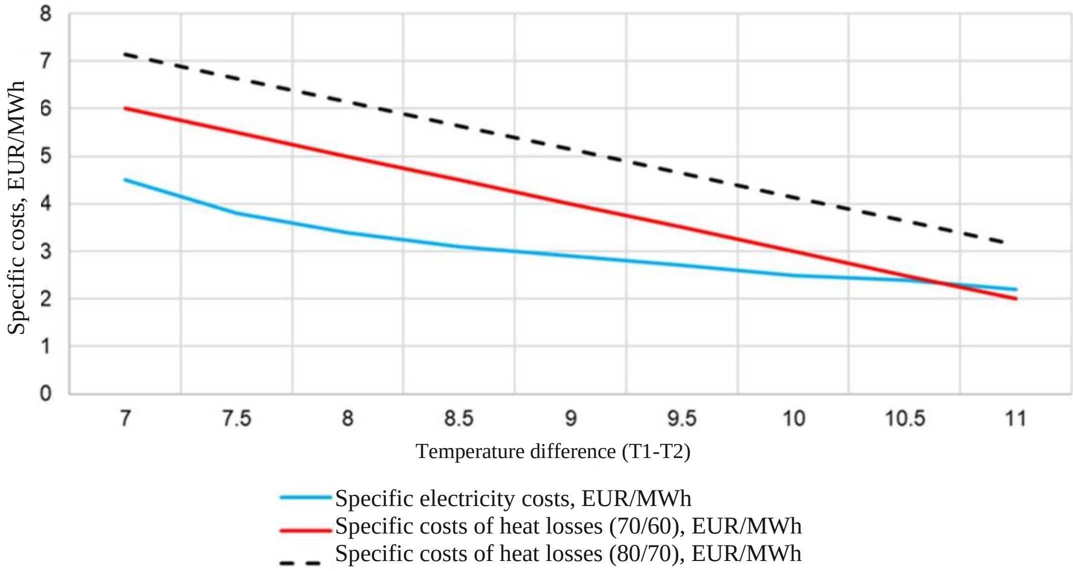


Figure 5.3.9. Comparison of heat losses and electricity costs

Every specific heating system requires individual analysis. For the Palsmane heating system, the optimum solution would be attaining a Δt of approx. 10 °C at the outdoor air temperature of -0.20 °C, which is the average temperature during the heating period (Priekuli (*Priekuļi*), 197 days of heating and average outdoor air temperature -0.20 °C according to LBN 003-19). In the last heating season, Δt was 7.5 °C. Increasing the supply and return temperatures, e.g., up to 80/70, the costs of heat loss will increase by equal Δt values.

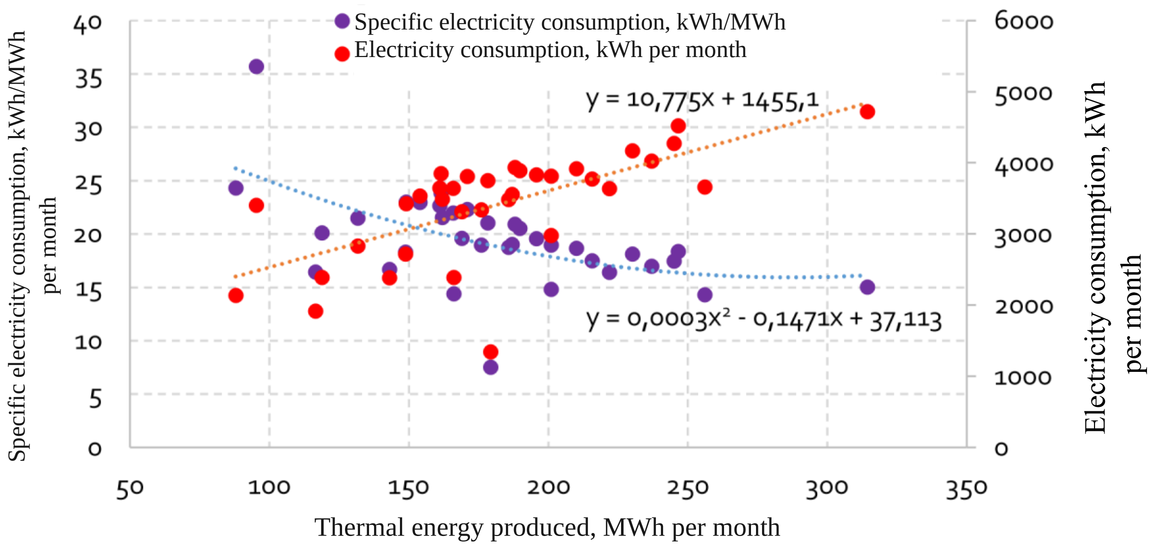


Figure 5.3.10. Electricity consumption in the Palsmane boiler house

Analysing the operation of the heating system, it was found that the electricity consumption increases when the volume of produced thermal energy increases and the specific consumption of electricity reduces (Figure 5.3.10). Consequently, the more thermal energy the heat source produces, the relatively lower costs may be attained.

Consumers

During the operation of the district heating system, 15 objects were connected to it in Palsmane Village. The list of buildings connected to the Palsmane boiler house and their descriptions are presented in Table 5.3.3. Three private houses – Gravas, Kastanas and Zemites – were disconnected from the DH in 2019. Two objects have been connected to the district boiler house from 2020: the Special Primary Boarding School and the multi-apartment house Dujinas (*Dūjiņas*).

Table 5.3.3.

List of buildings connected to the Palsmane boiler house

No.	Name	Heated area, m^2	Building description
1	Special Primary School dormitory	2,289.8	Municipal institution Building connected in March 2020
2	Primary School	802.8	Municipal institutions. Connected objects
3	Madaras	131.4	

4	Primary Boarding School	846.0	
5	Kindergarten	1,192.7	
6	Culture centre	895.0	
No.	Name	Heated area, m^2	Building description
7	Office building	268.0	Legal entity. Connected object
8	Rozites (*Rozītes*)	784.6	Multi-apartment residential buildings. Connected objects
9	Smaidas	1,360.5	
10	Varpas (*Vārpas*)	548.9	
11	Zvaigznites (*Zvaigznītes*)	374.8	
12	Dujinas	902.6	Multi-apartment residential building Building connected in March 2020
13	Gravas	135.2	Private houses. Buildings disconnected in April 2019
14	Kastanas	82.8	
15	Zemites	100.8	
16	Total as of April 2020	10,265.7	Total as of April 2020

In April 2020, the total heated area was 10,265.7 m^2. The thermal energy consumption in Palsmane Village by years is presented in Figure 5.3.11, showing a reduction in the last two heating seasons.

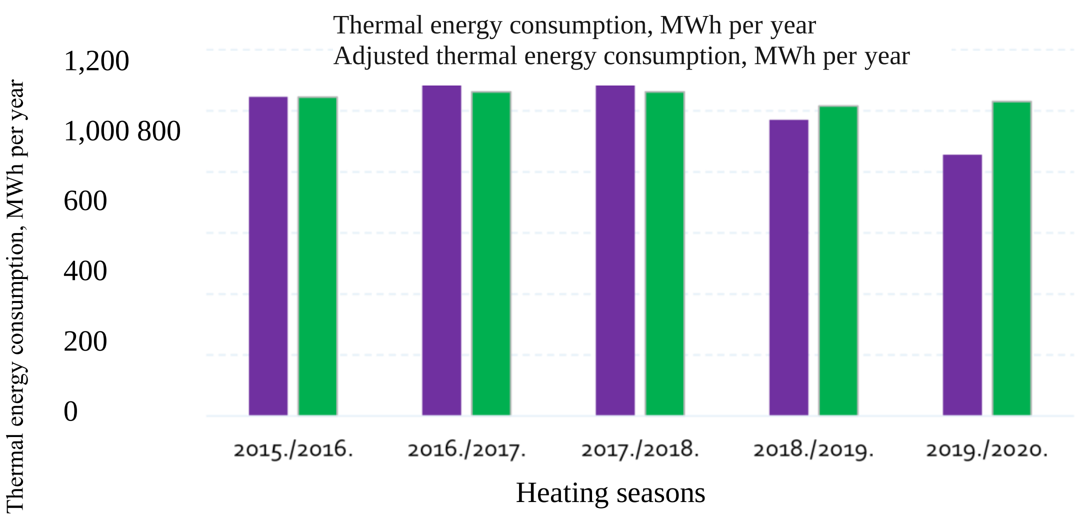


Figure 5.3.11. Thermal energy consumptions in Palsmane Village

The Palsmane boiler house provides consumers with heating only, no hot water supply is provided. During the last two heating seasons, the actual thermal energy consumption decreased due to warmer weather — the thermal energy consumption adjusted for the same conditions has been equal. Palsmane Village thermal energy consumptions adjusted by considering climate data and duration of heating seasons (Table 5.3.4) have been summarised in Table 5.3.11.

Table 5.3.4

Calculation of climate adjusted ratios

Heating season	Duration of heating season, days	Average outdoor air temperature, °C	Adjusted ratio
2015/2016	212	1.22	0.99
2016/2017	212	0.45	0.96
2017/2018	211	0.61	0.97
2018/2019	206	1.53	1.05
2019/2020	195	3.04	1.20

According to Table 5.3.4, during the last two heating seasons, not only the duration of the heating season was shorter, but also the outdoor air temperature was higher. Figure 5.3.12 summarises the thermal energy consumptions of the last five heating seasons of the heating supply objects Dujinas and Special Primary School connected to the Palsmane Village network in March 2020.

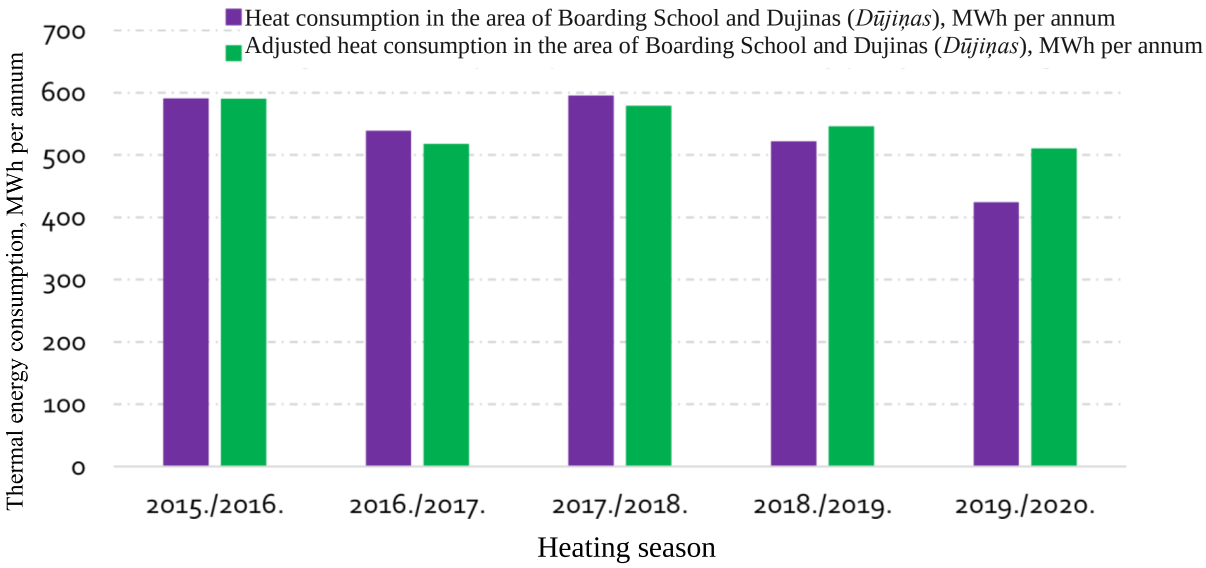


Figure 5.3.12. Thermal energy consumptions of Palsmane Boarding School and Dujinas multi-apartment building

Also, the actual thermal energy consumption of Palsmane Boarding School and Dujinas multi-apartment building has considerably decreased during the last year, while the adjusted thermal energy consumption was equal to the heating season of 2016/2017.

The kindergarten in Palsmane Village was renovated in 2009 using the funding from the Climate Change Financial Instrument (CCFI). Within the scope of the renovation project, the following works have been carried out: heating insulation of building foundations, external walls, roof and ground floor flooring structures. All window and door units were replaced with heat-preserving three-chamber windows with wooden frames and metal linings. The in-house ventilation systems were fully renovated. The heating system of the building remained unchanged. Pipe connections with temperature controllers were fitted to the radiators, where possible. Solar collectors with an area of 20 m^2 were connected to the existing utility networks and placed on the building's roof. The heat from the solar collector is directed to the water tank and used for heating of the building when necessary (Figure 5.3.13). As a result, the kindergarten building became more energy efficient, and the average specific thermal energy consumption for heating during the last five heating seasons constituted 36 kWh/m^2 per year (marked green in Figure 5.3.14).

Figure 5.3.13. Solar collector system

Specific thermal energy consumption of buildings is presented in Figure 5.3.14. According to Figure 5.3.14, the average specific thermal energy consumption for heating of four buildings (marked blue) ranges between 100 and 150 kWh/m^2 per year, while for seven heating objects (marked with yellow) it ranges between 150 and 200 kWh/m^2 per year. The average specific thermal energy consumption of one private house — Kastanas (marked red), which is now disconnected from the DH, was 208 kWh/m^2 per year. All heating objects have independent connection schemes and individual heating units with recording meters installed that allow heat consumption to be monitored.

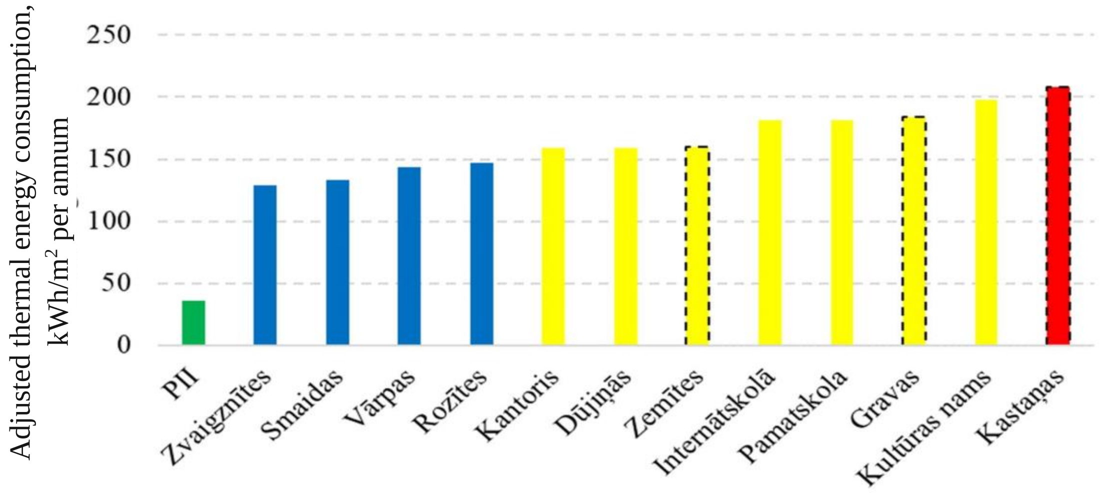


Figure 5.3.14. The average specific adjusted thermal energy consumption for heating in the last five heating seasons (disconnected private houses marked with a dashed line)

According to Figure 5.3.14, the majority of buildings has high consumption — blue colour matches energy efficiency class E, yellow colour — efficiency class F. Analysing energy efficiency of all heating objects, it is clear that they, except for the kindergarten, need to implement measures to increase energy efficiency. Determination of the required energy efficiency measures would require an energy audit for each building. Data show that consumers in Palsmane Village are not energy efficient and have a high potential for the reduction of heat consumption and load.

Distribution network

A new ductless heating main was designed and constructed in 2019–2020 to connect both boiler houses, and heat supply from the Palsmane boiler house to Special Primary School and Dujinas residential building began in March 2020. The heating main of Palsmane Village was fully renovated in 2009. During renovation, pre-insulated pipes were laid in ground using a ductless technology. Figure 5.3.15 presents the scheme of the district heating main (according to the Palsmane Village energy manager's data). The heating main marked with the red line was renovated in 2009, its length is 820.3 m (pipe pair length), and its average diameter is 77.7 mm.

The buildings disconnected in spring 2019 are marked with the red dashed line in Figure 5.3.15. The new main crossing the Palsa River and leading to the dormitory of Special Primary School of Smiltene Municipality and Dujinas buildings was put into operation in 2020; it is marked with the purple line in Figure 5.3.15. The length of the heat main is 475.2 m (pipe pair length), and its average diameter is 88 mm.

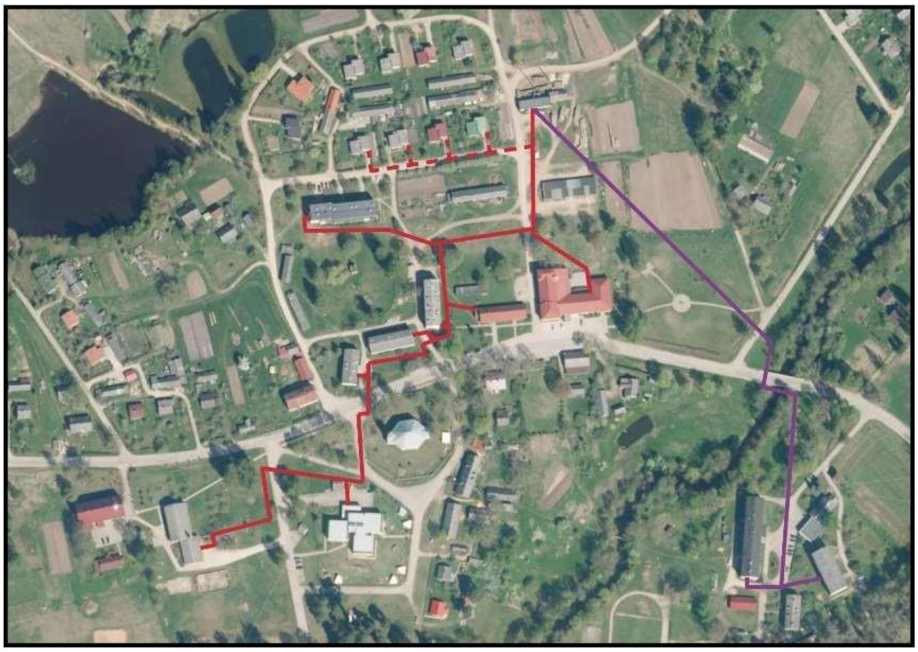


Figure 5.3.15. Scheme of the heat main in Palsmane Village

Combining the data of the two mains, the total length of the heat mains is 1,295.5 m, and the average diameter is 81.5 mm.

Heat load curve

The total nominal installed capacity of boilers is 2.14 MW. A heat load curve was obtained by summarising the data of the last five heating seasons (Figure 5.3.16).

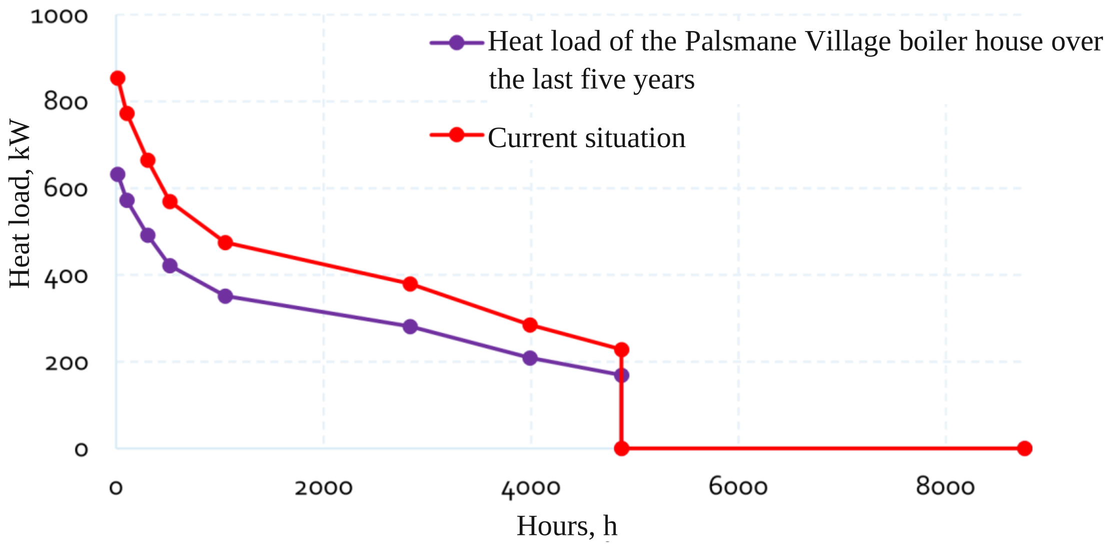


Figure 5.3.16. Palsmane Village heat load curve

The maximum capacity that would be necessary for heating in Palsmane Village before connecting the heating consumers Dujinas and Special Boarding School is 630 kW. This means that the operation of either one AK-1000 firewood boiler by Komforts JSC (*AS*), or the natural gas boiler together with the AK-600 firewood boiler would be required in the coldest winter days.

Since in 2020 the heating objects Dujinas and Special Boarding School were connected to the Palsmane Village boiler house, the heat load climbed to 854 kW (Figure 5.3.16, red line).

District heating energy efficiency rates and indicators in Palsmane Village

Palsmane Village energy supply strategy should be based on the efficiency rates and indicators of the existing DHS. To make the plan and scenarios of the energy efficiency measures to be implemented, the parameters of the existing system should be analysed, which depend on the specific properties of the heating scheme, installed equipment, development objectives, available resources and other parameters. Analysis of the DH in Palsmane used several technological parameters and indicators summarised in Table 5.3.4.

Table 5.3.4.

Technological parameters and indicators

No.	Indicator	Designation, formula	Measurement unit
1	Thermal energy consumed	Q_{cons}	MWh per year
2	Thermal energy produced and transmitted within network	Q_{prod}	MWh per year
3	Primary energy consumption	Q_{prim}	MWh per year
4	Annual average efficiency factor of the boiler house	$\eta=Q_{prod}\cdot 100\%/Q_{prim}$	%
5	Specific primary energy consumption of the DHS — describes its overall efficiency	$K_{prim}=Q_{cons}\cdot 100\%/Q_{prim}$	%
6	Annual average heat losses in networks	$K_{loss}=(Q_{prod}-O_{cons})\cdot 100\%/Q_{prod}$	%
7	Electricity consumed	E	kWh per year
8	Specific electricity consumption	$E_e=E/Q_{prod}$	kWh/MWh
9	Supply temperature	T1	°C
10	Return temperature	T2	°C

Depending on the range of installed technologies, the list of technological parameters and indicators used for the analysis may be expanded. Additionally, it should be noted that parameters and indicators may be both quantitative and qualitative.

Parameters of the last five heating seasons of the Palsmane Village boiler house are summarised in Figure 5.3.17. The average thermal energy consumption (sold volume) in the buildings during the last five heating seasons was 1,014 MWh per year, the volume of produced thermal energy — 1,272 MWh per year, the consumption of primary energy sources (input energy quantity) — 1,652 MWh per year. The direction for improving the energy efficiency of the Palsmane DH system is related to the reduction in the volume of all types of thermal energy (Figure 5.3.17).

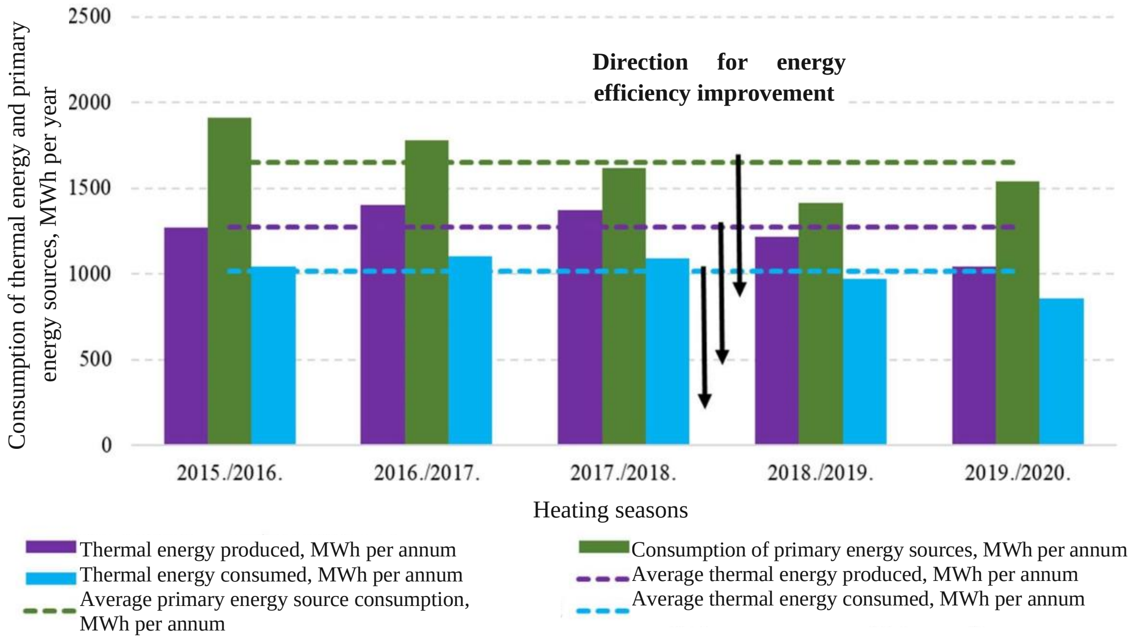


Figure 5.3.17. Parameters of the Palsmane Village boiler house

Efficiency indicators of the existing DH system are presented in Figure 5.3.18. During the last five heating seasons, the average efficiency factor of the boiler house was 76.79 %, the specific primary energy consumption — 61.72 %, heat loss in networks — 19.5 %. It should be noted that after the connection of the Special Primary School dormitory and Dujinas buildings and the increase in the volume of consumed heat, heat losses in the networks dropped to 13.93 %.

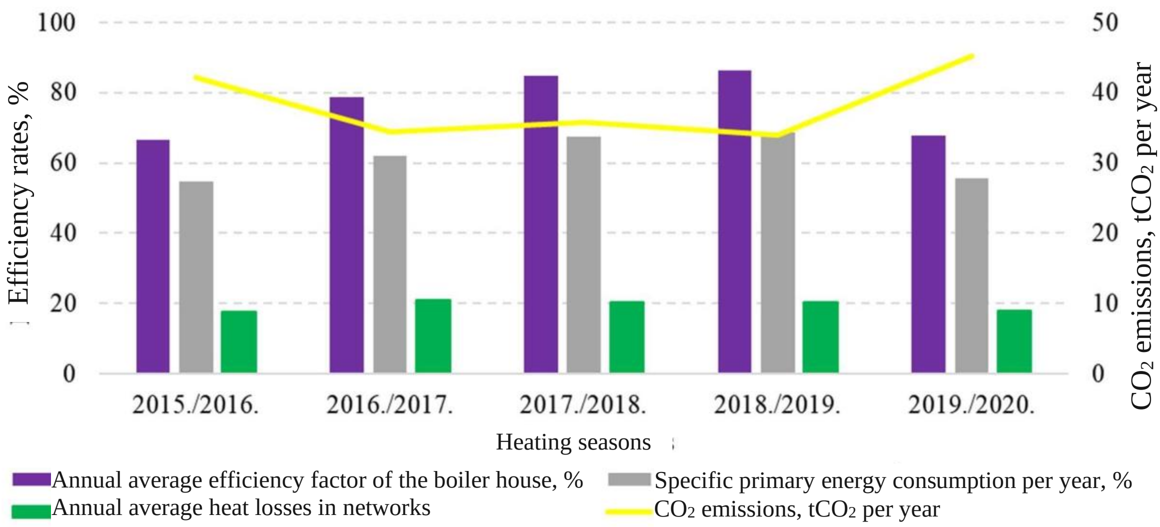


Figure 5.3.18. Palsmane DH indicators

Cabinet Regulation No. 243 regarding the Energy Efficiency Requirements for Centralised Heating Supply Systems in the Possession of a Licenced or Registered Energy Supply Merchant, and the Procedures for Conformity Inspection Thereof establishes the boiler efficiency factors to be attained in heating. In equipment, where solid biomass is used as fuel, the attainable efficiency factor is 75 %, in the case of natural gas combustion — 92 %. Considering the standards laid out in laws and regulations and the data about the last five heating seasons, the average weighed efficiency factor should be 76.95 % (considering the respective proportion of biomass and natural gas consumption), which is close to the present factor. However, since 88 % of the thermal energy is produced by firewood combustion, the obtained comparatively high efficiency factor creates doubt about correct recording of the fuel wood.

Rational use of energy sources is related not only to reduction in fuel consumption, but also to technologies used in the heat source and their emissions. The objectives of the European Union (EU) Strategy on Heating and Cooling [18] and EU Clean Energy for All Europeans Package [19] pertain to the increase in proportion of renewable energy sources, which is particularly important for Latvia, its energy independence in particular. Transition from fossil fuel and natural gas to renewable energy sources, i.e. wood, solar energy and other technologies, reduces CO_2 emissions.

When evaluating DH development scenarios, special attention must be drawn to the environment and climate indicators (Table 5.3.5).

Table 5.3.5.

Environment and climate indicators

No.	Indicator	Designation, formula	Measurement unit
1	Natural gas emission factor	R_{ng}	t_{CO2}/MWh
2	CO_2 emissions	EM	t_{CO2} per year
3	Proportion of renewable energy sources	PRES	%

Reduction of greenhouse gas emissions achieved in thermal energy production by transition from fossil energy sources to renewable energy sources is determined by the CO_2 emission factor and the quantity of consumed fuel. CO_2 emissions created by the Palsmane boiler house are summarised in Figure 5.3.19 and correlate with the proportion of natural gas in the fuel used in the boiler house. For example, the heating season of 2019/2020 had the highest proportion of natural gas in the last five heating seasons, and therefore the level of CO_2 emissions is the highest as well — 45.15 tCO_2 per year (Figure 5.3.18).

The consumer determines the demand for thermal energy, but actually the volume of thermal energy required for heating is most affected by climate conditions and thermodynamic parameters of building envelopes. Depending on the time of construction of buildings, the standards for envelopes varied. The buildings constructed in the previous century do not comply with the current standards and should be renovated. To assess the energy efficiency level of buildings, specific thermal energy consumption for heating, which is the institutional indicator, is being used (Table 5.3.6).

Table 5.3.6.

Institutional indicators

No.	Indicator	Designation, formula	Measurement unit
1	Specific thermal energy consumption for heating	S_{heat}	kWh/m^2 per year

2	Target specific thermal energy consumption for heating	SM_{heat}	kWh/m^2 per year
3	Tax for the quantity of carbon dioxide (CO_2) emissions	N_{CO2}	EUR/tCO_2

Analysing the thermal energy consumption of Palsmane buildings, it was found that the average specific thermal energy consumption for the heating of seven objects ranges between 150 and 200 kWh/m^2 per year, and for one heating object it is above 200 kWh/m^2 per year (Figure 5.3.14). The group of institutional indicators also includes taxes, which the government may use to either support or restrict the DH development processes. The group of economic indicators is important in describing the impact (Table 5.3.7).

Table 5.3.7.

Economic indicators

No.	Indicator	Designation, formula	Measurement unit
1	Thermal energy tariff	T	EUR/MWh
2	Fuel costs	K	EUR/MWh
3	Electricity price	E_{el}	EUR/MWh
4	Production costs	T_{prod}	EUR/MWh
5	Transmission and distribution costs	T_{trans}	EUR/MWh
6	Sale costs	T_{sale}	EUR/MWh
7	Technology costs	C_{tech}	EUR/MWh

The range of economic indicators may be expanded. Thermal energy tariff is one of the key indicators. On 23 December 2013, the heat tariff of 47.01 EUR/MWh excl. VAT was established for the Palsmane boiler house by a decision of the Smiltene Municipality Council, and this tariff has remained unchanged until May 2020. The heat tariff for Special Boarding School and Dujinas residential building was 62.64 EUR/MWh excl. VAT before the objects were connected to the Palsmane central boiler house. According to the data of Palsmane, the average price of natural gas in 2019/2020 was 27.38 EUR/MWh excl. VAT, and the firewood price — 14.80 EUR/MWh excl. VAT.

District heating also has a significant social impact. E.g., the use of wood — a local energy source — supports local production, thereby not only increasing the GDP but also employing the local labour force. This reduces the social tensions. Social indicators were not considered in this study.

5.3.2 Description of Strategic Development Directions

The energy plan and associated DH development strategies are based on several parameters or indicators, which describe the implementation of renewable energy sources and measures for increasing the energy efficiency. Most frequently, thermal energy tariff is considered as the main indicator, which combines economically substantiated implementation of both the renewable energy sources and the measures for increasing the energy efficiency. The energy planning process, which has been described in detail in Ekodoma LLC (*SIA*) contract work "Collection and Analysis of Data Necessary for Heat Supply Planning. District Heating Long-term Trends until 2030" [20], consists of several interrelated stages:

- raw data collection and analysis;
- selection of engineering solutions;
- climatic and environmental substantiation;
- economic feasibility;
- socioeconomic feasibility.

Directive 2012/27/EU of the European Parliament and of the Council on energy efficiency envisions that DH must be based on cost-to-benefit analysis [21], and therefore it has been considered in this study when comparing the development scenarios.

The future of DH is definitely with the 4th generation systems (Figure 5.3.19) [22]. The present DH systems are the 3rd generation systems, which are typical for closed heating networks, sometimes with a comparatively high temperature of the heat-transfer agent in the transmission networks and increased thermal energy consumption in buildings. Main indicators describing transition from one generation to the next one:

- all types of system efficiency increase;
- lowering of heat-transfer agent's temperature;
- expanding of the range of technological solutions used for thermal energy production;
- transition to renewable energy sources in the 4th generation.

A heating system consists of three interrelated stages: heat source, transmission and distribution systems and consumers. Implementation of a low temperature regime in heating networks should be evaluated in the context of the entire system, because its implementation also affects the equipment and schemes of the other heating stages.

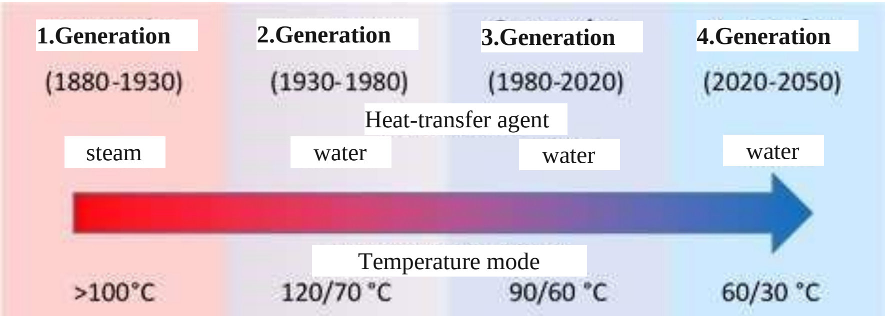


Figure 5.3.19. Historical changes in district heating [12]

Therefore, implementation of low temperature does not mean only reduction of supply and return temperatures; it also entails an audit of the consumers' heating scheme and installed radiators to determine their conformity to a low temperature mode.

Transition to the 4th generation means creation of sustainable DH, and it is the strategic development objective of the heating system. As a result, the 4th generation systems can ensure heating supply to low-energy-consumption buildings and low heat losses in networks; they also have integrated low temperature heat sources and are controlled using a smart control system.

5.3.3 Improvements in Energy Efficiency

The first step in the energy planning process is related to the selection of priority DHS development directions. Thermal energy consumption is among the main factors influencing the operation of the system. During the analysis of strategic development directions, the system extension when connecting new consumers, the energy efficiency increase when insulating the buildings and reduction of the total thermal energy consumption are assessed. The system extension scenario is being currently implemented by adding two consumers to the Palsmane Village boiler house — Palsmane Special Boarding School and multi-apartment house Dujinas. The heat load graph is presented in Figure 5.3.16.

Considering the common objectives of EU and Latvia in relation to increasing the proportion of RES, transition to RES is selected as the priority for the energy planning strategy in Palsmane. Therefore, already in the base scenario (Figure 5.3.20), natural gas boilers and firewood boilers with the low efficiency factor will be replaced with an automatically controlled heating boiler that will use woodchips as fuel. To balance out the operation of the boiler and reduce the effect of peak load, the boiler must be equipped with a heat accumulation tank.

When upgrading the boiler house, installation of more efficient circulation pumps is required to reduce electricity consumption in heat transmission. In addition, connection of an automated data reading system (SCADA) in all heating objects would be necessary. Considering that the strategic objective of the Palsmane DH is related to a high-quality implementation of low temperature, special attention should be drawn to the adjustment and upgrade of in-house heating systems of consumers.

During the 2019/2020 heating season, in five DH objects the specific thermal energy consumption for heating ranged between 150 and 200 kWh/m^2 per year (Figure 5.3.14): four of them are municipality buildings — Primary School (dormitory and school), Culture Centre, Palsmane Special Boarding School; one building is owned by a private entity (office building); and one is a multi-apartment residential building. To estimate heat load after increasing the energy efficiency of the buildings, it was determined that municipality buildings require heat insulation. Latvian Construction Standard LBN 00219 Regulations regarding the Latvian Construction Standard LBN 002-19, Thermotechnics of Building Envelopes, establishes that the minimum acceptable level of building energy efficiency for renovated and reconstructed buildings owned by the state or municipality and possessed by institutions will be ≤90 kWh/m^2 per year as of 1 January 2021. When renovating multi-apartment buildings, energy efficiency assessment for heating must be ≤80 kWh/m^2 per year as of 1 January 2021. Due to the high average specific thermal energy consumption for heating of these five objects, their renovation would be required.

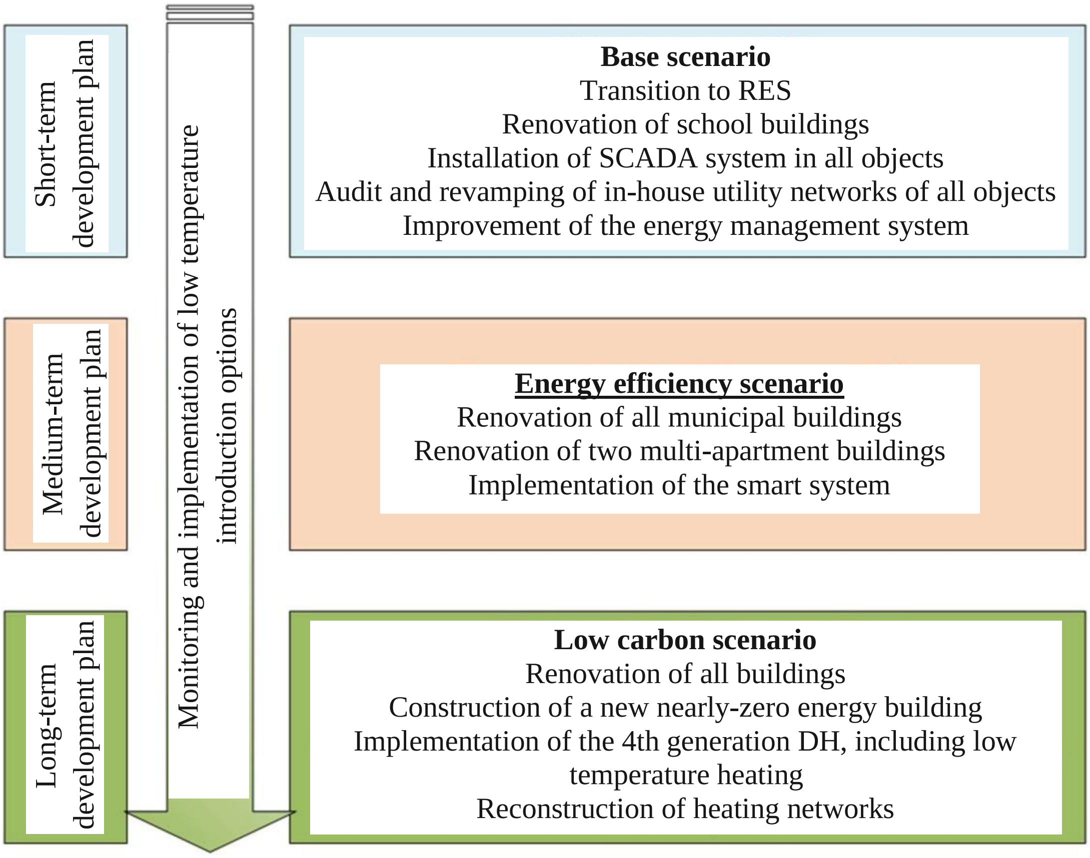


Figure 5.3.20. DH development scenarios in Palsmane Village

The conditions for renovation processes currently present in the financial market hinder performing multi-apartment building renovation, because building owners must cover approx. 50 % of costs (the support programme is subsidising 50 % of the attributable costs). Considering the welfare level or population in rural areas, building residents often are unable to agree on building renovation. Therefore, in a short term and according to the base scenario, implementation of energy efficiency measures in the Primary School and Palsmane Boarding School buildings has been envisaged. After implementation of the energy efficiency measures, the specific thermal energy consumption for heating the buildings will be 90 kWh/m^2 per year. As a result, it was established that the increase in energy efficiency can potentially yield a reduction in thermal energy consumption of approx. 360 MWh per year or 24.3 %, consisting of the current consumption in the multi-apartment and municipality buildings and the temperature regime lowering to 65/50.

After discussions with the Palsmane Village energy manager, it transpired that Palsmane Village currently has no potential new DH consumers. However, the prospective development plan of the village envisions construction of a new object — sports hall, even though no funds are going to be available for such an object in the near future. No hot water supply will be provided in the village.

Progress towards the 4^{th} generation DH system was assumed in preparing the medium-term DH development scenario or **energy efficiency scenario** (Figure 5.3.20). This means that energy efficiency measures will be implemented in all municipality buildings and also that two multi-apartment buildings (Dujinas and Rozites) will be renovated. During renovation, the in-house utility networks will also be reconstructed and radiators will be replaced or refurbished in the apartments in conformity with the low temperature regime. When introducing low temperature heating, simultaneous transition to the smart control of the heating process would also be important. Therefore, installation of an automated pellet boiler with a nominal capacity of approx. 560 kW and an accumulation tank would be a technologically justified solution, because the boiler operates fully automatically and has a higher efficiency factor (92–95 %) compared to a woodchip boiler. As a result, thermal energy consumption will drop by 38.4 % compared to the current situation.

The DH development objective would be implementation of the **low carbon scenario** and thereby also implementation of the 4th generation system concept. The scenario envisions renovation of all buildings and construction of a new building. Palsmane Village is planning to build a sports hall with an area of 2,500 m^2, which would be a Class A building with the thermal energy consumption of 45 kWh/m^2 per year for heating [14]. With the new sports hall, the thermal energy consumption will climb by 112 MWh per year, while thermal insulation of multi-apartment buildings will continue in the village and the thermal energy consumption will drop by 40.6 % compared to the current situation. In addition, the heating network main will be reconstructed using a ductless technology and high efficiency polymer pipes, allowing further temperature regime lowering to 60/40. Heat loss will drop from 249.4 to 160.0 MWh per year or by 36 %, while the length of the heating networks will extend insignificantly, because the sports hall will be located by the school, which is already connected to the network.

Modelled heat load graphs for different development scenarios are presented in Figure 5.3.21. The Primary School (dormitory and school) and Special Boarding School buildings are the major heat consumers with comparatively low energy efficiency rates, which will be improved by renovating these buildings already within the scope of the base scenario. The base scenario envisions installation of one new 660 kW woodchip boiler. The efficiency factor of the new boiler ranges within 85 % and 90 % (a factor of 87 % used in the calculations). The base scenario sets forth a thermal capacity necessary for heat supply that is by 20.9 % less than the current capacity.

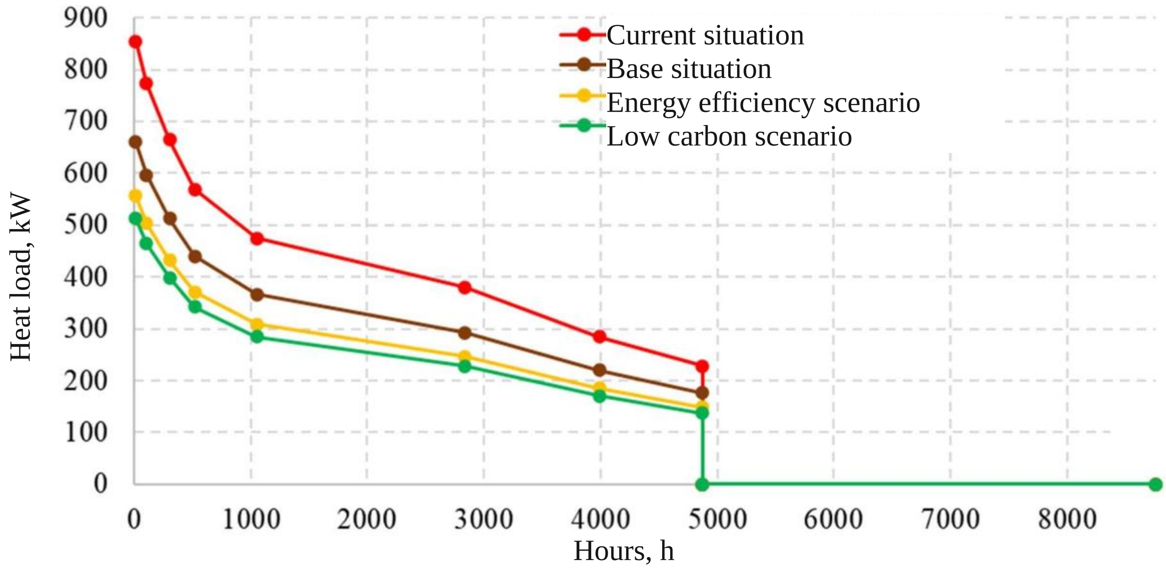


Figure 5.3.21. Heat load curves for analysed scenarios

The energy efficiency scenario envisions further renovation of the existing buildings, whereby the thermal energy consumption will drop by 33.1 % compared to the current situation. In a long-term perspective, energy planning in Palsmane Village should opt for implementation of the low carbon scenario. Its implementation will allow a reduction of the thermal energy consumption by 39.1 % compared to the current rate. However, considering the additional capacity required for heating the sports hall, the reduction would constitute 57.5 %. In the event of the low carbon scenario, the required heat capacity will be 513 kW.

During energy efficiency increase in Palsmane Village, special attention must be drawn to renovation of the heating systems of the buildings aiming at the implementation of a lowered temperature regime (65/50 or 60/40) compared to the existing one. Individual heating units (IHUs) of consumers have already been installed in all Palsmane heating objects. IHU design includes several elements, the correct selection and application of which ensures the desirable level of comfort and significant saving of energy resources [23]. IHU works as a link between the external networks of the heating system and the in-house heating system to ensure precise and safe heat supply to consumers. Main tasks of IHU [24]:

- Optimum thermal energy consumption;
- High cooling rate for water in the heating network;
- Minimum interruptions of operation;
- Minimum maintenance works.

The automated control system ensures precise and safe control of the heating unit's equipment. Depending on the outdoor air temperature, it is possible to adjust the function of lowering the heat-transfer agent's temperature in the heating system during the night. IHU ensures the thermal energy quantity necessary for the consumer using the quantitative adjustment method. Automatically adjusted valves restrict the heat-transfer agent's flow in the primary circuit.

Figure 5.3.22 shows the principal scheme of the heat unit, with the unit's three base equipment items marked, the successful operation of which may be affected by transition to a lower temperature regime.

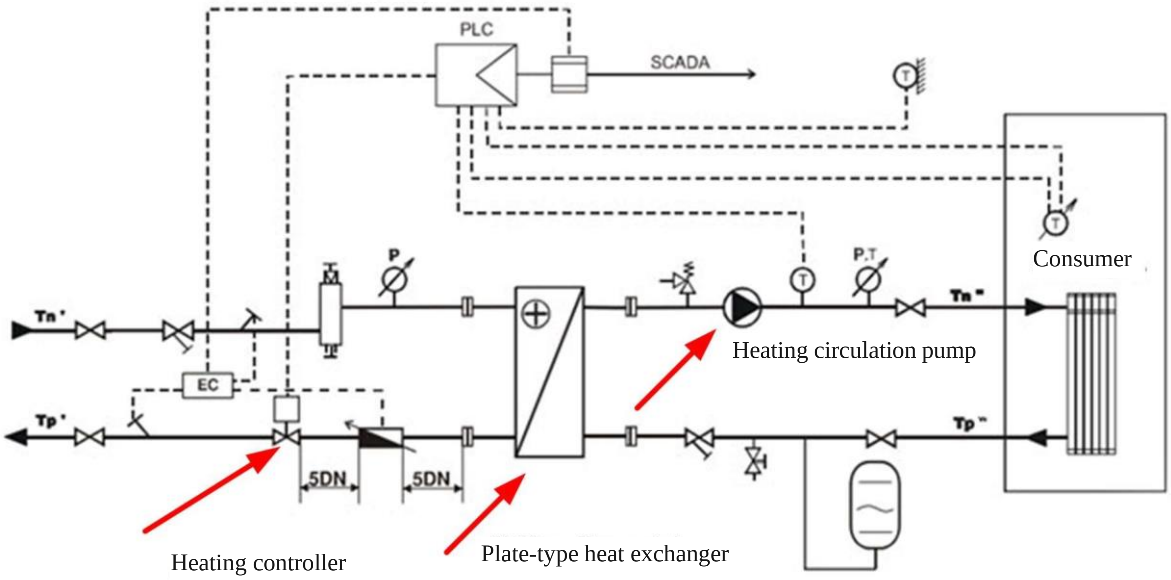


Figure 5.3.22. Principal scheme of the individual heat unit

Detailed analysis of heating equipment — controllers, heat exchangers and pumps — installed on the consumer side would require connection of all objects to SCADA system already with the base scenario.

When selecting the lower temperature regime, the operation parameters of the heating controller, heat exchanger and circulation pump on the secondary side should be additionally evaluated. For example, the heat-transfer agent's flow rate, which creates pressure loss in the controller, may be a restricting factor on the primary side for operating the heating controller. Incorrectly selected controller's operation can make noise and fail to ensure the required quantity of the heat-transfer agent to maintain the heating load. Optimum pressure loss fluctuations must be within the range between 0.4 and 0.7. Pressure loss must be determined using the characteristic curves of the controller's manufacturer, with a fully opened valve. For instance, if the maximum flow rate of the controller (KVs) fails to comply with the new mode, the controller should be replaced.

A circulation pump ensures continuous circulation of the heat-transfer agent on the IHU's secondary side, thereby transmitting thermal energy from the heating system to the in-house system of the consumer. With a temperature regime change, conformity of the secondary side circulation pumps with the new operation parameters should be assessed by comparing it to the characteristic curve of the pump. Table 5.3.8 summarises the analysed scenarios.

Table 5.3.8

Output data, assumptions and calculated values of the analysed scenarios

Parameter	Current situation	Base scenario	Energy efficiency scenario	Low carbon scenario
Used fuel	Firewood, natural gas	Woodchips	Pellets	Pellets
Installed capacity of the boiler, kW	2,150	660	560	520
Length of heating networks (pipe pairs), m	1,296	1,296	1,296	1,306
Temperature regime	70/60	65/50	65/50	60/40
Accumulation tank capacity, m^3	n/a	10	10	10
Thermal energy produced, MWh per year	1,813	1,433	1,213	1,104
Fuel consumption, MWh per year	2,362	1,610	1,270	1,147
Electricity consumption of the boiler house, MWh per year	27.4	21.2	17.8	11.5
Heated area, m^2	10,266	10,266	10,266	12,766
Specific average thermal energy consumption for heating, kWh/m^2	150	115	94	73
Distribution heat losses, %	13.8	15.5	18.4	14.7

Heat consumption density, MWh/m	1.21	0.91	0.74	0.72

As the energy efficiency rates in the buildings increase, the thermal energy required for building heating will drop from 1,813 MWh to 1,104 MWh. Notwithstanding that the temperature regime is gradually reduced, heat losses in the networks will be climbing from 13.8 % in the current situation to 18.4 % in the energy efficiency scenario. In case of the implementation of a high-quality low temperature system with the temperature regime of 60/40 in the low carbon scenario, heat losses will go down to 14.7 %, which is in compliance with the effective standards of laws and regulations. Heat losses increase in the energy efficiency scenario because the heat consumption in the buildings decreases.

5.3.4 Economic Analysis of Measures

The development scenarios were assessed by taking into account the potential investments, production costs (fuel and electricity costs), labour force costs and other related costs. It was assumed that the municipal utility enterprise will provide heating in the village. Profit of the enterprise was not included in the calculation, and the thermal energy tariff was accordingly set, covering all costs of the heating enterprise, with the proceeds equal to the expenditure.

The cost analysis made assumptions with regard to the boiler efficiency factors described above. Other assumptions related to the costs of equipment, construction and energy carriers have been summarised in Table 5.3.9.

Table 5.3.9

Assumptions used in the cost-to-benefit analysis

Parameter	Value
Length of reconstructed heating networks (pipe pairs), m	820
Woodchip boiler with automated feed, EUR/kW	600
Pellet boiler, EUR/kW	450
Accumulation tank costs, EUR/m^3	900
Construction of the heat main, EUR/m	250
Price of woodchips, EUR/MWh	17
Price of pellets, EUR/MWh	35
Electricity costs, EUR/MWh	130
Current thermal energy tariff, EUR/MWh	47.01
Equipment service life, in years	20
Service life of pipes, in years	30

Since all of the scenarios expect involvement of consumers, they have to cover a part of the costs for improving the energy efficiency of the Palsmane Village buildings. During the previous planning period from 2014 to 2020, a national support programme was available for increasing the energy efficiency of multi-apartment houses [25], where the costs on average depended on the measures implemented within the scope of the projects. From 2016 to 2019, the costs fluctuated within the range from 125.91 to 187.67 EUR/m^2. The calculation assumed the average costs at 157 EUR/m^2. The costs include the construction of in-house heating systems in the buildings required for implementation of a high-quality low temperature system with the optimum temperature difference between the supply and return flows. The achieved thermal energy saving ranged between 45.3 % and 49.2 %. Table 5.3.10 summarises the costs that the consumers would have to cover when implementing improvements of different stages for the energy efficiency of the buildings, as well as the costs of attracting new consumers.

Table 5.3.10

Costs of energy efficiency measures

Parameter	Current situation	Base scenario	Energy efficiency scenario	Low carbon scenario
Renovated area, m^2	n/a	3,938	2,582	2,552
Costs, EUR	n/a	618,360	405,405	400,695
New building, m^2	n/a	n/a	n/a	2,500
Costs, EUR	n/a	n/a	n/a	2,500,000

The costs of the new sports hall may range between EUR 2,500,000 and EUR 4,000,000, depending on how it is fitted.

For all heating system development scenarios, a single-part thermal energy tariff T (EUR/MWh) was calculated using the methodology approved in the Republic of Latvia [26]. The single-part tariff consists of three parts and is expressed with the following equation:

$$T = T_{prod} + T_{tr} + T_{sale} \quad (2)$$

where:

T_{prod} — production tariff, EUR/MWh;
T_{tr} - transmission tariff, EUR/MWh;
T_{sale} — sale tariff, EUR/MWh.

Each part of the tariff consists of the values of fixed and variable costs. E.g., the production tariff is established as follows:

$$T_{prod} = (VC_R + FC_R)/Q_{prod} \tag{3}$$

where:

VC_R — variable costs of the production tariff, EUR per year;
FC_R — fixed costs of the production tariff, EUR per year;
Q_{prod} — produced quantity of thermal energy, MWh per year.

Variable costs of the production tariff consist of the sum of several constituents:

$$VC_R = Q_{prod}(C_{fuel}/\eta + C_{taxR} + C_{el}Q^{el}_{prod} + C_{othR}) \tag{4}$$

where:

VC_R - variable costs of the production tariff, EUR per year;
Q_{prod} - produced quantity of thermal energy, MWh per year;
C_{fuel} — fuel price, EUR/MWh;
η — technology efficiency factor;
C_{taxR} — taxes, EUR/MWh;
C_{el} — electricity price, EUR/MWh;
Q^{el}_{prod} — electricity consumption for production, MWh_{el}/MWh_{th};
C_{othR} — other production costs, EUR/MWh.

Variable costs in the sale tariff are comparatively insignificant. Fixed costs are calculated for all parts of the tariff using the same method.

$$FC = Q \quad C_{\&} + \frac{C\,N}{\tau} + C + C + C + C \tag{5}$$

where:

FC_i — fixed costs of the tariff, EUR per year;
i — selected part of the tariff (production, transmission or sale tariff);
Q_{prod} — produced quantity of thermal energy, MWh per year;
$C_{M\&R}$ — equipment repair and maintenance costs, EUR/MWh;
C_{eq} — equipment costs, €/MW;
N_N — installed capacity of the equipment, MW;
τ_{cr} — credit repayment period, in years;
C_{pr} — credit interest payment, EUR per year;
Cs — salaries with social insurance contributions, EUR per year;
C_{ins} — insurance costs, EUR per year;
C_{othR} — other costs, EUR per year.

Enterprise's credit liabilities were not factored in the calculation. Calculation results are summarised in Table 5.3.11. A scenario of the current situation without action shows changes in the thermal energy tariff in the event when all consumers have implemented the energy efficiency measures, but no improvements in the heat source and distribution are made.

It must be emphasised that no long-term operation with such a scenario is possible, because the boilers become obsolete and their efficiency factor decreases. Nevertheless, this scenario is presented to enable assessment of tariff changes in the event additional investments are made into transition to lower temperatures. The efficiency factor used in the calculations is 50 %, which is forecasted for the long term without renovation of boilers.

Table 5.3.11

Results of the cost-to-benefit analysis. Heat tariff calculation

Parameter	Current situation	Current situation without action	Base scenario	Energy efficiency scenario	Low carbon scenario
Installed capacity, kW	2,150	850	660	560	520
Thermal energy produced, MWh per year	1,813	1,066	1,401	1,180	1,089
Thermal energy losses, MWh per year	249	249	217	217	160
Thermal energy sold, MWh per year	1,564	817	1,184	963	930
Investments	0	0	405,000	317,000	295,000
Installation of boiler equipment, EUR	0	0	396,000	308,000	286,000
Accumulation tank costs, EUR	0	0	9,000	9,000	9,000
Heating network construction costs, EUR	0	0	0	0	410,000[1]
Number of employees	5	5	2	2	2
Personnel costs, EUR per year	4,500	4,500	1,800	1,800	1,800
Continuous production costs, EUR per year	**14,713**	**14,713**	**22,050**	**17,650**	**16,550**
Fuel type	firewood	firewood	woodchips	pellets	pellets
Fuel consumption, MWh per year	2,362	2,133	1,610	1,269	1,147
Fuel costs, EUR per year	40,892	36,934	27,367	44,419	40,128
Variable production costs, EUR per year	**40,892**	**36,934**	**27,367**	**44,419**	**40,128**
Total production costs, EUR per year	**55,605**	**51,647**	**49,417**	**62,069**	**56,678**

[1] The new sports hall (which has been considered in costs) connected

Production tariff, EUR/MWh	**30.66**	**48.43**	**35.28**	**52.59**	**52.04**
Electricity consumed, MWh per year	27	27	21	18	12
Electricity costs, EUR	3,565	2,096	2,753	2,320	1,499
Heat loss costs, EUR per year	7,647	12,077	7,655	11,410	8,306
Transmission variable costs, EUR per year	**11,212**	**14,174**	**10,409**	**13,730**	**9,804**
Depreciation of fixed assets, EUR per year	5,200	5,200	5,200	5,200	13,667
Other costs, EUR per year	1,037	1,037	1,037	1,037	1,037
Transmission fixed costs, EUR	**6,237**	**6,237**	**6,237**	**6,237**	**14,704**
Total transmission costs, EUR	**17,449**	**20,411**	**16,646**	**19,967**	**24,508**
Transmission tariff, EUR/MWh	**11.16**	**24.98**	**14.06**	**20.73**	**26.36**

Parameter	Current situation	Current situation without action	Base scenario	Energy efficiency scenario	Low carbon scenario
Thermal energy sale costs, EUR per year	469	245	355	289	279
Sale tariff, EUR/MWh	0.30	0.30	0.30	0.30	0.30
Total costs, EUR per year	**73,523**	**72,303**	**66,418**	**82,325**	**81,465**
Thermal energy tariff, EUR/MWh	**47.01**	**88.49**	**56.12**	**85.46**	**87.64**
Proceeds, EUR per year	73,523	72,303	66,418	82,325	81,465

The variable part of production costs is strongly affected by the quantity and price of consumed fuel. If implementing energy efficiency measures that reduce thermal energy consumption in the base scenario compared with the current scenario by 24 % and if transitioning to a 100 % renewable energy source — wood, the fuel costs decrease by 33 %. However, the transmission costs, despite of their decrease in absolute terms (in the current situation EUR 17,449 per year against EUR 16,646 per year), will relatively increase by 26 % (see Fig. 5.3.23). At the same time, if no investments are made in the heat source and heating networks but the buildings are insulated, it is evident that the volume of sold thermal energy will decrease significantly and the tariff will increase. The thermal energy tariff with the scenario of the current situation without action is slightly higher for all the scenarios considered. In addition, in scenarios with lower temperatures, there are other extra benefits, e.g., lower CO_2 emissions and more comfort for the residents of the building. The calculations show that the renovation of the old heat source and transmission pipes and adaptation to the 4th generation DHS do not increase the costs compared to the scenario in which the heating would be provided using the existing outdated boilers and pipes.

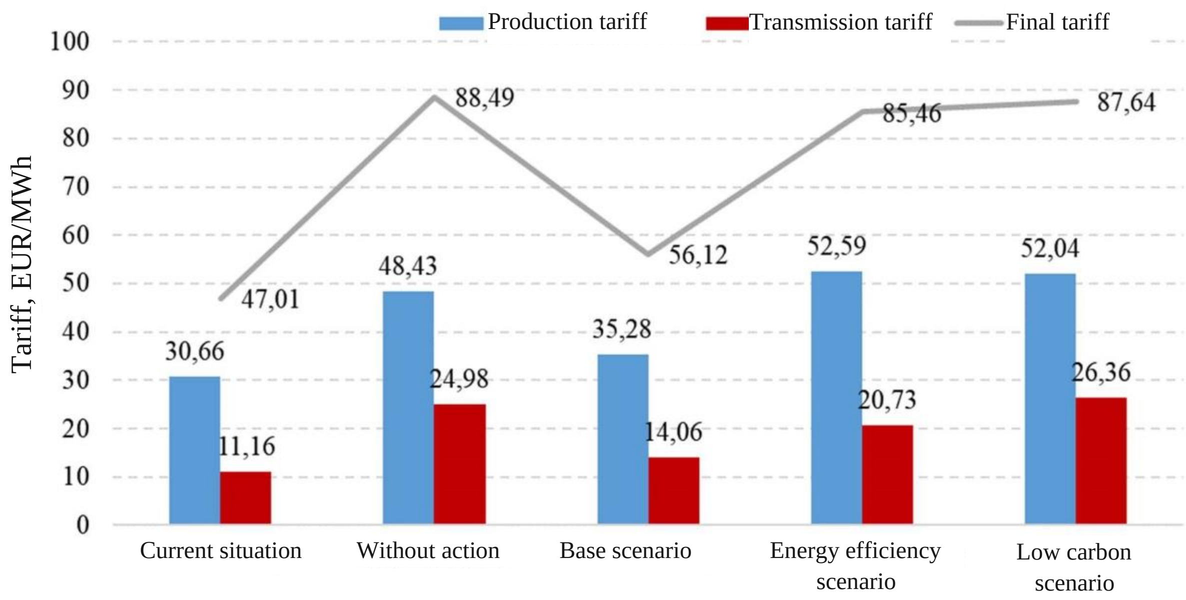


Figure 5.3.23. Changes in the production and distribution/transmission tariffs

The maximum production tariff is achieved in the energy efficiency scenario (52.59 EUR/MWh), because, compared to the current and the base scenario, the fuel costs increase by transitioning to pellets, while the thermal energy consumption decreases. Overall, gradual implementation of energy efficiency measures and pursuance of the low carbon scenario will cause a 40 % drop of the thermal energy consumption and an 86 % increase in the thermal energy tariff.

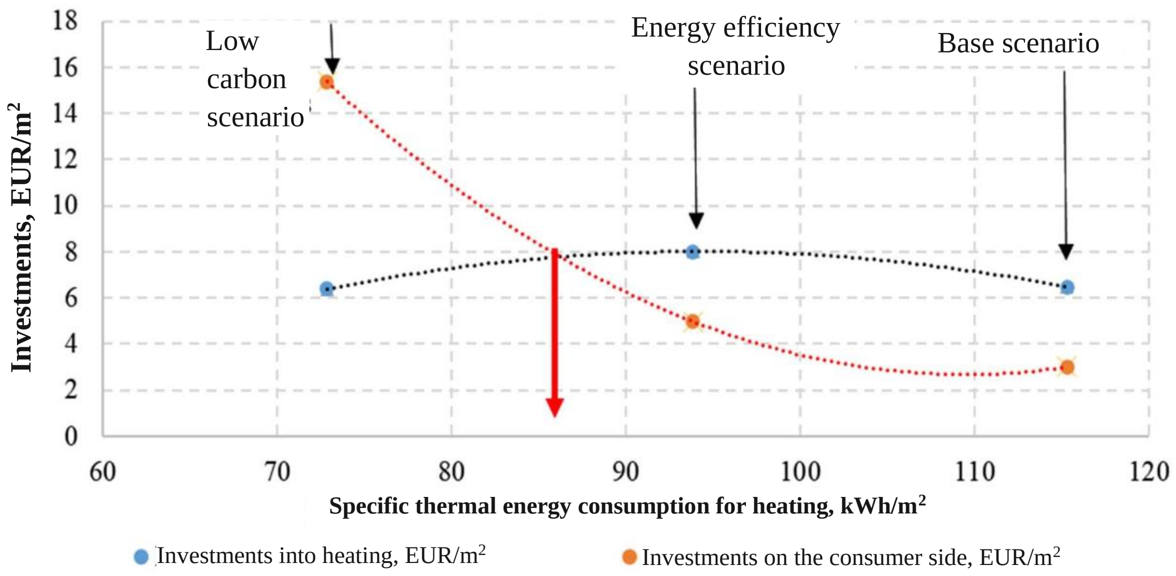


Figure 5.3.24. Efficiency of investments

Analysing the efficiency of investments in Palsmane Village in different scenarios, it must be noted that investments on the consumers' side are growing fast with construction of new objects. Therefore, support funding for such projects should be sought (Figure 5.3.24). According to the assumptions of the cost efficiency calculation, the optimum building efficiency level of the Palsmane Village heating objects would be approx. 85 kWh/m^2 per year, which correlates well with the norms accepted by the

Latvian Construction Standard LBN 002-19 Regulations regarding the Latvian Construction Standard LBN 002-19, Thermotechnics of Building Envelopes.

5.3.5 SWOT Analysis and Risk Analysis

SWOT analysis was carried out during the assessment of all heating system development scenarios. SWOT analysis is a structured planning method, which was applied in this study to assess the strengths, weaknesses, opportunities and threats related to the heating system development scenarios. SWOT analysis incorporates determination of an objective and identification of internal and external factors:

- internal factors are the strengths and weaknesses related with efficient heating system development in the municipality;
- external factors are opportunities and threats occurring irrespective of organisation.

Strengths of the base scenario are related to two pros — a comparatively little increase in the thermal energy costs (a 10 % increase against the current situation) and transition to a 100 % renewable energy source — woodchips (Table 5.3.12). Weaknesses of the base scenario, in turn, are related to the high heat losses and the relatively low energy efficiency level of the buildings.

Table 5.3.12

SWOT analysis for the base scenario

Strengths	Weaknesses
Proportion of 100 % renewable sources Lower temperature regime (65/50) Lower return temperature Higher efficiency of the entire system Lower fuel costs	Alignment of the accumulation system Adaptation of the consumers' system to lower temperatures
Opportunities	**Threats**
Attraction of external funding Increase in heating efficiency	Increase in woodchip costs Low interest of consumers in the implementation of innovations Lack of experience of designers in implementation of low temperature systems

Strengths of the energy efficiency scenario are related to the further improvement of energy efficiency level on the consumers' side and reduction of the total thermal energy consumption (Table 5.3.13). In addition, the transition to pellets as fuel will allow fully automated thermal energy production and ensure the high efficiency factor of the combustion equipment. Weakness is the higher fuel costs. Opportunities of the scenario lie in the attraction of the European Union funding for thermal insulation of the multi-apartment buildings.

Table 5.3.13

SWOT analysis for the energy efficiency scenario

Strengths	Weaknesses
Higher efficiency of the entire system Fully automated heating production	Alignment of the accumulation system Adaptation of the consumers' system to lower temperatures Higher fuel costs
Opportunities	**Threats**
Attraction of external funding Increase in heating efficiency	Increase in fuel costs Low interest of consumers in the implementation of innovations Inability of consumers to agree upon joint implementation of thermal insulation Lack of experience of designers in implementation of low temperature systems

The low carbon scenario has a high degree of efficiency on the consumer's side, in the networks and in the source (Table 5.3.14). Its weaknesses are related to the high costs of renovation of the heating networks and construction of a new heating object — the sports hall. Additional problems may be caused by insufficient funding for implementation of the planned measures.

Table 5.3.14

SWOT analysis for the low carbon scenario

Strengths	Weaknesses
Higher efficiency of the entire system Low temperature mode in the networks — low heat losses	Adaptation of the entire heating system to lower temperatures Higher costs of thermal energy transmission
Opportunities	**Threats**
Attraction of the European Union funding Increase in heating efficiency	Increase in fuel costs Low interest of consumers in the implementation of innovations Inability to find funding for construction of new objects

Risks must be identified before starting the development projects, so that special attention could be paid to them during implementation of these projects. Simplified risk analysis is presented in Table 5.3.15. Impact of all risks on each scenario has been identified.

Table 5.3.15

Risk analysis

Risk	Probability of the risk	Impact of the risk (low, medium, high)	Risk prevention actions
Low understanding of the need to introduce innovations	Base scenario — medium Energy efficiency scenario — medium Low carbon scenario — medium	High	Knowledge transfer and distribution activities on the part of introducers of innovations
Transition of consumers to individual heating	medium	High	Monitoring of DH cost efficiency and management of market situation Awareness of consumers regarding costs incorporated in the tariff
Lack of experience of designers in implementation of low temperature systems	Base scenario — medium Energy efficiency scenario — medium Low carbon scenario — medium	Medium	Participation in seminars and trainings
Increase in wood fuel prices	High	High	Increase in DH operation efficiency to minimise fuel consumption
Inability of residents to agree upon	Base scenario — low Energy efficiency scenario	Base scenario —	Advertising and education campaign
a jointly implemented project	— medium Low carbon scenario — high	low Energy efficiency scenario — medium Low carbon scenario — high	

Lack of investments	High	Base scenario — medium Energy efficiency scenario — medium Low carbon scenario — high	Attraction of funding from structural funds and attraction of services of ESCO (energy services companies)
Inefficient management of heat production and transmission	Medium	High	Implementation of the SCADA system and data monitoring
Lack of experience in smart heating system management	Medium	Base scenario — low Energy efficiency scenario — medium Low carbon scenario — high	Experience exchange programmes, seminars, training

Two high probability risks have been identified with respect to costs of fuel and other constituents of the tariff, and this is related to the potential wish of consumers to transition to individual heating. Reduction of these risks would require monitoring of the efficient operation of the heating system and informing consumers about advantages of the DHS system and benefits of connection to it. Increase in fuel costs also is a potential risk. Lack of investments is determined as a high probability risk, which may be reduced by scrutiny of the financial market and offers by ESCO companies.

Inefficient management of heat production and transmission has been qualified as a medium probability risk. To reduce its probability, the SCADA system must be introduced in the energy efficiency scenario and the smart system — in the low carbon scenario. The task of the energy manager would be the monitoring of an efficient operation of the heat production equipment, including aspects like equipment efficiency factors, losses in networks, a temperature mode matching the outdoor air temperature, and other parameters.

5.3.6 Implementation of Low Temperature District Heating System in Palsmane. Conclusions

- Implementation of low temperature is closely related to the increase in the efficiency of the consumer and the heat source. Implementation of low temperature is possible by gradual implementation of different measures, which have been broken down into three steps and identified as three scenarios: base scenario, energy efficiency scenario and low carbon scenario.

- The first step towards implementation of low temperature is related to transition to a 100 % RES, renovation of the school buildings, implementation of the SCADA system in all objects, audit of the in-house utility networks of the buildings and improvement of the energy management system. Investments required for this purpose constitute EUR 405,000. As a result, energy efficiency of the heat source will increase from 77 % to 87 %, ensuring saving of 214 MWh per year of the fuel energy.
- Implementation of the SCADA system and monitoring of the heating parameters will allow prevention of losses that arise from supply temperature fluctuating in a wide range in certain climatic conditions and will also allow potential errors to be monitored. Audit of the utility networks of buildings will ensure decrease of return temperature.
- Measures of the second step have been identified in the energy efficiency scenario and are related to the medium-term objectives: renovation of all municipality buildings and a part of the multi-apartment buildings, and implementation of the smart system. During renovation, the in-house utility networks will also be reconstructed and radiators will be replaced or refurbished in the apartments in conformity with the low temperature regime. Smart adjustment of heating processes will allow implementation of low temperature heating with a relatively higher temperature difference between the supply and return flows.
- The low carbon scenario is the main long-term target scenario, which conforms with a low temperature DHS. It includes renovation of all buildings, construction of a new nearly-zero energy building and reconstruction of the heating networks using a polymer pipe. Implementation of all measures will ensure all preconditions for the operation of the low temperature system.
- By implementing the aforementioned scenarios, the maximum tariff of thermal energy sale will be achieved in the low carbon scenario (87.64 EUR/MWh), because, compared to the current and the base scenario, fuel costs will increase by transitioning to pellet fuel, while the thermal energy consumption will decrease. Transition to pellets as fuel will allow fully automated thermal energy production and implementation of smart heating management. Gradual implementation of energy efficiency measures and pursuance of the low carbon scenario will cause a 40 % drop of the thermal energy consumption and an 86 % increase in the thermal energy tariff. According to the assumptions of the cost efficiency calculation, the optimum building efficiency level of the Palsmane Village heating objects would be approx. 85 kWh/m^2 per year.
- The thermal energy tariff with the scenario of the current situation without action is slightly higher for all the scenarios considered. The calculations show that the renovation of the old heat source and transmission pipes and adaptation to the 4th generation DHS do not increase the costs compared to the scenario when the heating would be provided using the existing outdated boilers and pipes.

6 Recommendations regarding LTDHS Implementation Possibilities, Taking into Account the Regional-level Energy Documents

6.1 Recommendations for the Existing Normative Documents

Generally, the examined planning documents include objectives and measures for energy consumption reduction (in buildings and in DHS) and for transition to renewable energy sources. Local government planning documents likewise include actions for the increase of energy efficiency level. The Vidzeme Planning Region’s development strategy indicates that municipalities in their development strategies have already emphasised the need for increasing the energy efficiency of public and multi-apartment buildings and revamping of public utility services. Energy efficiency of the municipal and multi-apartment buildings is an important step towards low temperature district heating systems. Still, some improvements are in order for more successful future transition to the 4th generation DHS:

1. The current laws and regulations do not establish specific requirements for adaptation of heating systems after renovation, envisioning a possibility to ensure heating with a lower temperature regime in the building. It is recommended to incorporate into the legislative requirements for internal heating networks of buildings that, after their renovation, they would be compatible with low temperature district heating systems.

2. In the planning documents, to provide for gradual planning of mandatory thermal energy metering both in boiler houses and in at least one multi-apartment building.

3. Gradual transition to the three-part thermal energy tariff in order to facilitate the progression of consumers towards the 4th generation DHS, as shown in Figure 6.1.

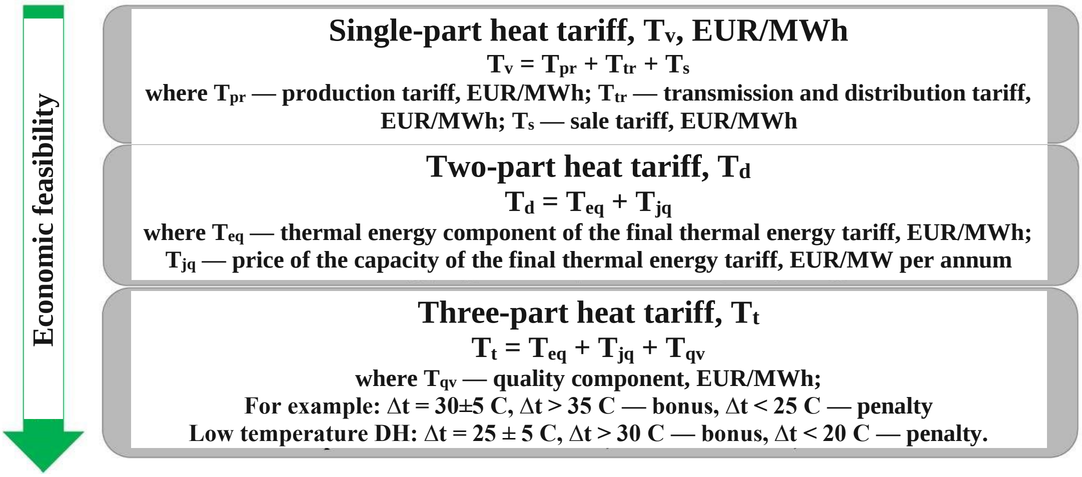


Figure 6.1. Progression of thermal energy tariffs in order to facilitate implementation of the 4th generation

4. More detailed steps towards implementation of the 4th generation have been incorporated into the Roadmap to a Sustainable, Low Carbon Economy 2050. Transposing the objectives and measures prepared in the roadmap into local government planning documents for transition to the 4th generation heating systems is recommended.

5. Incorporation of the recommendations given in this study — "Low temperature district heating system (LTDHS) implementation options: development of recommendations in addition to the existing energy documents of the Vidzeme Planning Region" — into the planning documents of the regional and municipal levels for transition to low temperature heating systems step by step.

6.2 Step by Step Towards Implementation of Low Temperature District Heating Systems

In order to implement an LTDHS, it is necessary to revamp systematically the entire DHS, which includes not only technical solutions but also complex DHS energy planning. Transition to the 4th generation district heating system takes place gradually, together with renovation of buildings and transition to RES.

While striving towards the 4th generation heating systems, it is important to fix up the consumer side first: renovate buildings, with reduction of heat load, and adapt in-house heating networks of buildings for low temperature district heating. After the load reduction, the heat source fuel may be replaced with efficient renewable energy sources, and the district heating system pipes may be replaced so that they would meet the requirements for low temperature (see Fig. 6.2).

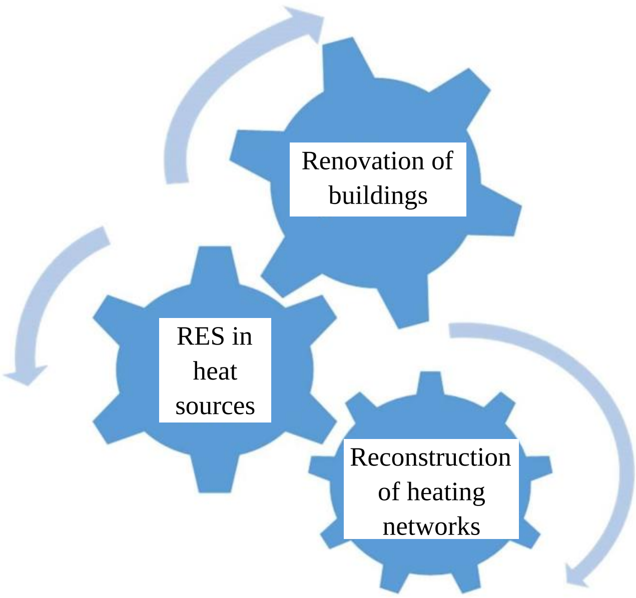


Figure 6.2 Main factors of influence on the way to the 4th generation DHS

A principal scheme for transition of the Vidzeme Planning Region DHS to a low temperature heating system, which has been developed based on the example of Palsmane Village, is presented in Figure 6.3. Renovation of buildings and transition to RES take place gradually and simultaneously with the implementation of the LTDHS.

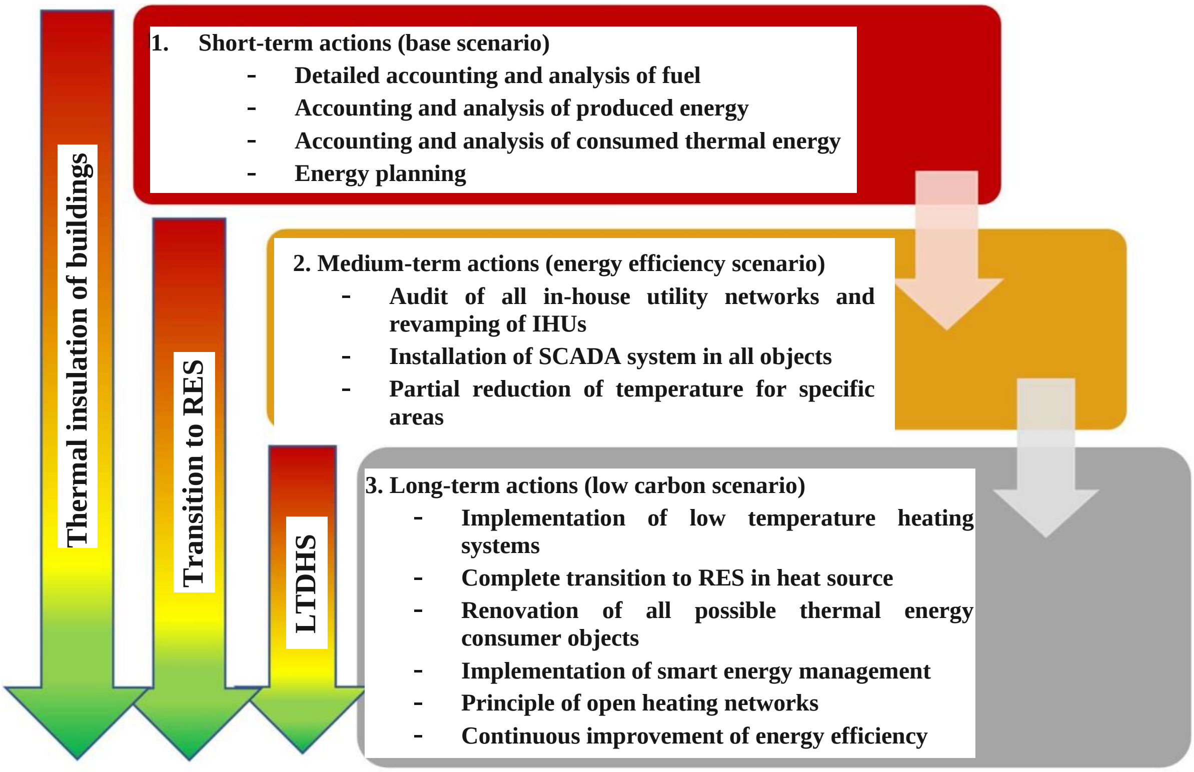


Figure 6.3 Principal scheme for transition of the Vidzeme Region DHS to a low temperature heating system

The first step towards the 4th generation district heating system involves sorting out and analysis of all types of accounting systems. This is necessary for drawing up a high-quality DHS energy plan. During the analysis of strategic development directions, the system extension when connecting new consumers, the energy efficiency increase when insulating the buildings, and reduction of the total thermal energy consumption are assessed. Thus, the load graph is assessed while the buildings are gradually insulated; and the proper pipe diameter, capacity of the heat source and the thermal energy tariff are planned.

Audit of all internal utility networks of consumers and overhaul of IHUs is carried out in the medium term. In addition, connection of the automated data reading system (SCADA) in all heating objects is required. Transition to lower temperatures takes place gradually in the objects where it is already possible, or specific areas may be separated (see Figure 6.4).

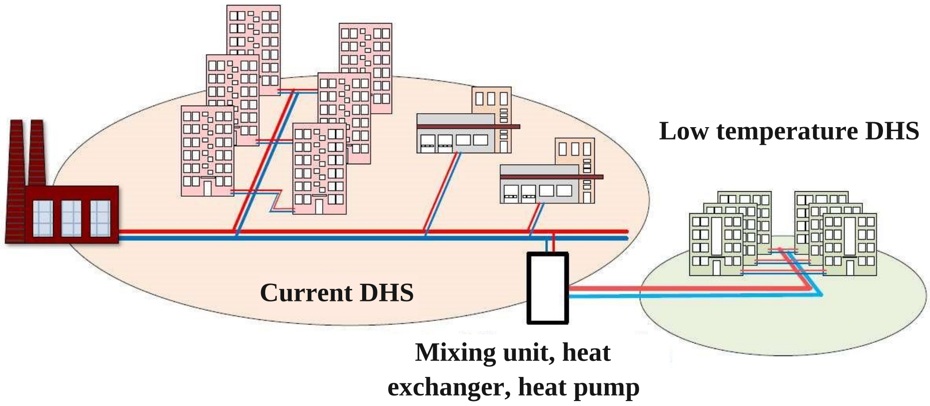


Figure 6.4 Partial transition to low temperatures in the district heating system

In a long term, when all consumers have undergone renovation and 100 % of the produced energy comes from the heat source utilising renewable energy sources, reconstruction of heating networks and their adaptation to the 4th generation heating system is required, with gradual and complete transition to the low temperature DHS.

The case of Palsmane Village demonstrates that the renovation of the old heat source and transmission pipes and adaptation to the 4th generation DHS do not increase the costs compared to the scenario where the heating would be provided by the existing outdated boilers and pipes. In addition, in scenarios with lower temperatures, there are other extra benefits, e.g., lower CO_2 emissions and more comfort for the residents of the building. Also, the pilot project implemented in Belava Village (Section 5.1) proves that LTDHS can considerably reduce not only heat losses but also the thermal energy tariff.

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