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Pilot energy strategy

Strategy for low temperature district heating system implementation in Ilmajoki municipality

Thermopolis Oy/PP 9

Lassilantie 12

62100 Lapua

Tel. +358 (0) 6 4331 290
info@thermopolis.fi

Pauli Sneck
Sauli Jäntti

Tel. +358 (0) 040 047 1740
sauli.jantti@thermopolis.fi

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1 Introduction

This pilot energy strategy (PES) for Low-Temperature District Heating System implementation in Ilmajoki municipality was developed with the aim to improve district heating (DH) and find possibilities to use waste heat resources in city-owned District heating Kurikka network in the Ilmajoki region. One of the main targets is to increase DH energy efficiency in every way and to guide the way for this with the help of PES. The document contains background information on district heating and determines existing heat and cooling supply situations and challenges, including the characterization of energy sources.

The strategy defines three main directions of DH development - lowering of heat carrier temperature, integration of alternative energy sources incl. waste heat and improving energy performance in buildings.

Based on the defined technical and political background and results of development steps obtained, the PES concludes on the current situation and analyses the possible DH development directions.

2 The Finnish energy system

Finland has a high energy consumption per capita due to its geographical location, industrialization and general welfare. Requirements for energy usage are set by the prevailing environmental conditions (cold climate, darkness, etc.) and by the citizens that are used to a high standard of living. Therefore, energy is consumed especially in heating (space heating and domestic hot water preparation), in public lighting as well as in energy-intensive industrial processes.[1]

The final energy consumption was about 313 TWh (1,127 PJ) in the year 2018. The industrial sector was by far the most energy-consuming sector covering almost half of the final energy consumption (47 %). One-fourth of the final energy consumption was covered by space heating, meanwhile, the residual share of the final energy consumption was divided between transport (16 %) and other use (12 %).[2]

Finland's long-term objective is to be a carbon-neutral society. Therefore, the energy sector is the main factor in terms of reducing carbon-dioxide emissions, since approximately 80 % of all greenhouse gas emissions in Finland are due to energy production and consumption.

2.1 Political framework and energy objectives

The present Government Programme is "Inclusive and competent Finland – a socially, economically and ecologically sustainable society" by Prime Minister Sanna Marin's Government. The Programme identifies strategic goals, which will enable building a socially, economically and ecologically sustainable Finland. The strategic themes are:

- Carbon neutral Finland that protects biodiversity
- Globally influential Finland

- Safe and secure Finland built on the rule of law
- Dynamic and thriving Finland
- Finland built on trust and labour market equality
- Fair, equal and inclusive Finland

Finland that promotes competence, education, culture and innovation.

From these, the theme of „Carbon neutral Finland that protects biodiversity "covers the foreseen future implementations within the field of district heating.

The present Programme will support the adoption and piloting of new methods for producing district heating and heat storage without burning fuel.[3]

2.1.1 Energy tax reform

Tax reform for sustainable development is one of the key actions concerning the utilisation of surplus heat with heat pumps in district heating networks. Furthermore, in the Programme, it has been initiated that heat pumps and data centres generating heat for district heating networks will be transferred to category II electricity tax. Tax category I is 0.02253 €/kWh and tax category II is 0,0087172 €/kWh. VAT (24 %) is included in both tax categories.[3]

2.1.2 Intensive reduction of peat

According to the Government Programme, Finland aims to be the world's first fossil-free welfare society. Therefore, both heat and electricity production must be nearly emission-free by the year 2030. This objective is pursued by decreasing the use of peat for energy by at least half by 2030. To achieve the set objectives, necessary changes to the taxation of peat are foreseen.[3]

2.1.3 Increasing the energy performance of buildings

The Government Programme takes into account the need for refurbishments in the existing building stock. The already implemented energy subsidy scheme was adopted as a tool to decrease the carbon footprint of housing, to improve the energy efficiency of the existing building stock and to support the transition to emission-free heat generation. The target group for the subsidy are housing companies that support improvements in the energy performance of buildings and measures aiming toward smart, flexible energy consumption.[3]

2.1.4 Energy Efficiency Agreements

The voluntary Energy Efficiency Agreements are a tool to fulfil the EU energy efficiency obligations set for Finland without resorting to legislation or other coercive measures. Therefore, the Agreements are a key instrument for achieving the Energy Efficiency Directive objectives. The Agreements cover most industries, the municipal sector, and the property sector.[4]

The extensive joining to Energy Efficiency Agreements (covers about 60 % of total energy consumption in Finland) has several benefits. The key benefits for municipalities are, for instance, the institutionalization of energy-efficient implementations, constant monitoring and reporting, and monetary benefits.[4]

2.2 Monetary framework

2.2.1 Energy aid

Energy aid is granted for investment and investigation projects that promote:

- the production or use of renewable energy,
- energy savings or improving the efficiency of energy production or use, and
- otherwise replacing the energy system with a low carbon one.

Energy aid is available for companies of all sizes, communities and organisations, such as municipalities, parishes and foundations.

There are some restrictions that complicate the exploitation of available energy aids within the field of district heating. For instance, it is restricted that:

- heat generation projects of more than 1 MW are not eligible unless new technology is implemented, and
- renewable energy must comprise at least 70 % of fuel used in heating plant investments.

Investments that include new technology may be granted up to 40 % of the investment costs. Other relevant and eligible investment projects for municipalities are, for instance:

- solar heat and electricity projects (20 %),
- small CHP and small wind power projects (15-20 %), and
- heat pump projects that are subject to aid percentages related to energy savings.

In addition, investigation projects, such as energy audits in the municipal sector, micro-enterprises and SMEs related to energy efficiency agreements are subject to a 50 % grant. Meanwhile, other investigation projects, such as energy audits, analyses and investigation projects are subject to a 40 % grant.[5]

2.2.2 The Housing Finance and Development Centre of Finland, ARA

The Housing Finance and Development Centre of Finland (ARA) is a governmental agency of the Republic of Finland operating under the supervision of the Ministry of the Environment. ARA implements social housing policy and is responsible for granting, for example, investment subsidies for special needs groups and renovation subsidies. The subsidies related to housing and construction are granted from state funds. Furthermore, since 2020 ARA has granted subsidies directed especially at housing companies that are improving the energy performance of their buildings.[6]

3 Regional energy systems - South Ostrobothnia

South Ostrobothnia is a sparsely populated region, with a population density of 14.12 inhabitants/km². Resulting, the regional market share of district heating is lower than the national share (51 %), as the regional share of district heating is approximately 33 %.

There are two operational cogeneration plants in South Ostrobothnia. The larger CHP plant (100 MW_t, 120 MW_e) locates in the regional centre, in the city of Seinäjoki, and the smaller one (20 MW_t, 4.5 MW_e) in the City of Lapua (Figure 1). These two plants produce typically more than 40 % of all the generated district heat in South Ostrobothnia. The rest of the regional district heat demand is produced with heat-only boilers, which are split all over the region.

The regional heat production at the moment is relying strongly on local fuels such as peat (59 %) and wood fuels like wood chips, industrial wood waste and other biomasses (altogether 36 %). A minor part of district heating production is covered by oil, which is used especially when covering the peak loads. However, the region is not distinguished to have numerous potential waste heat sources due to the rather high amount of agricultural and forest industry versus energy-intensive industries. Therefore, waste heat is utilised in district heating production mostly from high-temperature waste heat sources. These waste heat solutions are implemented on a moderate level and on case-by-case, however low-temperature waste heat sources have become a more attractive alternative energy source.

3.1 District Heating in Ilmajoki

Ilmajoki is one of the 18 municipalities in the region of South Ostrobothnia. The municipality is located next to Kurikka and Seinäjoki. Map of South Ostrobothnia is presented in Figure 1.

District Heating Kurikka (Kurikan Kaukolämpö Oy) produces, distributes and sells district heat in Kurikka, Jalasjärvi, Jurva and Ilmajoki. In Ilmajoki, the responsible company for district heating selling and distribution is Ilmajoen Lämpö Oy, which is a subsidiary of District Heating Kurikka.

District heating Kurikka is a limited company. The company is owned by the municipality of Kurikka (100 % of the shares). District Heating Kurikka owns 80 % of its subsidiary Ilmajoen Lämpö Oy.

Moreover, district heat is generated in smaller heat-only boiler production units in Ilmajoki municipality. These heat-only boilers are split around the heating networks in order to maintain sufficient heat production for each customer. Apart from the main district heating network, located in the administrative area of Ilmajoki municipality, there are two smaller district heating networks that are not connected to the main heat network. Besides the heat-only boilers, each of the three networks has adequate reserve and peak load boiler units to ensure a reliable heat supply year-round.

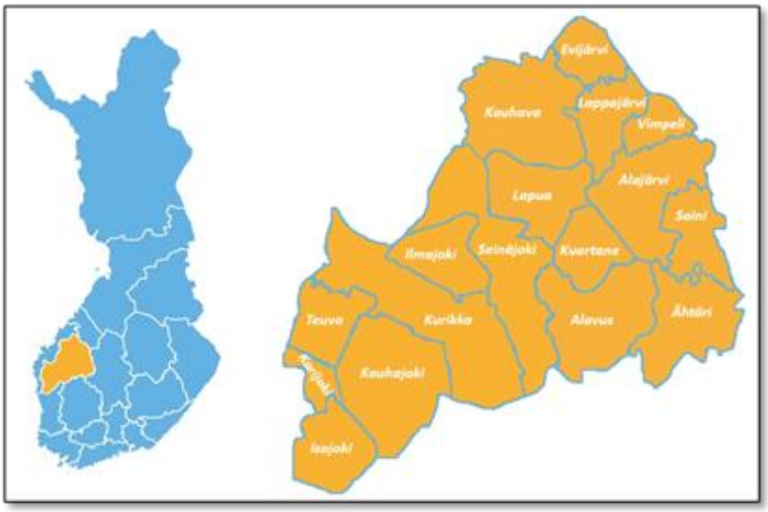

Figure 1: Ilmajoki location in South Ostrobothnia, Finland

The heat-only boilers are representing combustion-based technology. The used energy sources in District Heating Kurikka's heat generation are relying mainly on woodchips and peat. In general, heat distribution and transmission are following conventional practices recognized both nationally and internationally.

Characteristic of heat generation is that seasonal differences drive heat generation. Typically, heat demand is higher during heating seasons, especially during winter. During these seasons, the supply temperature peak is 115 ˚C. Daily supply and return temperatures are presented in figure 2.

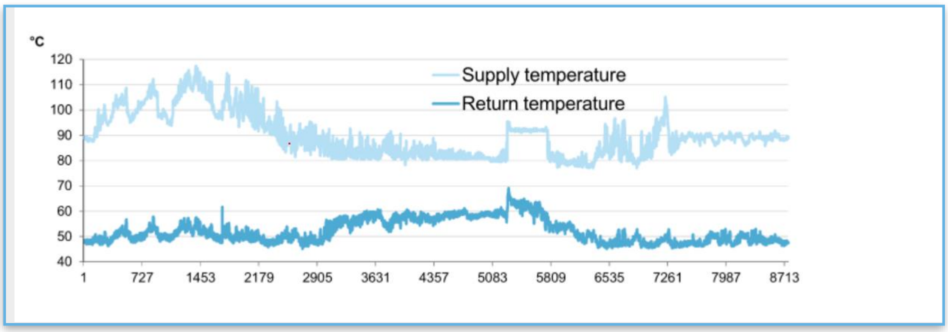

Figure 2. Supply and return temperatures in District Heating Kurikka network.

The next replacement investment concerning heat production in the Ilmajoki heat network is envisaged to take place during the 2020s. Therefore, the evaluation of alternative heat sources is necessary to make an extensive overview of the environmental, economic, and social benefits of new heat generation unit(s).

3.2 Locations and performance of district heating generation units

District heating is generated in three different areas in the municipality of Ilmajoki. The largest and most heat consuming area is the administrative area of Ilmajoki. Meanwhile, the parishes of Koskenkorva and Rengonharju have smaller separate district heating networks.

3.2.1 Administrative area of Ilmajoki

District heat is generated with two solid-fuel heat-only boilers. In more detail, the two base-load boiler units are KPA1, which is a 4.0 MW unit, and KPA2, which is a 6.0 MW boiler unit. Both of these generation units are grate boilers, and both are equipped with flue gas scrubbers. Likewise, both of the boilers are fired with woodchips, sod peat and milled peat.

In addition, next to these main district heating boilers, there are two light fuel oil (LFO) boilers as reserve and peak load capacity. Reserve oil boiler #1 is a 3 MW boiler and reserve oil boiler #2 is a 4 MW boiler.

The main district heating plants (and the reserve oil boilers) are located in the administrative centre of Ilmajoki, and more specifically, in the industrial area. The main restrictive feature in heat production and distribution planning and implementation are the city cutting river and the railroad. The river and railroad partly restrict the planning and building of a district heating network. For instance, these blockades locate between the district heating plants and some of the customers.

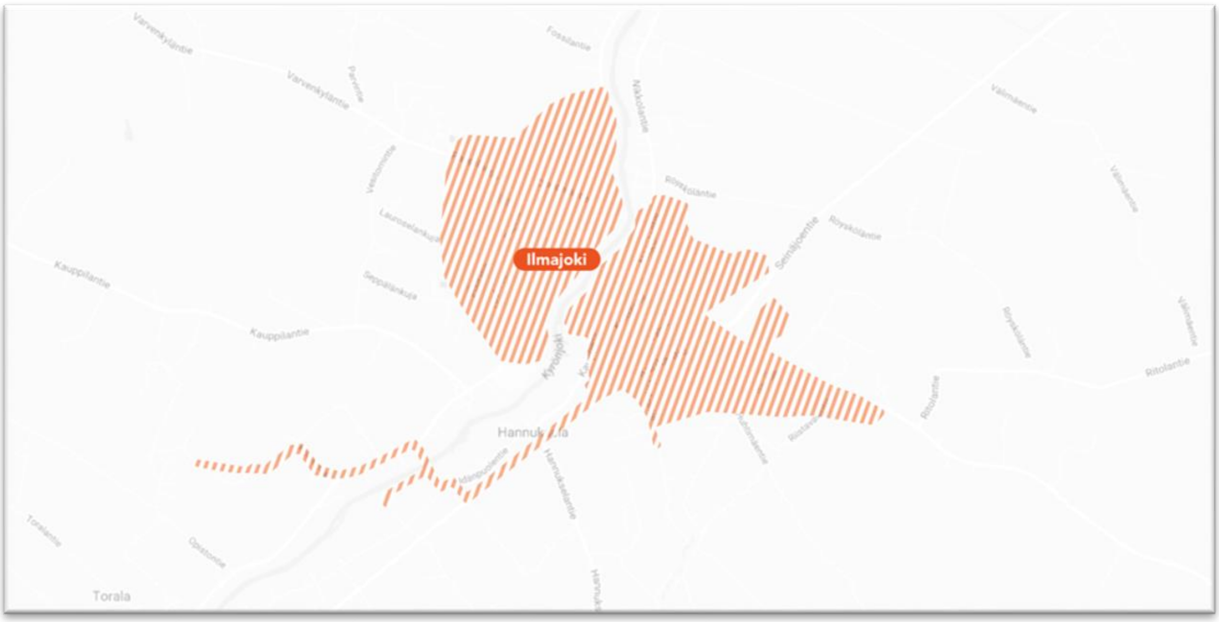

Figure 3. District heating area in Ilmajoki.

3.2.2 Reserve and peak load boilers in Ilmajoki administrative area

- There are two Light Fuel Oil (LFO) boilers next to schools (Koulukeskus) in the administrative area of Ilmajoki municipality. LFO 1 = 1.0 MW and LFO 2 = 1.5 MW.
- LFO = 4 MW at Ilmajoki agricultural school training center (Ilmajoen Maatalousoppilaitos, koulukeskus).
- 2 MW LFO at Homesojantie, next to the health center of Ilmajoki municipality. This reserve

boiler can be restricted to produce heat only for the health center.

3.2.3 District heat production in Koskenkorva

District heat is generated with KPA1 = 1 MW and KPA2 = 1 MW grate boilers. These solid fuel boilers are fired with woodchips, sod peat and milled peat.

In addition, the reserve load is covered with 2+1 MW transferable LFO boilers.

3.2.4 Heat production in Rengonharju

District heat is generated with KP1 = 1 MW solid fuel grate boiler. KP1 in Rengonharju is fired with woodchips, sod peat and milled peat.

In addition, reserve and peak load is covered with a 1 MW LFO boiler.

3.3 Heat distribution networks and district transfer stations

Pipe lengths for Ilmajoki administrative area are compiled from the network simulation model, whereas pipe lengths for the Koskenkorva network are estimated lengths based on the district heating network maps. Therefore, some of the information may not be exact. Inaccuracy is considered especially in smaller pipe sizes. Pipeline lengths are presented in table 1.

PARISH (name)> PIPE SIZE (DN)	ILMAJOKI ADMINISTRATIVE AREA	KOSKENKORVA
DN25	11,860 m	700 m
DN32	447 m	
DN40	9,279 m	850 m
DN50	6,911 m	550 m
DN65	5,996 m	1,850 m
DN80	5,217 m	1,550 m

DN100	4,829 m	500 m
DN125	1,442 m	150 m
DN150	1,558 m	
IN TOTAL	**47,520 m**	**6,150 m**

Table 1. District heating pipeline lengths and diameters in Ilmajoki DH networks

3.4 Fuels in district heat generation

The overall fuel consumption in district heat generation in Ilmajoki networks (3) is from the year 2017. The overall fuel consumption was 51,097 MWh (Table 2.).

PARISH (name)	SOD PEAT (MWh)	MILLED PEAT (MWh)	WOODCHIPS (MWh)	OIL (MWh)
Ilmajoki central area 2017	15,605	0	30,100	538
Koskenkorva 2017	0	0	4,056	0
Rengonharju 2017	0	0	547	251
In total	**15,605**	**0**	**34,703**	**789**

Table 2. Area-specific fuel consumption (MWh) in Ilmajoki

The most common fuel is woodchips (68 %), followed by peat (30 %). The use of light fossil oil (LFO) is about 1 % of all fuel consumption. In addition, a noteworthy accomplishment was achieved during 2017 as heavy fuel oil (HFO) was replaced by LFO.

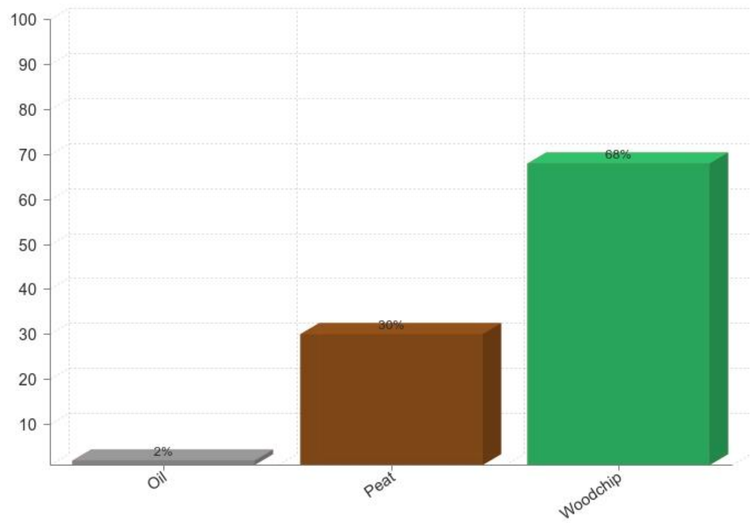

Figure 4. Fuel distribution in Ilmajoki DH network.

Furthermore, fuel consumption can be evaluated by the network, from which Ilmajoki administrative area is by far the most energy consuming. Network classification shows that Koskenkorva parish was completely fired with renewable woodchips. Meanwhile, Ilmajoki administrative area (central area) was fired mostly with woodchips (65 %) and peat (34 %), resulting in that the use of LFO was only about 1 %. Rengonharju parish was mostly fired with woodchips (69 %) but the share of LFO was the highest (31 %).

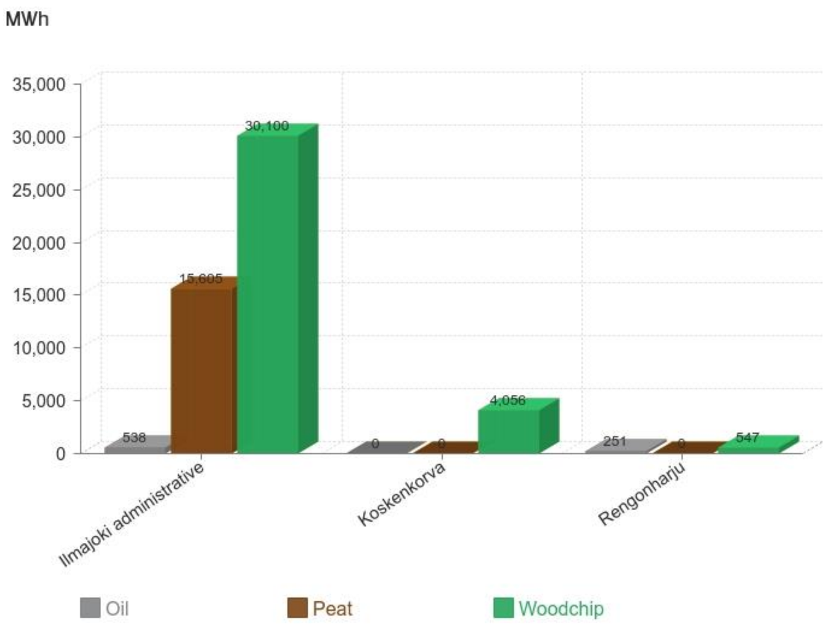

Figure 5. Fuel distribution and heat production in Ilmajoki DH networks (3).

3.5 Technical preconditions summary

Technical preconditions summary is presented in table 3, which includes information about heating power plant types, power capacities, fuels and heating capacities.

PARISH (name)	ILMAJOKI ADMINISTRATIVE AREA	KOSKENKORVA	RENGONHARJU
Baseload plant(s)	KPA1 + KPA2	KPA1 + KPA2	KPA1
Boiler types	Solid fuel grate boiler	Solid fuel grate boiler	Solid fuel grate boiler
Overall capacity of base load	10 MW (4+6)	2 MW (1+1)	1 MW
Reserve and peak load plant(s)	Reserve oil boilers 1&2 LMO LFO Boiler LFO 1 & 2 LFO at Homesojantie	Koskenkorva reserve LFO	Rengonharju reserve LFO
Boiler types	LFO boilers	Transferable LFO boilers	LFO boiler
Overall capacity of reserve and peak load	3 MW + 4 MW 4 MW 1MW + 1.5 MW 2 MW	2 MW + 1 MW	1 MW
Fuels in 2017	Woodchip 65 % Peat 34 % LFO 1 %	Woodchip 100 %	Woodchip 69 % LFO 31 %
Fuels consumption	Woodchip 30,100MWh Sod peat 15,605 MWh LFO 538 MWh	Woodchip 4,056 MWh	Woodchip 547 MWh LFO 251 MWh
Overall capacity, all Fuels, in total	25.5 MW (10 +15.5) 46,243 MWh	5 MW (2 + 3) 4,056 MWh	2 MW (1 +1) 798 MWh

Table 3. Technical preconditions summary in Ilmajoki

4 Urban preconditions in Ilmajoki municipality

The examined urban preconditions consider only buildings that are already connected to the existing district heating network. Therefore, the connected customers mostly have existing buildings with varying needs for supply temperature, but mostly high temperatures. The collected information of each customer group and district heating network is based on data from 2018.

4.1 Customers statistics in Ilmajoki heat network

The Y-axis of figure 6 represents the annual heat consumption (MWh). The X-axis represents the name of each customer property category that is connected to district heating. For example, there are 47 one-apartment houses connected to the district heating network in Ilmajoki administrative area.

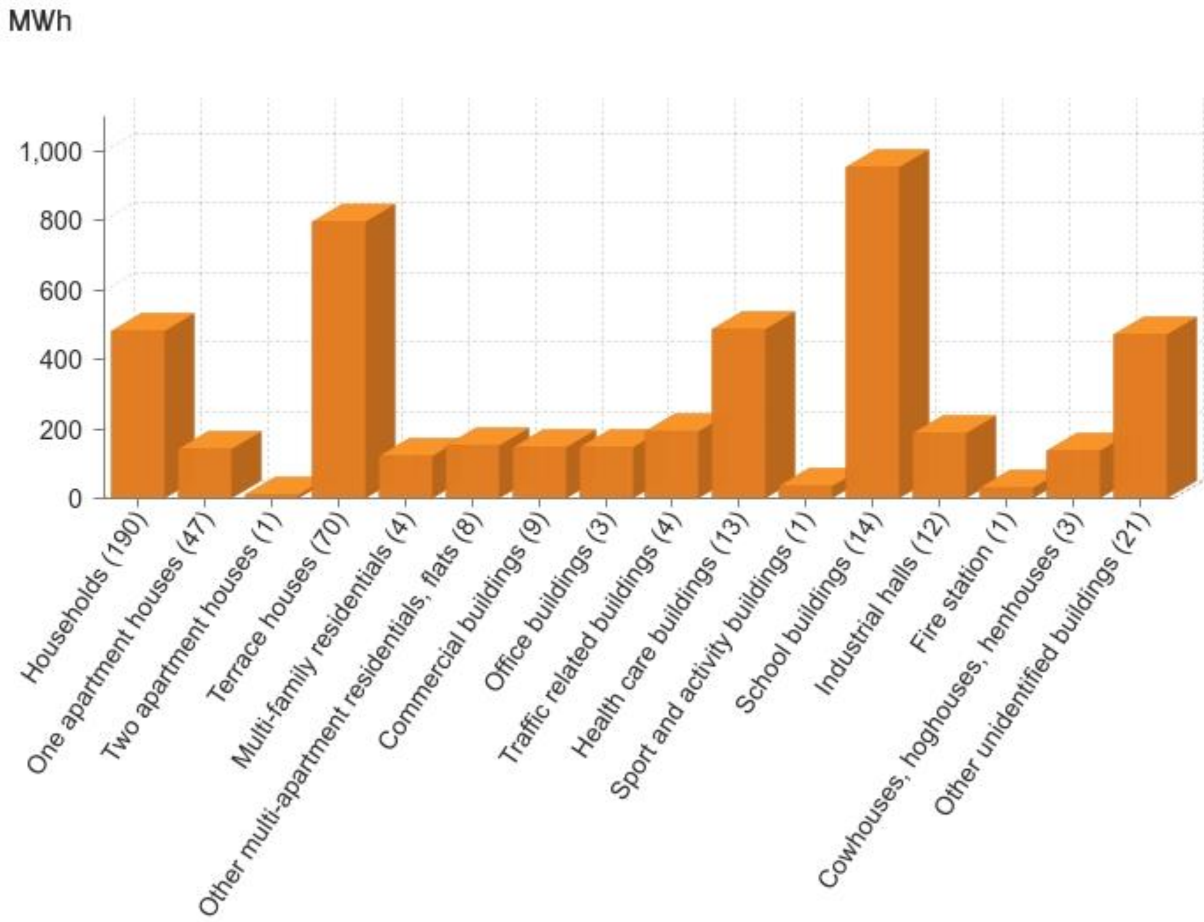

Figure 6. Customer statistics in Ilmajoki administrative area DH network

4.2 Customer statistics in Koskenkorva parish

The Y-axis represents the annual heat consumption (MWh). The X-axis represents the name of each customer property category that is connected to district heating. For example, there are 12 one - apartment houses connected to the district heating network in Koskenkorva parish.

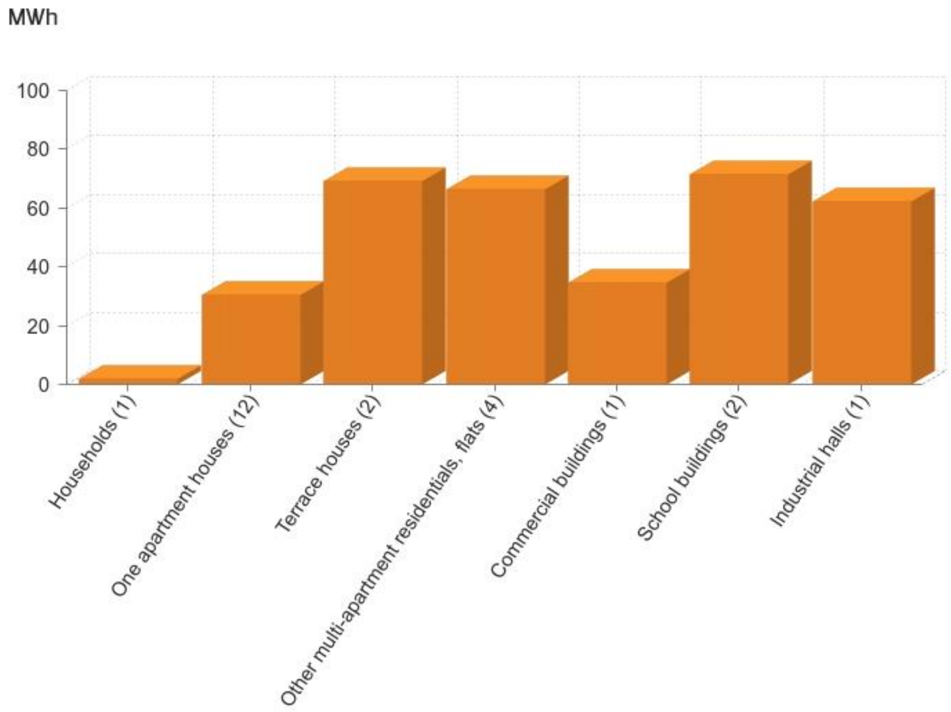

Figure 7. Customer statistics in Koskenkorva parish.

4.3 Customer statistics in Rengonharju parish (2018)

The only heat customer in Rengonharju is identified as "other traffic buildings ". Therefore, both monthly heat consumption and the only customer category are presented in the same picture. There are two property buildings within this category.

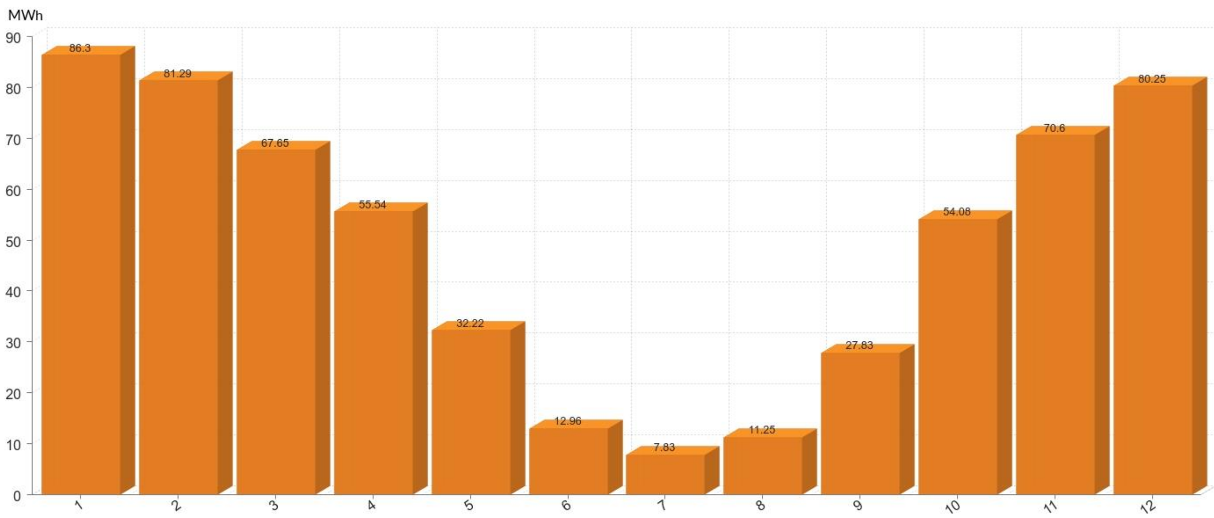

Figure 8. Customer statistics and monthly heat consumption in Rengonharju parish

4.4 Urban preconditions summary

The district heating network was established in Ilmajoki municipality during the early 2000s. The establishment of a DH network was based on the decision of connecting municipal-owned buildings to a centralized heating system. Therefore, most of the municipally owned buildings within the administrative area of Ilmajoki are connected to the DH network.

This summary presents the annual heat consumption per heating network (Figures 9, 11, 13). In addition, monthly heat consumption data is presented in a chart from the past 3 years (Figures 10, 12, 14). The presented data includes both municipal and residential buildings that are connected to the DH network.

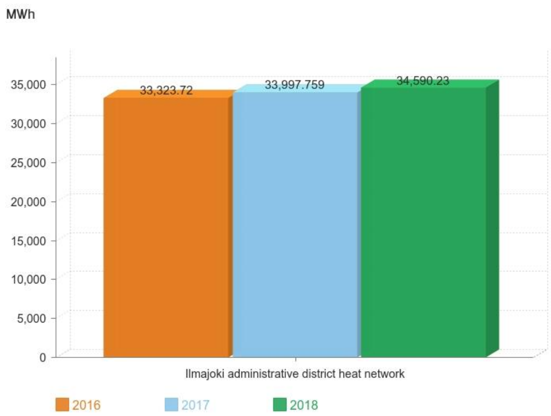

Figure 9. Annual heat consumptions in Ilmajoki DH network

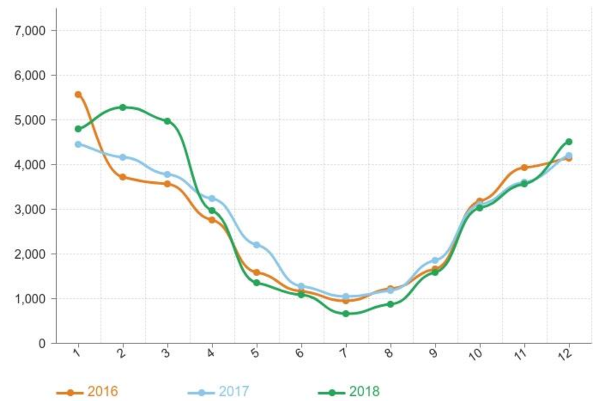

Figure 10. Monthly heat consumption in Ilmajoki DH network

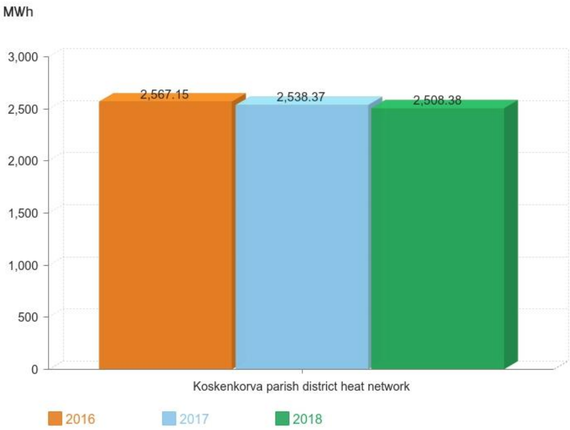

Figure 11. Annual heat consumptions in Koskenkorva DH network

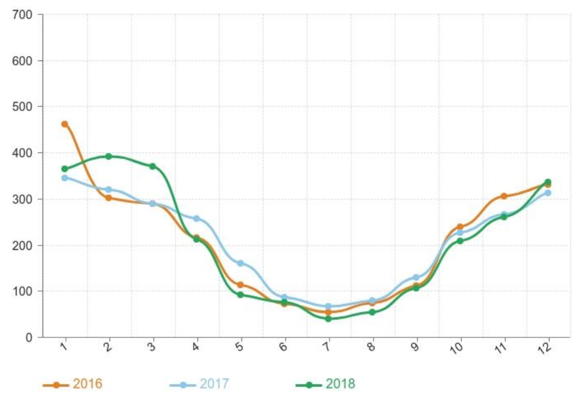

Figure 12. Monthly heat cons. in Rengonharju DH network

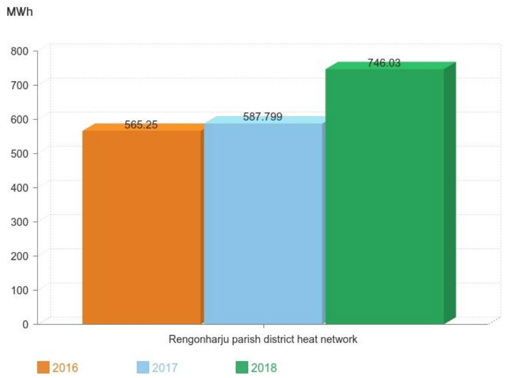

Figure 13. Annual heat consumptions in Rengonharju DH network

Figure 14. Monthly heat cons. in Rengonharju DH network

4.5 Stakeholder evaluation

In order to realize the development potential of district heating, it is useful to look at the actors involved in the heating system. In this way, it is possible to determine how the views of stakeholders affect the development of the heating system. The municipality of Ilmajoki and the heat transmission and distribution company District Heating Kurikka are the main stakeholders with the greatest impact and largely determine the development of the district heating system.

Consumers are stakeholders who have little role in the overall development of the district heating system, although they are a group that can make a significant impact on the application of district heating through their decisions and are significantly affected by the development. Although the development of the Ilmajoki municipality's DH is mainly carried out by the district heating company District Heating Kurikka, several municipal authorities are dealing with various environmental values, licence and DH organization issues. The responsibilities of heat producers are defined in heat production, distribution and sales agreements, which involve not only the district heating company but also the authorities, the municipality and the customers.

In the Altia Oy factory area, waste heat is generated in connection with the actual factory pro-cess, and this provides an opportunity to utilize waste heat and connect the waste heat process to the district heating network.

Involved and influential parties in DH's development are also the housing companies and companies providing services to the district heating area, which have an opportunity to offer cooperation as well as submit development proposals with the municipality or with the DH operator.

5 Strategic directions for implementation of low-temperature district heating

District heating has been practiced since the 1950s and it became a widely recognized heating system since the 1970s in Finland. During the past decades, district heating has undergone different technological phases, from which the 4th generation is the modern-day development trend.

The 1st generation of district heating was based on systems that relied on steam as a heat carrier. Meanwhile, the following generations were designed to use water as the heat carrier fluid. Characteristic for these former and still existing district heating generations is an extensive use of fossil fuels.

District Heating Kurikka's operational district heating units and distribution networks in Ilmajoki municipality are somewhat close to the 3rd generation district heating. Ilmajoki municipality's public buildings were connected to the district heating network in the early 2000s in order to achieve the desired transition from oil as the main fuel in heating. 3rd generation district heating systems are considered to operate at medium supply temperatures, which are around 60-100 ˚C. District Heating Kurikka's supply temperatures settle between these medium temperatures, excluding seasonal differences that may occur for instance during the winter season (max. 115 ˚C).

District Heating Kurikka is providing reliable and effortless heating systems for its customers. The district heating system in Ilmajoki is safe, environmentally friendly, easy to use and it provides employment for the local primary forest industry. In order to achieve 4th generation district heating systems, several approaches can be implemented. Therefore, the strategic directions in this pilot energy strategy for the implementation of new technological approaches are concerning the optimization of existing networks, integration of alternative energy sources and improving the energy performance of buildings. These three strategic directions support rather moderate measures than drastic actions when trying to achieve a district heating network with lower temperature levels.

5.1 Strategic direction I: Lowering the temperature of the heat carrier

The district heating networks in Ilmajoki are operating with supply temperatures of 70 ˚C – 115 ˚C. The district heating system is operated and maintained by professionals that ensure the availability of heat all around the year. In order to sustain the desired promises, District Heating Kurikka is actively developing and monitoring their heat distribution and generation. The overall objective of monitoring is to detect faults in the district heating production and especially in heat distribution. In retrospect, eliminating all possible temperature errors in existing distribution networks and substations is a significant part of making more efficient heat supply systems. Therefore, new implementations and solutions enable lowering of existing temperatures and are one of the key strategic directions.

STRATEGIC DIRECTION I:

LOWERING THE TEMPERATURE OF THE HEAT CARRIER

District Heating Kurikka's customers are households, public buildings and industrial companies who live and operate in changing conditions. District Heating Kurikka pursues meeting the requirements and expectations of their customers by offering versatile, and modern solutions that withstand both national and global comparison. Furthermore, reliable heating systems have high importance as a key value for the company. Customers are provided with reliable and efficient district heating systems. Other key values for the company are continuous improvement in terms of quality and enabling a healthy environment both for human health and the ecosystem.

In more detail, the first strategic direction of lowering the temperature of the heat carrier includes three strategic objectives.

STRATEGIC OBJECTIVE 1	STRATEGIC OBJECTIVE 2:	STRATEGIC OBJECTIVE 3:
SUSTAINABLE APPROACHES AND DEVELOPMENT PROJECTS	CONTINUOUS MONITORING OF PILOTS AND DEVELOPMENT PROJECTS	CONTINUOUS LEARNING AND AWARENESS RAISING

5.1.1 Strategic objective 1 – Premise of development

STRATEGIC OBJECTIVE 1
Premise of development: Sustainable approaches and development projects

STRATEGIC OBJECTIVE	EXPECTED OUTCOME
Implementation of sustainable and responsible development projects. These projects are advanced and benefit both local and regional societies.	Sustainable approaches and implemented projects enable: • development of own know-how in a changing environment in order to ensure quality • enthusiasm and competence for development projects • monitoring of risk-carrying capacity of own development projects • replicable new solutions for improved efficiency • increased responsibility of customer wellbeing by offering a clean environment and therefore a better quality of life
Refurbishment of existing district heating distribution network.	Outdated district heating network connections and specific parts of distribution networks are refurbished in good manners. Achieved benefits are: • decreased thermal heat losses • decreased pumping costs • energy-efficient power transmission • optimized cooling for district heating water

5.1.2 Strategic objective 2 – Premise of quality

STRATEGIC OBJECTIVE 2
Premise of quality: Continuous monitoring of pilots and development projects

STRATEGIC OBJECTIVE	EXPECTED OUTCOME
Primarily, all implementations and pilots improve the heat supply, meanwhile ensuring a reliable heating system for current and forthcoming customers. Explicit benefits of implementations are described thoroughly, and customers have equal rights to partake in development projects.	Customers are verifiably provided with a reliable and carefree heating system, which is more efficient and enables improved environments by ensuring: • good indoor climate • lower energy consumption • lower carbon footprint Achieved benefits are proven and visible to customers. Customer satisfaction is generally quite high.
Identification of best practices and continuous development driven by monitoring.	New implementations, renovations and pilots are monitored extensively. Verified best practices are replicated in other parts of the district heating systems. Heat generation and distribution are optimized, overall energy efficiency is improved, temperature levels are lower, and hydronic bottlenecks are eliminated.

5.1.3 Strategic objective 3 – Premise of know-how

STRATEGIC OBJECTIVE 3
Premise of know-how: Continuous learning and awareness-raising

STRATEGIC OBJECTIVE	EXPECTED OUTCOME
Recognition and approval of sustainable approaches. Development projects may serve other municipalities and regions as ideas that are considered as good practices.	Development projects are recognized and approved widely, and therefore implemented projects encourage other municipalities and district heating companies to similar actions.
Exchange of experiences	Operational approaches are reviewed after receiving new information about practices implemented elsewhere (lesson learned).
Cooperative approaches offer a solid platform for customer-driven development. A significant competence profile builds a tempting, reliable and easily approachable network for new pilots and development projects.	Competence within the field of district heating is developed and implemented in collaboration with external service providers. Development projects and pilots are implemented in dynamic collaboration with main stakeholders and customers, such as housing cooperatives, industrial companies and different departments of the municipality. Stakeholder's and customer awareness is increased by transparent dialogue and/or in public events. Customers are guided to apply for applicable grants, e.g., renovation grants in order to lower possible financial barriers. Stakeholders and customers understand the power of collaboration, and therefore they get in contact in an early phase of possible development projects.

5.1.4 Example of the refurbishment of old connections

District Heating Kurikka has, for instance, refurbished old heat channels in order to reduce temperatures especially in return flows. For example, aged inefficient heat channels and accumulators have been replaced with separate district heating connections and heat exchangers. Such implementation is described in figure 15, where blue connections represent new pipelines and yellow connections represent the former heat channels.

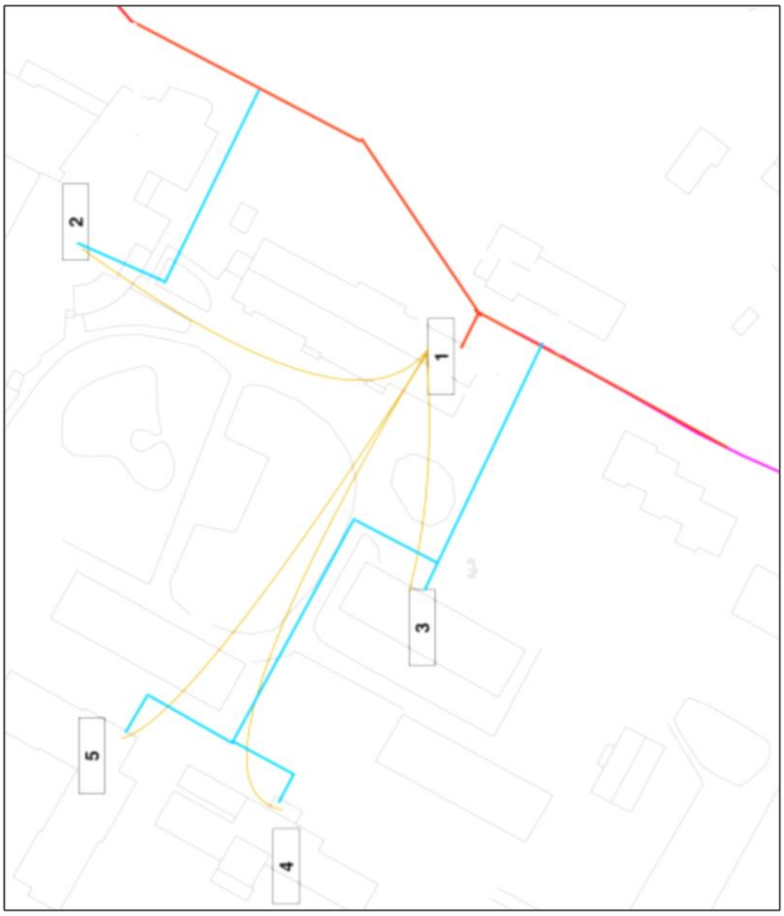

Figure 15. Example of the refurbishment of old District Heating Kurikka.

Figure 16 shows the return water temperature of the DN part to be regenerated (blue line). The time when the changes have been made at the end of the line can be clearly seen from the line. The change in return temperature is between 10-20 °C. The measurement point is on the same site as the KPA plant but in a different building (Yellow line in the image is not under consideration and the colours are not related to the colours in the previous image).

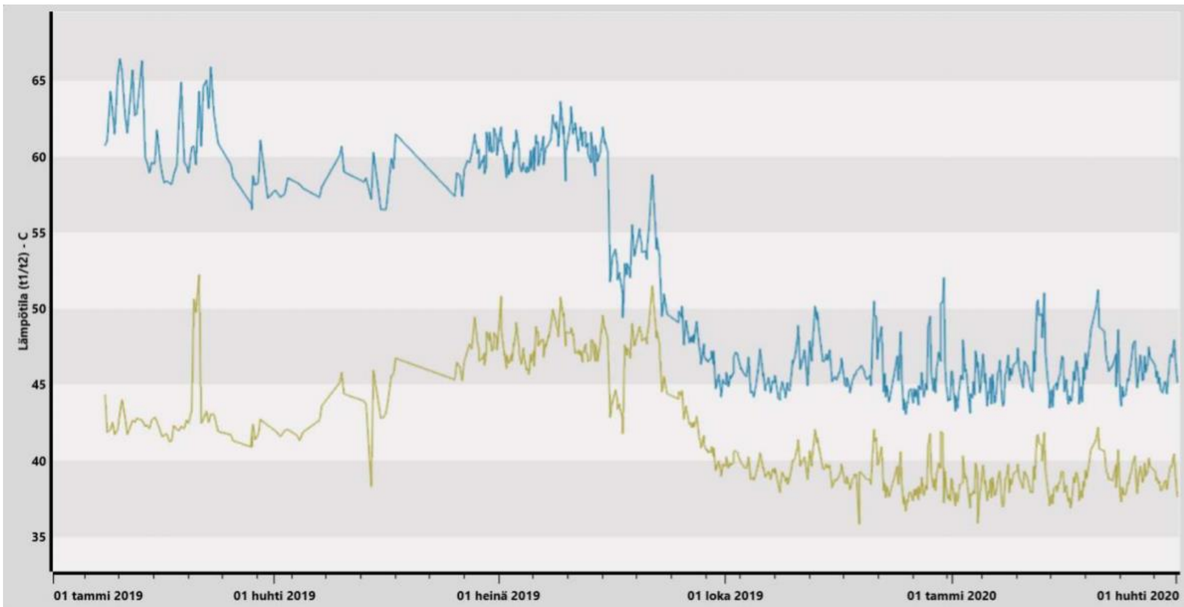

Figure 16. Return water temperature of the DN dropping in the regenerated part.

5.1.5 Example of smart building control and maintenance powered by IoT

On company level, there is also interest in discovering new Internet of Things (IoT) based technologies and solutions. Available products and services that help district heating companies, for instance, to cut their peak load demand, eliminate hydronic bottlenecks, and reduce the need for maintenance and improve fault tolerance are under District Heating Kurikka's interest.

5.2 Strategic direction II - Integration of alternative energy sources

District heat is generated with combustion-based heat-only boilers in Ilmajoki. Primary fuels are peat and woodchips, which are both received from regional primary forest industry entrepreneurs. Therefore, District Heating Kurikka is already generating rather environmentally friendly heat but also providing employment for local and regional entrepreneurs. However, the envisaged future scenarios do not embrace an extensive use of peat, which is one of the main reasons why alternative energy sources come into further consideration. At present, the geographical location combined with varying seasonal heating demands restricts some of the innovative and sustainable approaches. These restrictions concern, for example, the extensive use of solar thermal systems. In order to make an explicit change, solar thermal technologies should be considered to be implemented with seasonal heat storages. In future perspective of Ilmajoki district heat generation, the most potential and appropriate alternatives for primary fuels were identified to be large-scale utilisation of industrial surplus heat and/or biomasses such as woodchips and pellets.

STRATEGIC DIRECTION II:

INTEGRATION OF ALTERNATIVE ENERGY SOURCES

The main alternative heat source in this pilot energy strategy was identified to be industrial low-temperature surplus heat. The alternative solution was defined as a solid fuel boiler fired with woodchips. The areal overview confirmed that there is a significant amount of available surplus heat, which could be utilised in the district heating network. On the other hand, the established and extensive use of local biomasses is another alternative to be extended to previous experiences and practices.

The case-specific studies state that industrial surplus heat is supposed to be utilised in the existing district heating network with a heat pump unit. Due to the existing district heating network and rather aged building stock, the basis for the study was that surplus heat is utilised in the conventional district heating network, which operating supply temperature is typically varying between 80-115 ˚C. The same framework applies also to the alternative solid fuel boiler unit.

In more detail, the second strategic direction of integration of alternative energy sources includes three strategic objectives.

STRATEGIC OBJECTIVE 1	STRATEGIC OBJECTIVE 2:	STRATEGIC OBJECTIVE 3:
WASTE HEAT UTILIZATION	BIOMASS UTILIZATION	OTHER TECHNICAL SOLUTIONS

5.2.1 Potential of surplus heat

The estimated amount of the to be cooled surplus heat at the industrial site is equal to 4.5-6.2 MW. The prevailing factor for the available heat power is the season which is under review. Therefore, during the spring, summer and autumn seasons, the available heat power is approximately 4.5 MW. Meanwhile, heat power during the winter season is about 6.2 MW. Correspondingly, 4.5 MW heat power is utilisable 87 % throughout the year, and 6 MW is utilisable for around 20 % throughout the year.[9]

In order to describe the potential of the surplus heat source, the amount of energy produced by the heat pump was calculated at different heat pump capacities. Therefore, the power output of the selected heat pump determines the potential amount of generated heat. For example, approximately a 2 MW heat pump generates about 15,000 MWh heat, whereas a 6 MW heat pump may generate almost 35,000 MWh.[9] The latter power output would, in the best-case scenario, cover the greater part of Ilmajoki administrative areas district heat demand. Therefore, the potential of the surplus heat source is significant in Ilmajoki municipality.

5.2.2 Heat pump

Unutilised industrial surplus heat is generated from an industrial cooling process. The case-specific technical review covers both heat recovery exchanger (HR) and heat pump (HP).[9] The principle and layout are presented in figure 17.

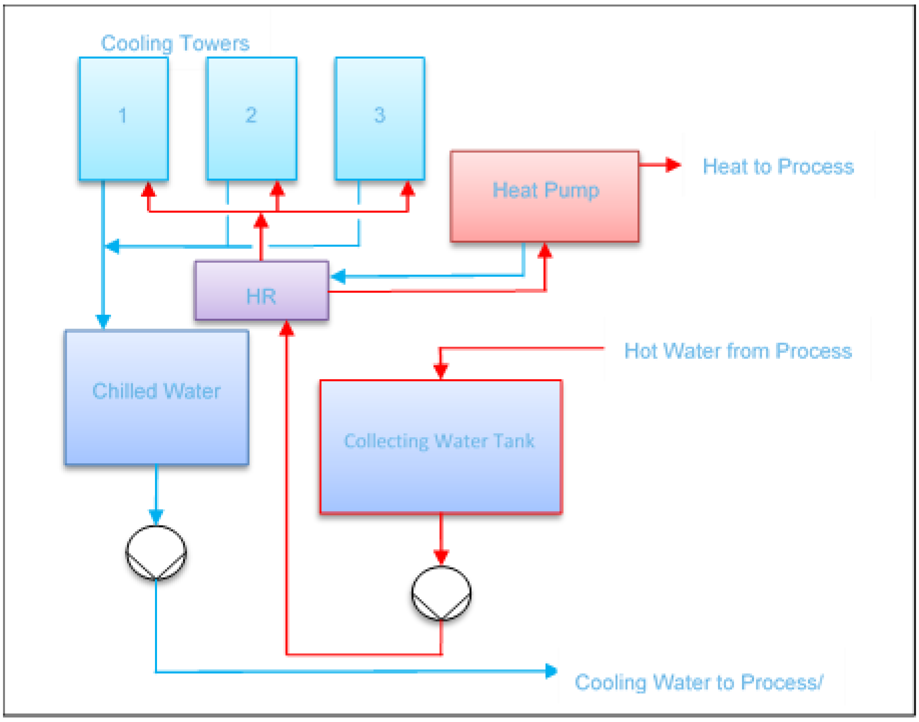

Figure 17. The Heat Recovery (HR) Exchangers and Heat Pump installed into the system.

Furthermore, different switching facilities were reviewed. From these, the best alternative was selected to be a switching where the HP unit is located in the industrial site.[9] Layout regarding the switching is presented in figure 18.

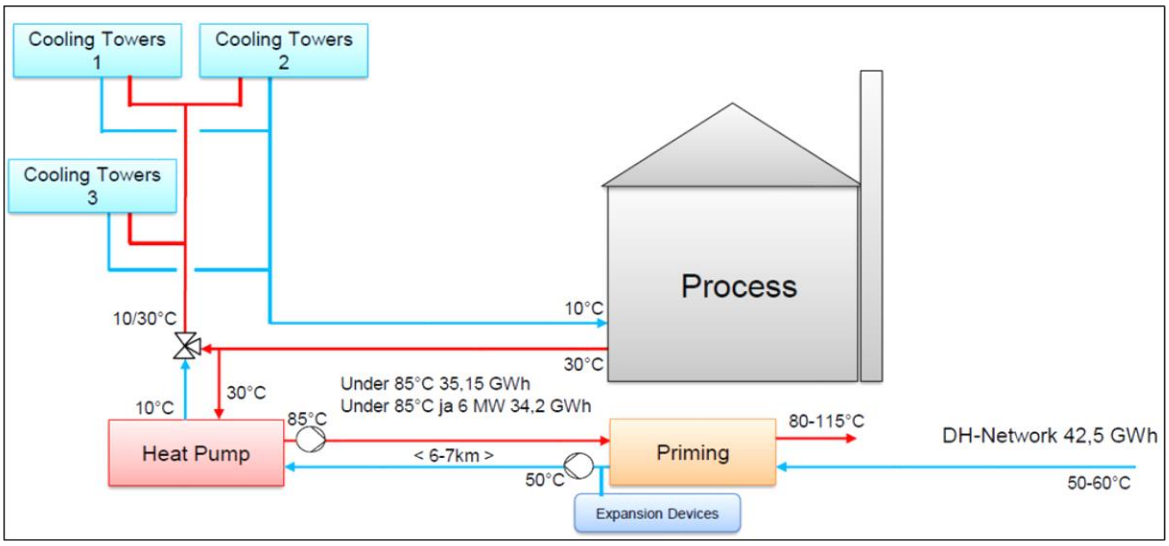

Figure 18. The connection layout.

In addition, the HP solution requires a priming unit in order to meet the demands of the existing district heating network in Ilmajoki municipality. In consideration of the economic aspects, the recommended solution is to implement a system with a 6 MW HP, a 3 MW solid fuel boiler fired with pellets (priming unit) and a sufficient back-up heating plant fired with light fuel oil. [9]

5.2.3 Biomass driven heat generation

The alternative future solution for district heating generation in Ilmajoki municipality is a solid fuel boiler fired with biomass. The selected biomass in this case is woodchips. Therefore, this alternative case scenario would replace the current combustion of woodchips and peat.

5.3 Strategic direction III - Improving the energy performance of buildings

Improving the energy performance of buildings is one of the nationally identified development areas. The need for refurbishing the existing building stock is acknowledged by the government. More extensive energy efficiency refurbishments are steered by new subsidies granted by ARA (The Housing Finance and Development Center), which implements Finland's housing policy. The grants are available during 2020-2022 and it is directed for private persons, housing cooperatives and ARA communities.

The potential utilisation of surplus heat is a key starting point for developing new residential areas with energy-efficient buildings. On the other hand, if surplus heat is not utilised, new separate district heating networks with lower temperature levels should be taken into account already in the design phase of new residential areas.

6 Analysis of future developments

6.1 LCA - Life Cycle Assessment

The LCA results can be of interest for energy planners and energy companies, engineers, DH operators, public officials and decision-makers including municipal planning merging the environmental perspective within new or updated planning processes for urban infrastructural development. The Life cycle assessment made by Riga University is based on the Pilot energy strategy for Low-Temperature District Heating System implementation for Ilmajoki Municipality.

The document represents a consistent guideline on how to perform LCA specifically addressed to the implementation of eco-design principle for the construction of new or renovation of existing DH system. The specific inventory utilized to evaluate the overall eco-profile of certain energy strategy implemented in Low-Temperature DH is reported both in the Annexes and as excel tables.

The results from an LCA made for a DH system make it possible to:

- Define an updated data inventory of all DH subsystems to be used as further benchmarks.
- Clarify which subsystems and past of a district heating system are affecting the overall environmental performance of the infrastructure.
- Provide alternatives based on eco-design perspectives implementable in Municipality Energy strategies including SECAP (The Social, Environmental and Climate Assessment Procedures) and compare them with the business-as-usual DH scenario (e.g., distribution network using natural gas). SECAP outlines how IFAD (The International Fund for Agricultural Development, a specialized agency of the United Nations) addresses the social, environmental and climate impacts associated with its projects and programmes. SECAP documents provide information on assessments, measures, monitoring and compliance conducted for environment, social, climate, resettlement, and Indigenous Peoples' issues.

The implementation of waste heat and heat pumps in the District Heating system has an environmental benefit in several mid-point categories, except for Ionizing radiation, Ozone layer depletion, Respiratory organics, Global warming, Non-renewable energy and Mineral extraction, where the increase related to the development of the proposed future scenario is 936 %, 180 %, 19 %, 1 % and 40 % respectively. On the other hand, the remaining 10 midpoint categories present an average reduction of 60 %, hence, here, it is necessary to implement a weighted factor in order to clearly display the overall environmental impact.[8]

The difference in endpoint categories, or areas of concern, is shown in Figure 19. The human health area is the one with the highest environmental toll, the reduction of moving from the current DH conditions towards implementing waste heat use, is 64 %. The total environmental score for the human health area under the current conditions in Ilmajoki municipality, delivers 46.2 kPts for the analysed FU, while under the future scenario the resulting score is 16.67 kPts. In the ecosystem quality area, the reduction is 67.4 %, although, climate change and resource areas show a minor increase from developing the future scenario strategy. For climate change, the raise corresponds to 16.2 %, and in the resources area 1.1 %.[8]

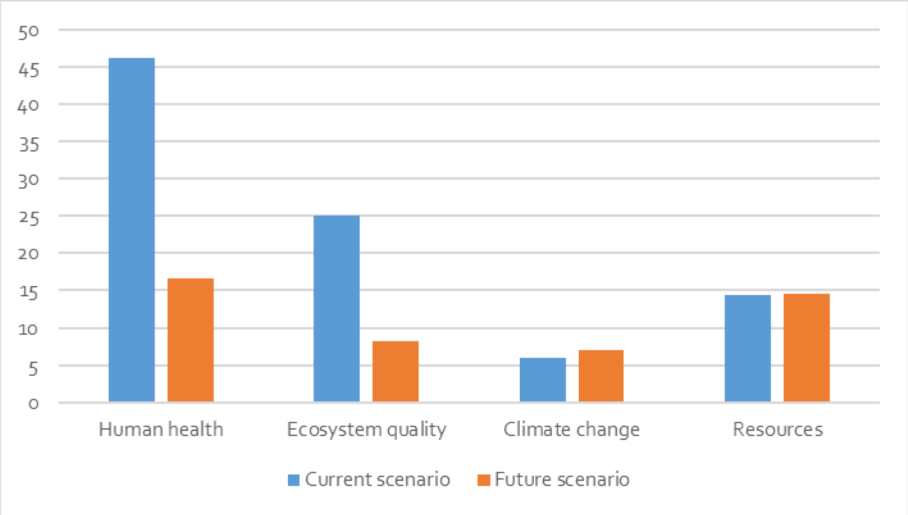

Figure 19. Weighted damage assessment comparison at endpoint categories

6.2 SWOT analysis

SWOT analysis is an examination of an organization's internal strengths and weaknesses, its opportunities for growth and improvement, and the threats the external environment presents to its survival. The primary aim of strategic planning is to bring a system into balance with the external environment and to maintain that balance over time. Organizations accomplish this balance by evaluating new programs and services with the intent of maximizing organizational performance. SWOT analysis is a preliminary decision-making tool that sets the stage for this work. [7]

The SWOT analysis discussed here cover three different strategic lines of action: Strategic direction I: Lowering the temperature of the heat carrier, Strategic direction II - Integration of alternative energy sources and Strategic direction III - Improving the energy performance of buildings.

Strategic direction I: Lowering the temperature of the heat carrier

Reducing the heat transfer and heat exchanger temperature from the traditionally used 70-115 ˚C significantly reduces heat loss. As a result, the need for the energy source used for heat production is also reducing, leading to cost savings in terms of fuel or electricity consumption, as well as reduced CO_2 emissions. The possible disadvantages are the increase in the flow of the district heat system and the increase in the heat exchanger surfaces, that may be required to ensure sufficient heat transfer. A very significant issue here is the design temperature of the transfer surfaces of customer equipment. This easily leads to a large investment from customers and is often identified as an unreasonable enlargement requirement for new heat exchangers and possibly also the other equipment in the system. It should also be noted that in Finland, the temperature for hot water is generally set at 55-65 ˚C.

Strength	Weaknesses
• Lower costs for energy source/fuels • Lower heat losses • Increased efficiency in transfer	• Higher investment costs for transfer and heat carrier • Heating system adjustments
Opportunities	**Threats**
• EU and state aid for alternative energy source	• Alternative energy sources • Consumer unwillingness to cooperate • Pricing instability possible • Temperature possible too low for some application

Table 4. SWOT analyses for strategic direction I: Lowering the temperature of the heat carrier

Strategic direction II - Integration of alternative energy sources

The use of waste heat, the use of biomass, heat pumps and other technical solutions for heat recovery are environmentally friendly and emission-reducing forms of energy production. The weaknesses of these solutions are the investment costs of the equipment itself, the potential need to balance the existing district heating network and the location of the heat source at the point of use. The technology still needs to be developed so that even in winter the temperature levels meet the requirements of the district heating network. During the summer, these solutions are currently very potential alternatives. Threats and weaknesses in the use of heat pumps include increasing dependence on electricity and the electricity market, and the price of electricity and especially transmission pricing are a challenge. If the sector integration and heat pumps become more widespread, there is a need for legislation to ensure that electricity transmission pricing stays at a reasonable level (sector integration here means the connection between electricity, heating and cooling, which makes energy recovery more efficient).

Strength	Weaknesses
• Use of local and renewable heat source - biomass • Lower costs for energy source/fuels • Environmental positive values • Increased efficiency in flue gas condenser	• Higher investment costs for biomass boiler • Heating unit adjustment • Transfer distance • Winter temperature/heat exchanger challenges
Opportunities	**Threats**
• EU and state aid support for alternative energy source	• Consumer unwillingness to cooperate • Electricity price stability

Table 5. SWOT analyses for strategic direction II - Integration of alternative energy sources

Strategic direction III - Improving the energy performance of buildings

Improving the energy efficiency of buildings brings clear cost savings in heat production. The disadvantages are the investment costs of insulation, both the construction of buildings and the provision of ventilation with sufficient efficiency. However, in the ventilation heat pump solutions for heat recovery can be used.

Strength	Weaknesses
• Lower costs for energy source/fuels • Lower heat demand and losses • District Cooling • Image value	• Waste heat unit price vs wood-chips/peat • Heating unit adjustment • Electricity and distribution prices
Opportunities	**Threats**
• EU and state aid support for energy efficiency	• Possible under-ventilation of airspace and structures

Table 6. SWOT analyses for strategic direction III - Improving the energy performance of buildings

6.3 Risk analysis

A simplified risk analysis is provided in Table 6, which analyses 6 different risks. The impact of the risks on each of the analysed scenarios has been assessed, on a scale of high, medium or low.

Risk	Probability	Impact	Actions to eliminate the risk
Changes in energy sources	Scen 1 -high Scen 2-average Scen 3-low	High	Tax and environmental guidance policy stability Ensuring cost efficiency of DH to minimize heat tariff
Consumer unwillingness to cooperate	Scen 1 -High Scen 2- Average Scen 3- Low	Average	Informing consumers about the operation and costs of DH Ensuring cost efficiency of DH to minimize heat tariff State support for the construction of heating systems
Pricing instability possible	Scen 1 -Average	Scen 1 -Average	Increase DH performance to minimize fuel consumption

	Scen 2- Average Scen 3- Low	Scen 2 -High Scen 3-Average	
Electricity price stability	Scen 1 -High Scen 2- High Scen 3- Average	Scen 1- High Scen 2-High Scen 3-Average	Need for electricity transfer legislation
Side effects in functionality	Scen 1 -Average Scen 2- Average Scen 3 -Average	Scen 1 -High Scen 2- Average Scen 3 - High	Transparent and multidisciplinary development Regular monitoring of systems Continuous system performance improvement

Table 7. Risk analyses for strategic directions I-III

6.4 Pilot testing measure

During the project, the utilization of a significant 4.5-6.2MW waste heat site was investigated (Figure 18). Since the water temperature level of this waste heat site is only 30 ˚C, utilization in the current situation requires a heat pump solution if the site is applied together with the existing network. Due to the location of heat recovery sites (e.g., residential areas), an additional 7-8 km of new heat transfer piping is required. Therefore, the investment is under consideration, no decisions have yet been made on its launch. The investment is reviewed in company level at company District Heating Kurikka together with Altia factory on an annual basis, but it is still too early to assess when the investment could possibly take place.

7 Conclusions and recommendations

Investments in LTDH networks must take into account integrability with existing DH-networks that are still in use. Reducing grid temperature is possible by eliminating deficiencies in generation and distribution but also by integrating new technical solutions, e.g., IoT-technology. It is important to guarantee a sufficient amount of heat to the customer under reasonable investment conditions, and presumably, this requirement is particularly important in countries with cold winters. Ongoing investments have been able to lower the return temperatures of the networks and thus improve energy efficiency and reduce emissions.

The most potential applications for LTDH networks have been identified, like new residential areas under construction and upgrades in connection with the renewal of networks. The utilization of waste heat is a very important part of the development of district heating networks. Heat pump solutions and applications can be used to develop connection options for both LTDH and existing traditional DH networks. In heat production, it is important to move step by step to low-carbon solutions. The suitability of heating plants for different fuels makes it possible to use different fuels and their mixtures, which makes it easier to maintain the price stability of district heating. At the moment, it is important to find suitable solutions to replace peat fuel. Industrial low-temperature surplus heat from Koskenkorva is the main alternative energy source in Ilmajoki municipality (in connection with a heat pump unit). Due to its extent, biomass is still another alternative.

The most appropriate steps can be taken to use an increasing number of alternative energy sources for heat production and to improve the energy efficiency of existing buildings. Improving the energy performance of buildings in any case goes hand in hand with Finland's housing policy.

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