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Pilot energy strategy for District Heating

Tartu municipality

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Introduction

The Pilot energy strategy (PES) for district heating in Tartu municipality (hereinafter - Strategy) was developed with the aim to improve district heating (DH) and cooling systems in City of Tartu in order to increase energy efficiency. The document describes and assesses existing heating and cooling supply situations and developing systems for using 4th generation district heating (4GDH) and known as Low Temperature Disrict Heating (LTDH).

The strategy assesses the preconditions for DH development (planning documents, regulatory framework, stakeholders) as well as availability of alternative solutions for LTDH.

The strategy defines the main directions of DH development – the efficiency of systems, reducing of carbon emissions, integration of renewable energy sources (RES) and waste heat, as well as adaptation to the heat load of low-consumption buildings. For the DH system, a number of development alternatives have been defined which were compared by applying cost-benefit analyses. Main barriers from supply and consumption of DH are described.

The usage of LTDH in a city district, namely Karlova district, are described as well. For Karlova district SWOT analyses and risk analyses were composed.

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

The document is a follow-up of the new sustainable energy and climate action plan for the City of Tartu called „Tartu Energia 2030“.

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1 Analysis of the preconditions for the development of DH

1.1 Analysis of existing planning documents

1.1.1 Estonian heat sector overview

The total annual heat consumption of Estonia is ca. 6,600 GWh. In 2018, 70% of this amount (4,300 GWh) was taken up by district heating.

In 2018, data about the heating sector was [1]:

- The total length of district heating pipelines is 1,524 km
- including pre-insulated pipelines 846 km (56%)
- including new connections in 2018 21 km
- The average age of the pipelines is 21.55 years
- Average construction year of biofuel boilers 2010 (234.89 MW)
- Heat energy in the district heating network 5.04 TWh
- Heat energy sales 4.30 TWh
- Heat network losses of 0.72 TWh (14%)
- The average limit price is 61.68 Euros / MWh
- The average sales price is 58.27 Euros / MWh

Approximately 30% of the population use individual heating solutions, generating thermal energy mostly from wood, natural gas and heat pumps (as a growing sector).

The district heating sector plays an important role in the achievement of Estonia's renewable energy objectives. Estonia promotes the co-generation of thermal energy and electricity, if this is economically and technically feasible, which can contribute to diminishing environmental impacts caused by the heating supply and help to conserve more energy than it would be possible in the case of the separate generation of electricity and thermal energy.

District heating costs can be optimised by consumers themselves. The best alternative for some cost savings would be to decrease the thermal energy consumption of an apartment house by a properly renovated façade and efficiently operating technical systems.

The statute of the label "Efficient district heating" was developed in 2018. The label is applied for the network operator separately for each district heating system and is issued on the basis of a decision of the Estonian Power and District Heating Association (EPHA) expert committee. The label shall be awarded to a district heating system that uses at least 50% renewable energy or 50% waste heat or 75% cogeneration or 50% of a combination of such energy and heat to produce heat. The district heating network, which has been awarded the label "Efficient district heating", fully complies with the definition of efficient district heating and cooling in the European Union Energy Efficiency Directive 2012/27 / EU. The labels for efficient district heating will be handed over to companies at the annual EJKÜ conference in spring. Companies and district heating systems recognized with the label in previous years are listed on the EPHA website. [2]

The Estonian Power and District Heating Association, established in 1995, is the largest and oldest organization in Estonia representing energy and heat companies and acting in the common interest of these companies. Today, the association includes 41 companies, including 31 energy and network companies and 10 technology, design and construction companies.

1.1.2 Planning documents from the City of Tartu

Sustainable energy and climate action plan for City of Tartu „TARTU energia 2030"

The use of carbon-free district heating and its development is an important way for the city of Tartu to reduce CO2-emissions. District heating areas in Tartu was formed by the "Master Plan of the City of Tartu until 2030 "(2017). In Tartu, district heating provides the heat of about 1,700 buildings. 50% of the consumer sector is the housing sector, 8% are municipal authorities and 42% are other institutions and companies. The consumers of the city of Tartu are supplied with district heating and district cooling by the energy group Fortum Tartu. Biofuels are mainly used for heat production (wood chips, over 75%), followed by natural gas (18.5%) and to lesser extent peat (5.5%). Fortum Tartu is the first in the Baltics to offer a district cooling service.

The strategic targets of developing heating and cooling in Tartu are:

- free fossil fuel district heating and cooling by 2030;
- from 2024, Tartu's municipal buildings will not consume energy produced from fossil fuels (excluding district heating, which will be fossil-free until 2030);
- expansion of the district heating network, especially in Karlova and Supilinn. As a result of meeting the targets, by 2030 the city will have district heating thermal energy consumption increased by 15%;
- The energy consumption of district cooling is 29,000 MWh;
- the city's district heating and -cooling carbon emissions in 2030 will be 0 tons. Due to joining the district heating service, the business sector has carbon emissions further reduced by up to 13,000 tons per year.

Indicator	2010	2017	2030	Change	Change%
Heat sales (MWh)	504 118	514 231	580 000	75 882	15%
Cooling sales (MWh)	0	2 949	29 000	26 000	90%
CO_2 emission target (tCO_2)	71 000	66 196	0	105 333	-100%

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Absolute heat loss (MWh)	68 560	63 000	63 000	-5,560	-8%
Relative heat loss (%)	13.6%	12.3%	10.9%		
Number of customers	982	1,411			
Total length of the network (km)	115	177			

Table 1: Historical and target values for 2030 of district heating and cooling in Tartu (source: "Tartu energy 2030")

Development goals for district heating by Tartu energy and climate action plan "Tartu Energia 2030"

- The municipal sector is moving to renewable energy sources (Community agreement) by 2024. The goal is lead by Tartu City Government;
- Cooperation agreement between the city of Tartu and the energy producer to achieve carbon neutrality in district heating. The goal is lead by Tartu City Government and Fortum (energy producer);
- Decommissioning of fossil fuel district heating and cooling by 2030. Lead by Fortum (energy provider)

The supported activities to reach the goals are show in Table 2.

Activity	Responsible	Year
Expansion of the district heating area	Tartu City Government	2021
Introduction of energy storage in district heating in production and distribution	Energy producer	2030
Reduction of network losses in district heating	Energy producer	continuous
Low temperature district heating and exhaust use of residual heat in the district heating network	Energy producer	continuous
Gradual building of Karlova and Supilinn buildings district heating connection	Tartu City Government, Energy producer	continuous

Table 2: actions foreseen in action paln "Tartu Energia 2030"

Development goals for district cooling by Tartu energy and climate action plan "Tartu Energia 2030"

The existing refrigeration market is dominated by house-based traditional ones electric refrigeration appliances with low energy efficiency. District cooling reduces CO_2-emissions by 50-70% compared to conventional solutions, given the current situation use of primary electricity.

The main advantages of district cooling compared to traditional cooling systems is:

- higher energy efficiency ensures lower energy consumption and reduces CO_2 issue,
- prevention of hot islands in the city,
- noise reduction in urban areas,
- less visible technical equipment in buildings and a more visually beautiful urban space,
- there is no need to increase the capacity of the electricity network and it can optimize infra-structure,
- reduces greenhouse gas emissions from refrigerant leaks.

There are two cooling plants in Tartu and in January 2020, the length of the cooling network is 7.2 km.

According to the plans of company it can be estimated that in year 2030, the actual demand for district cooling in Tartu will be 25 MW per year, and consumption volume will be about 29 GWh.

The goal of district cooling is to achieve consumption target (29GWh, see Tabel x) by connecting both refrigeration plants to a central district cooling network. The network will be supported by a cold storage, which will make it possible to cover the summer peaks and to provide additional security of supply for hospitals.

Air quality improvement plan for Tartu

According to the data of 2019 (Estonian Environmental Research Center, 2020), the air pollution in some districts in Tartu is lightly increasing. Two main pollutant are benz(a)antracene and benzo(a)pyrene (BaP). For both the main source is incomplete combustion of organic matter like residential wood burning and for BaP also exhaust fumes of cars. Content of benz(a)anthracene and benzo(a)pyrene increased slightly compared to the previous year. Tartu Monitoring Station is located in the area of domestic heating, where many residential buildings are also heated by stoves, therefore the measured concentrations of benzo(a)pyrene will reflect the effect of domestic heating on ambient air quality. The accumulation of pollutants in Tartu is also facilitated by the location of the city in the Emajõgi primeval valley, which makes the dispersion of pollutants somewhat more difficult and the measurement of higher pollutant concentrations is also justified.

In 2019, an air quality improvement plan for air pollution in Tartu was prepared in Tartu, which proposed five measures:

- transition to district heating
- insulation of residential buildings
- renovation of heating stoves, use of high-quality and dry heating material
- traffic dissipation, development of the light traffic network and continued national regulation to reduce emissions from point sources
- switching to renewable energy sources

1.2 Political framework and energy objectives

In Estonia, the organisation of the heating sector is the task of local governments. Local governments have the right to establish, within their territory, district heating areas and the procedure of provision of services. There are 230 district heating areas in Estonia.

The heating sector is regulated by the **District Heating Act** [3]. According to the law, the heat undertaking must coordinate the price of heat sold to the consumer with the Competition Authority. When coordinating the price, the Authority takes into account the fact that the costs incurred for the production and transmission of heating energy are justified.

According to the legislation regulating the district heating sector, heat distribution operators will be required to ensure an effective, reliable and secure heat supply that meets the environmental requirements and needs of consumers at a justified price.

According to Article 9 of the District Heating Act, heat distribution operators will be required to harmonize the maximum fee chargeable for thermal energy sold to consumers with the Estonian Competition Authority.

For the purposes of price harmonisation, the Estonian Competition Authority will observe, above all, the principle of the maximum fee chargeable for thermal energy being cost-based while the expenditures made to generate and distribute thermal energy must be justified.

Available financial support schemas:

- Effective production and transmission of thermal energy (provided by Environmental Investment Center): the purpose of the measure is to reduce the final consumption of energy on the account of more efficient production and transmission of heat energy. The supported activities are:
    - Renovation of district heating boilers and replacement of fuel;
    - Renovation of amortised and inefficient heating piping;
    - Preparation of the development plan for heating management;
    - Construction of a local heating solution to replace district heating solutions.
- Renovation of multi-apartment buildings (Provided by Foundation Kredex): the purpose of the measure is to raise energy efficiency in the building stock and households. Kredex provides loans and grants to renovate private and family homes, apartment buildings, municipal buildings, and loans for companies to integrate energy-efficient technology. Loans for energy efficiency are targeted towards renovating existing buildings to make them more energy-efficient, including heating.

1.3 Stakeholder evaluation

For the implementation of the identified DH development directions and to set goals, it is important to conduct an analysis of the actors involved in the heating system. This allows to determine which stakeholders' views are relevant to the development of the heating system.

Fig. 1 shows the analysis of the stakeholders, indicating their impact and involvement. Tartu Municiplity and District Heating operator (heat and cold generator and distribution operator Ltd. Fortum Tartu, and citizens as main consumers are the main stakeholders that have the greatest impact and largely determine the development of DH in Tartu.

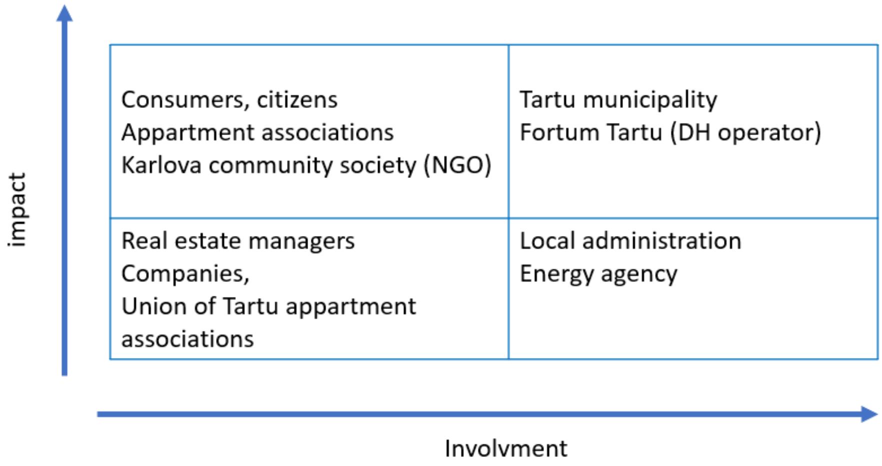

Figure 1: stakeholder impact and involvment

Energy agencies play an important role as consultant for consumers and as strategy developers.

Consumers, citizens and citizen organizations are stakeholders who have significant impact but their involvement is low. They are engaged but the participation during the process in the case of Tartu is lower then expected 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 of heating and cooling systems.

2 District heating and cooling in Tartu

District heating areas have been approved and enforced with the document "Tartu City Master Plan until 2030+" (2017). In the future, the boundaries of the Tartu district heating area should be expanded according to the situation where some consumers have joined the district heating network outside the last established district heating area from 01.09.2017 because as of 1.01.2018, Tähtvere municipality was merged with the city of Tartu.

The consumers of the city of Tartu are supplied with district heating and cooling by the 73-employee energy group Fortum Tartu. The group includes four companies: AS Fortum Tartu, AS Tartu Keskkatlamaja, AS Anne Soojus and AS Tartu Jõujaam.

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Fortum Tartu produces heat for Tartu in its cogeneration plant (located in the territory of Luunja municipality in Lohkva) and in boiler houses (currently 6 larger and some small boiler houses. The total installed heat capacity reached 303 MW).

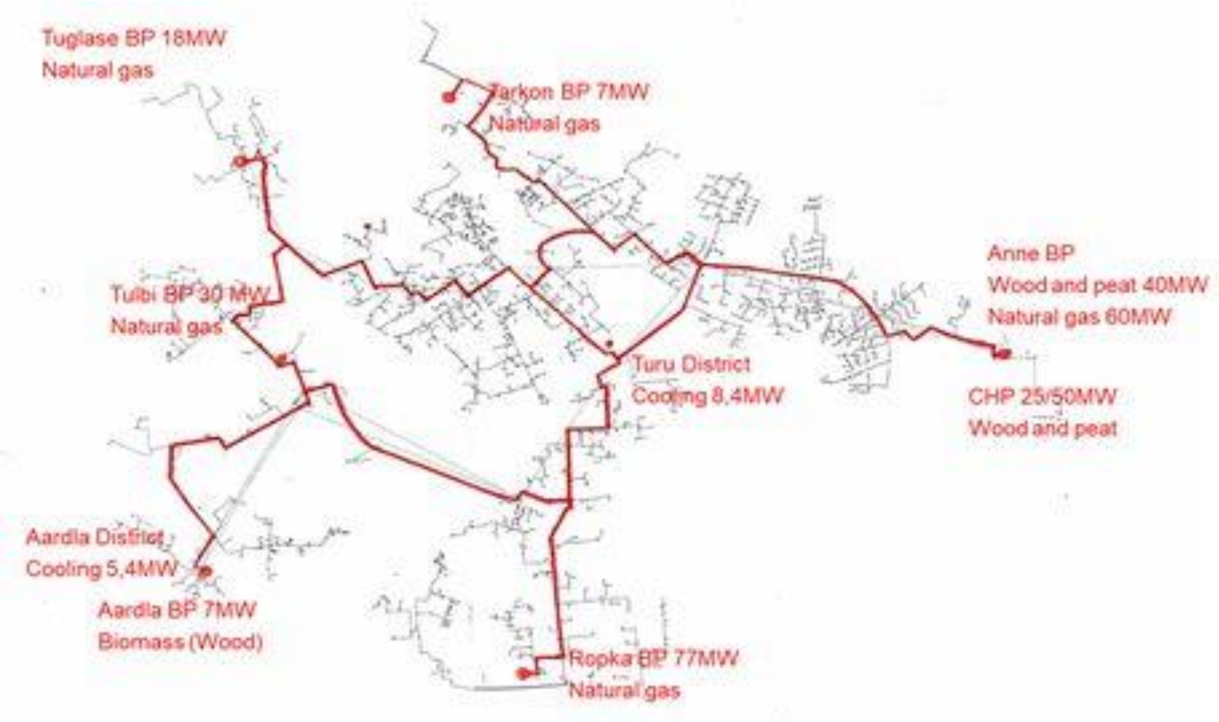

Figure 2: District heating system backbone inTartu with boilerhouses (source: Fortum Tartu)

The electrical capacity of the cogeneration plant is 25 MW and the thermal capacity is 50 MW. In addition, the power plant is equipped with a so-called flue gas "scrubber" (scrubber, max. capacity 15 MW), which cleans the flue gases and transmits the heat from the flue gases in the spring-summer-autumn period to the district heating network. The peak capacity boiler house is a gas-powered Ropka boiler house with an automatic control capacity of 2 × 38 MW, which was completed in 2014. The Aardla boiler house, which runs entirely on wood fuel, is also equipped with a scraper.

In Tartu, district heating is consumed by about 1,700 buildings, of which 60% are in the residential sector, which includes apartment associations, housing associations and private houses. 14% are public sector buildings and 26% are buildings of other institutions and companies.

In 2017, the city of Tartu was supplied with a connected district heating network with a total length of 177.7 km of pipelines (2017) with a total of six heat sources.

Biofuels (woodchips, over 75%) are predominantly used in heat production, followed by natural gas (18.5%) and to lesser extent peat (~ 6%)

The relative heat loss of the district heating network has decreased year by year despite the increase in the length of the pipeline. While the length of pipelines, compared to 2010, had increased by 53% by 2017, the relative heat loss had decreased by 25% at the same time.

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As a pioneer of district cooling production in Estonia and throughout the Baltics, Fortum today offers cooling to companies in the city of Tartu from two district cooling stations operating all year round: Kesklinna Külmajaama and Aardla Külmajaama. Environmentally friendly and high efficiency 13 MW Kesklinna Külmajaam is located by the Emajõgi River and from late autumn to early spring uses Emajõgi water for cooling, at other times refrigeration compressors with a heat pump operate. The entire production process is fully automated. 1.6 kilometers of district cooling network has been built in the center of Tartu. The second, Aardla cooling plant, which was completed in June 2017, is located in the Aardla district. In the first stage, a 5.4 MW station with a nearly 1.3 km long district cooling network has been built out of the planned 9.2 MW construction capacity, whereas the initial capacity of the cold store is calculated taking into account the needs of the future consumers. From early spring to late autumn, cooling machines are used for cooling in cooperation with cooling towers, and in winter, a heat pump is used to produce the required cooling energy. The entire production process is fully automated.

The cooling complex connected to the district heating system has also been built for the Estonian National Museum.

3 Strategic directions for implementation of low-temperature district heating

The district heating system conditionally consists of three parts: the producer, the network and the consumer. The development and improvement of existing heat supply systems can only work in an understanding and good way for the consumer and the producer to carry out basic research in order to find solutions to the problems that arise with the change of generations.

Thus, energy policy poses major challenges and goals for district heating system operators to increase energy efficiency, reduce losses in district heating systems and renovate systems to take into account the reduction of heat consumption by consumers. In order to increase the energy efficiency of the district heating system, it is emphasized that energy efficiency must start from the beginning of the energy conversion chain to the final consumer. Cooperation between the district heating system manufacturer, the network and the consumer is paramount in the development, deployment and problem solving of district heating systems.

The principle of the fourth-generation system consists of the transfer of heat from renewable energy sources to the district heating network using smart systems and the supply of heat to low-energy buildings with low distribution losses. The change of generations requires institutional and organizational cooperation in order to develop the optimal investment for the construction of the energy system and the distribution of the resulting profits between the producer and the consumer

The new generation of district heating must meet the following energy conditions to ensure sustainable development

- Capability to supply low heat carrier distribution temperatures to existing buildings, buildings under renovation and new low energy buildings.
- Capability to distribute and outperform the heat carrier with low losses. This requires the renovation or conversion of old district heating pipelines
- Capable of integrating and utilizing low-temperature renewable energy sources such as solar and terrestrial energy, using residual process heat or recovering waste heat with heat pumps.
- Capability to implement intelligent systems in cooperation with other distribution networks such as electricity, water and gas.

  Capability to ensure sustainable development for both consumers and producers. The development and improvement of existing heat supply systems can only work in an understanding and good way.

3.1 Evaluation of alternatives for low-temperature solutions in Tartu

Under the leadership of Fortum Tartu, the strategy working group has prepared and simulated five different scenarios for the possibility of implementing lower-temperature (including ultra-low-temperature) district heating in Tartu:

- The first scenario expresses the current situation in the Tartu district heating network.
- The second scenario is simulating the case where 50 new buildings are connected per year, increasing the heating demand in the district.
- The third scenario expresses the situation where the heat demand of the district remains the same as with scenario 2, but two new heat-production plants are added to the system: a 10 MW heat pump, using the waste-water as a cold source, and a large solar thermal installation with production of 30 MWh per year
- The fourth scenario includes two sources for the reduction of produced heat: reduction of supply temperatures and the refurbishment of some buildings.
- The fifth scenario expresses the situation where two new renewable energy sources (RES) are added to the production mix: waste heat stream (excess heat from different applications is injected into the grid, amounting to a capacity of 1 MW) and another heat pump (5 MW).

Scenario 1: Current State of the DH Network

The first scenario simulates the current situation of the DH network, including only the heat production plants that really exist. For this simulation, information from the DH owner, Fortum in Tartu, has been used, where the availability of each of the plants could be concluded from an image (Figure 3) that was sent. By this hourly evolution image, it is obvious that the CHP is switched off in the summer period.

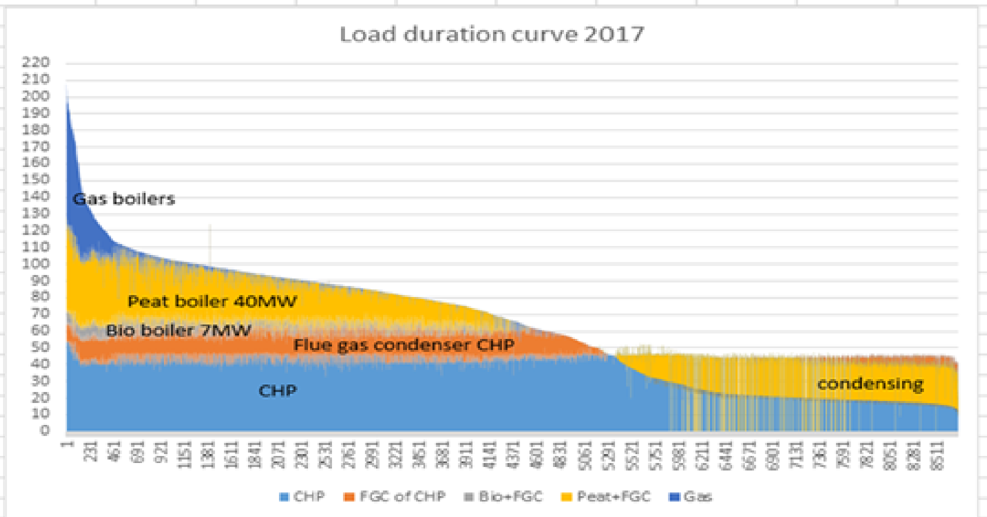

Figure 3: Real Production in mix of the DH in Tartu in 2017. (Source: Fortum Tartu)

On the other hand, the results from the simulations of the cost model are shown in Figure 4.

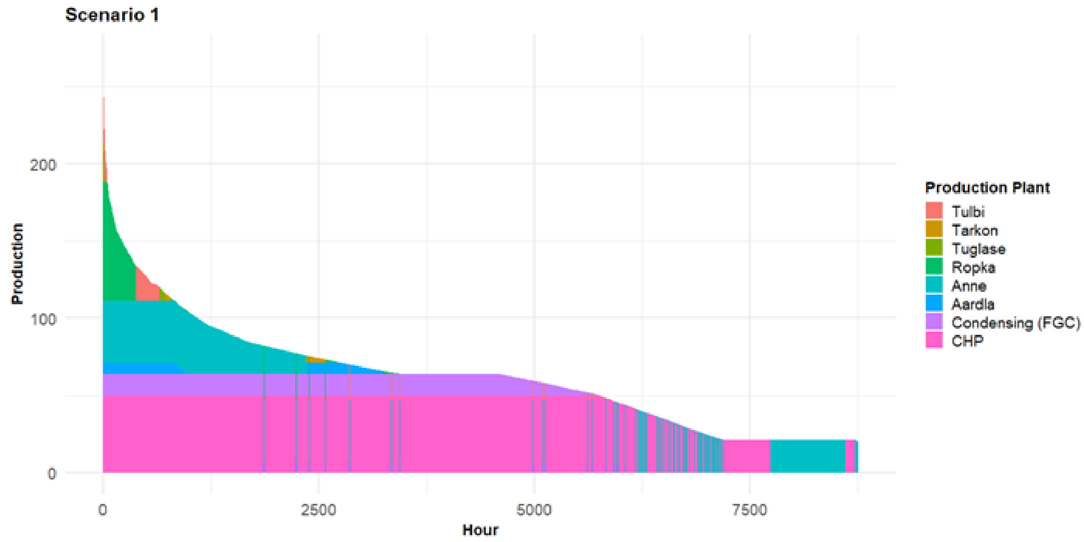

Figure 4: Hourly production mix in Scenario 1 in the DH in Tartu. (Source: Fortum Tartu)

Comparing the real energy coupling and the coupling from the real costs, it can be concluded that they are quite similar and that the cost model is validated with real data. In Figure 4 all the gas-peak boilers are combined as one producer and in Figure 32, these producers are divided. With regard to the energy coupling, it is highly important to know the number of hours that each plant is producing heat, as a rate of dependency of the respective production plant with the overall system.

Scenario 1	Current Situation: Functioning Hours
CHP	7272
Condensing	5658
Aardla	1970
Anne	3843
Ropka	891
Tuglase	100
Tarkon	325
Tulbi	358

Table 3: working hours of boilerhouses in Tartu DH system (Source: Fortum Tartu)

As it is known, the CHP is the base producer of the district, with more than 7,000 hours/year working, followed by the Flue Gas Condenser (FGC) system that is incorporated. The other main producers that operate for many hours per year are the biomass-based plants (Aardla & Anne), due to the competitive price of the biomass fuel source in the location. Then, gas boilers are used as peak plants for the most critical hours of the year.

The fuels costs in the CHP are so low because the revenue from selling electricity to the grid is also considered. This way, the CHP becomes the most economically feasible solution for the heat production. The costs in the system with Flue Gas Condenser (FGC) are considered to be equal to zero, because the heat from the exhaust gases in the CHP are used (the fuel is the CHP itself) and in consequence the only costs are the installation (initial investment) and operation and management (O&M) costs (EUR/year).

Regarding the rest of the producers, two different cost ranges are observed. A lower range for the biomass powered plants and a higher one for the natural gas-powered plants. This is caused because of the lower price for biomass compared with natural gas.

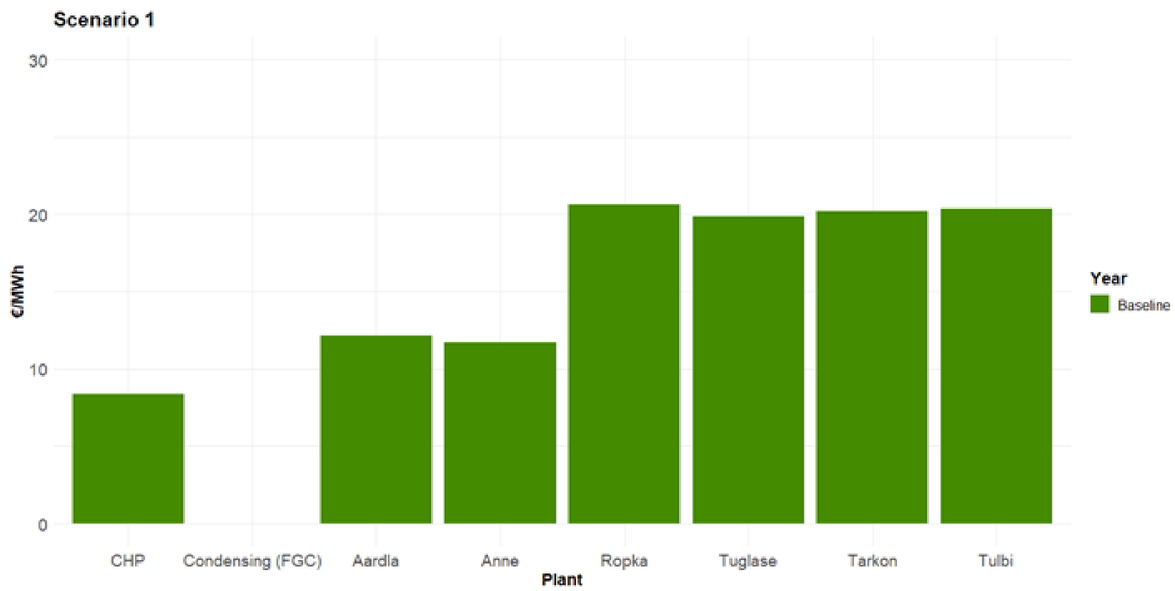

Figure 5: Fuel costs per production plant according to scenario 1 in Tartu

Scenario 2: Scenario 1 + 50 connections/Year

Looking at the estimations that the DH owner have made according to the new buildings that will be connected to the DH network, it has been simulated the case where 50 new buildings are connected per year, increasing the heating demand in the district.

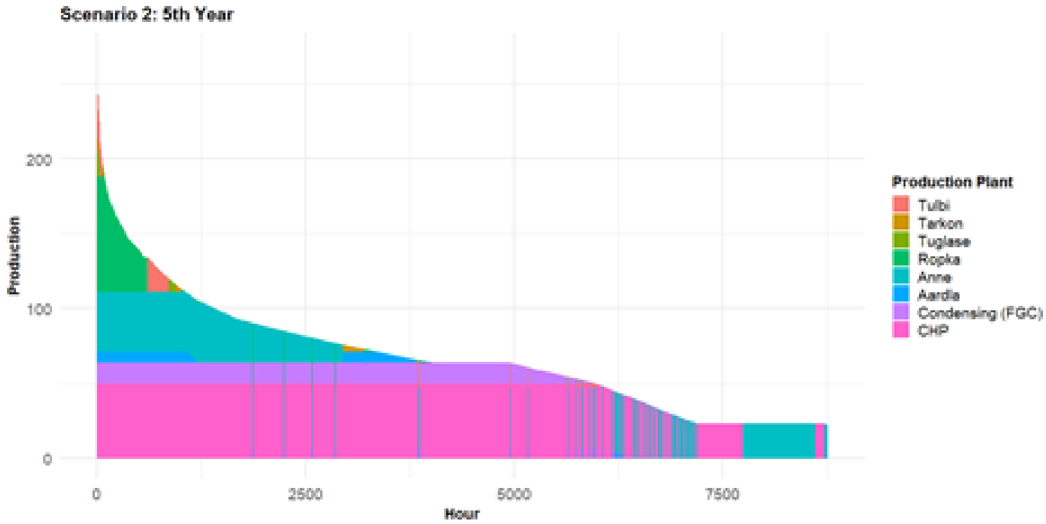

Figure 6: Hourly production mix in Scenario 2 in the DH in Tartu (Source: Fortum Tartu)

In Figure 6 , it can be seen that in the 5th year from the start of new connections to the DH network, the demand has not significantly increased, and the production difference is covered by the rest of the plants.

However, for the 20th year (see Figure 7), the demand has increased beyond the plant's capacity and they are not able to cover the full demand in the peak hours. Alternatively, new distributed heat plants are required to be installed in the following years.

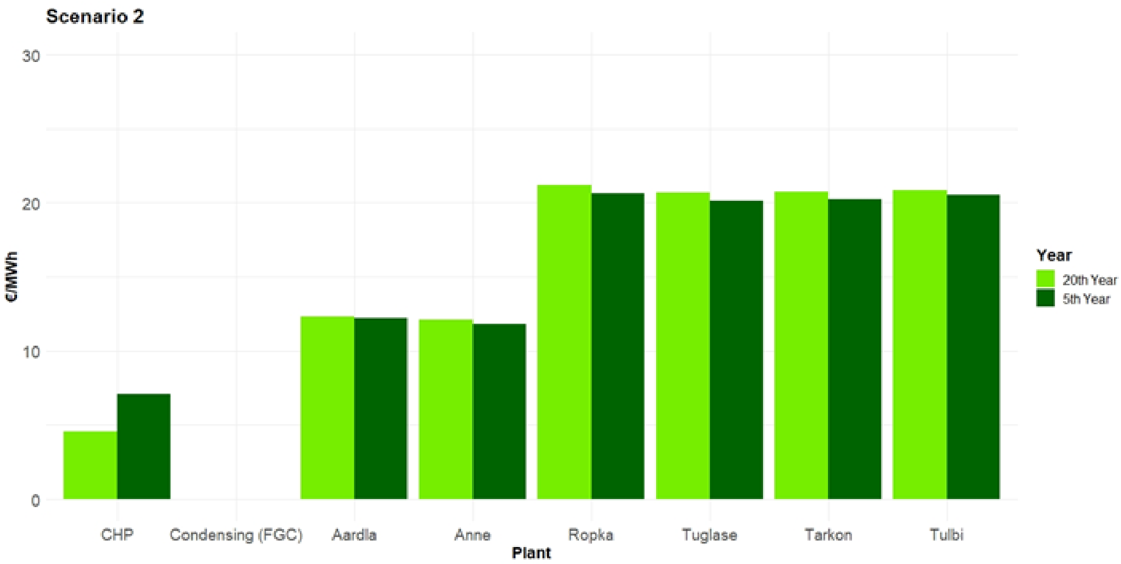

Figure 7: Fuel costs per production plant in scenario 2 (Source: Fortum Tartu)

As for the economic review, the situation is quite similar to the one in Scenario 1. The main remarkable fact is the cost reduction in the CHP plant for the 20th year. The only reason for this cost reduction is the highest revenue form the electricity selling.

Scenario 3: Scenario 2 + HP + LST systems

In this scenario, the heat demand of the district remains the same as with scenario 2, but two new heat-production plants are added to the system:

- 10 MW Heat-Pump (HP), using the waste-water as the cold source.
- A large solar thermal installation (LST). The production of this installation is dependent of the climatic conditions, but the maximum energy production reaches 30 MWh per year

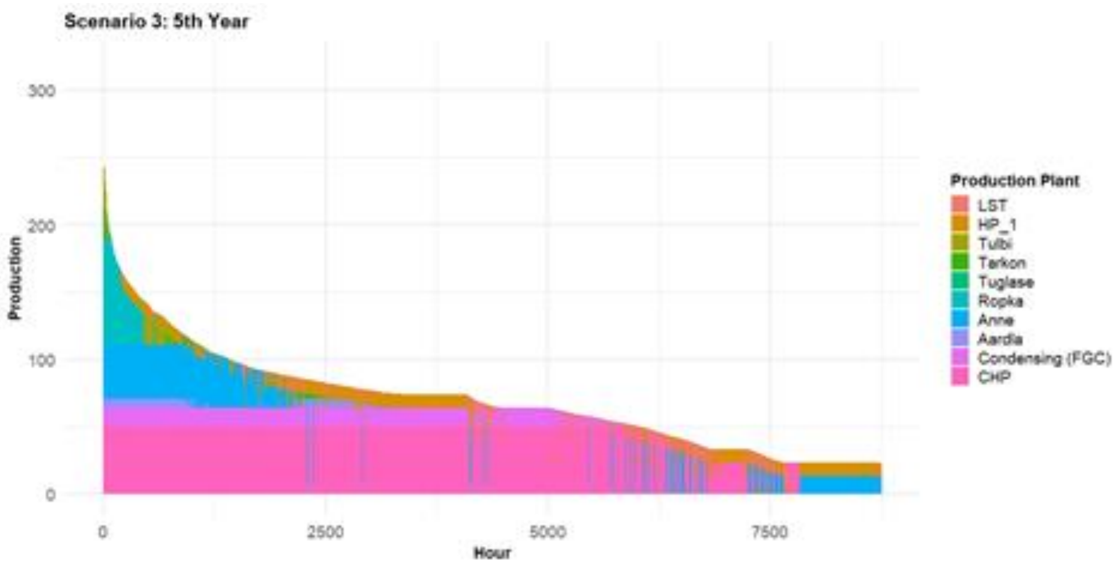

Figure 8: Hourly production mix in Scenario 3 in the DH in Tartu (Source: Fortum Tartu)

In Figure 9 it is shown how the aggregation of two new heat sources affects the production mix. The Heat Pump (HP) produces heat relatively constant through the year and contributes with all its capacity to the heat production. However, a large Solar Thermal Plant (LST) produces when the demand is not too high and in consequence, the plants that reduce its production are the "low" capacity boilers (Tarkon, Tuglase etc.).

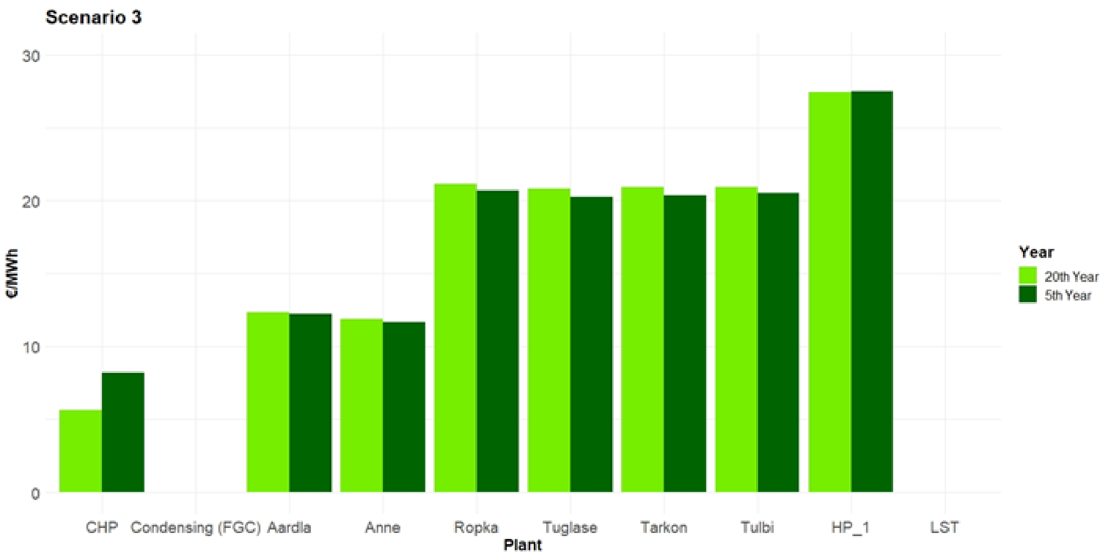

Figure 9: Fuel costs per production plan in the Scenario 3 (Source: Fortum Tartu)

The economic overview of this scenario incorporates a new fuel source into the scenario: electricity by means of the heat pump. Heat-pumps use electricity to produce high temperature heat. The elevated price of this fuel source makes this producer an expensive system. On the other hand, solar thermal system situation is similar to the FGC. The fuel that solar system use is the solar radiation which is a free to use energy source, so that the price is considered to be equal to 0.

Scenario 4: Scenario 3 + Heat-Loss reduction + Buildings' Demand Reduction

In this scenario, two sources for the production reduction are included:

- Reduction of supply temperatures. This way the heat-losses in the distribution pipelines are also reduced.
- Building refurbishment: Some of the buildings are considered to be refurbished, reducing the heating demand significantly.

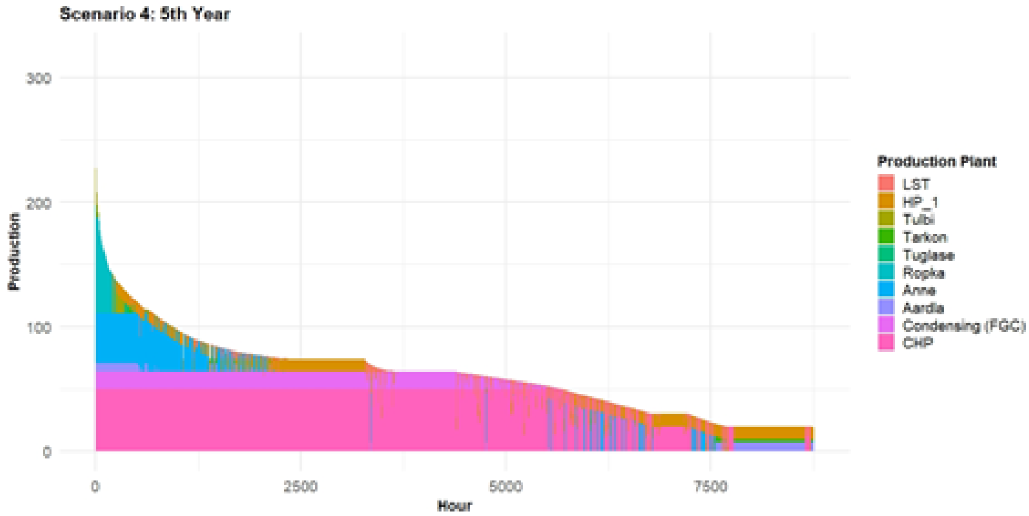

Figure 10: Hourly production mix in Scenario 4 in the DH in Tartu (Source: Fortum Tartu)

The effect of reducing the heating demand primarily affects again low-capacity plants that are used to satisfy peak demand. In this situation, large plants are able to cover the whole demand. The large heat plants have lower operation costs due to the economy of scale but in low partial loads, the efficiency of these plants is highly reduced.

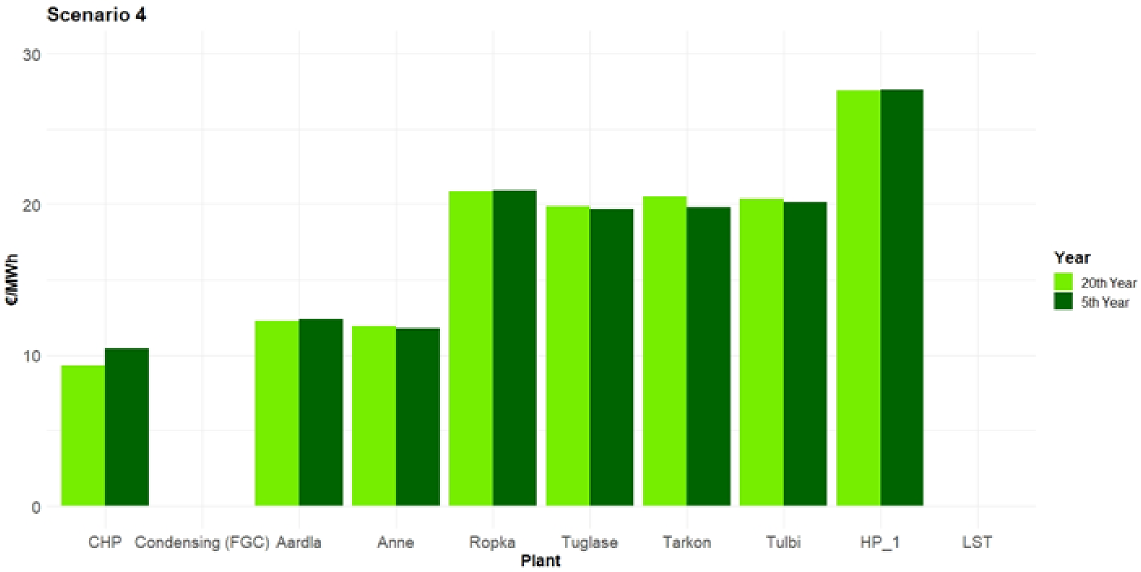

Figure 11: Fuel costs per production plan in the Scenario 4 (Source:Fortum Tartu)

Scenario 5: Scenario 4 + Waste Heat Stream Connection + Heat Pump 2 connection

In this final scenario, two new renewable energy sources (RES) are added to the production mix:

- Waste Heat Stream (1 MW) (WH) Excess heat from different applications is injected into the grid, amounting to a capacity of 1 MW.

- Another Heat-Pump (5 MW).

The injection of these two heat sources is added to the previous scenario (scenario 4).

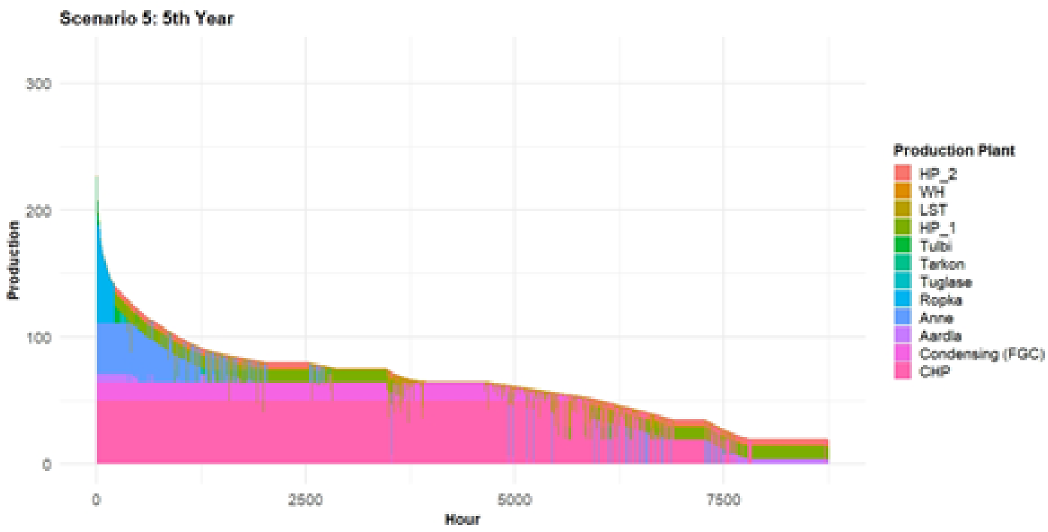

Figure 12: Hourly production mix in scenario 5 in the DH in Tartu (Source: Fortum Tartu)

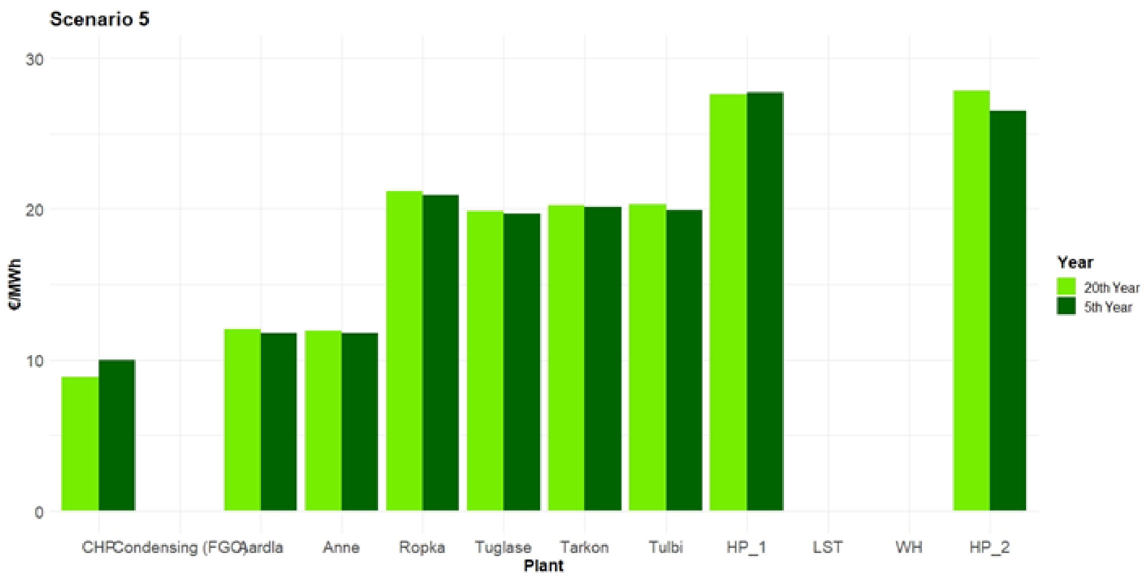

Figure 13: Fuel costs per production plan in the scenario 5 (Source: Fortum Tartu)

In this final scenario, the general overview is similar to the previous cases. The WH does not have fuels costs, since the heat source is a total free source. In this kind of installations, the largest economic part is due to the installation of the heat exchanger that has to be exploit the excess heat.

Summary

This last chapter referring to the DH system of Tartu aims to summarize all the scenarios analysed separately in the previous chapters.

Firstly, in Figure 3 the evolution of the operative hours in which the producers are contributing with heat to the DH network is shown. Observing that figure, the next following conclusion can be drawn:

- The biomass-based CHP is the most dominant producer, with the highest operability range.
- WH streams contribute with a relatively constant heat source along the whole year, since this heat source is not externally dependent.
- The production plant with highest demand-adaptability is Anne BP. It adapts its production capacity & operation hours in function of the instant heat load.

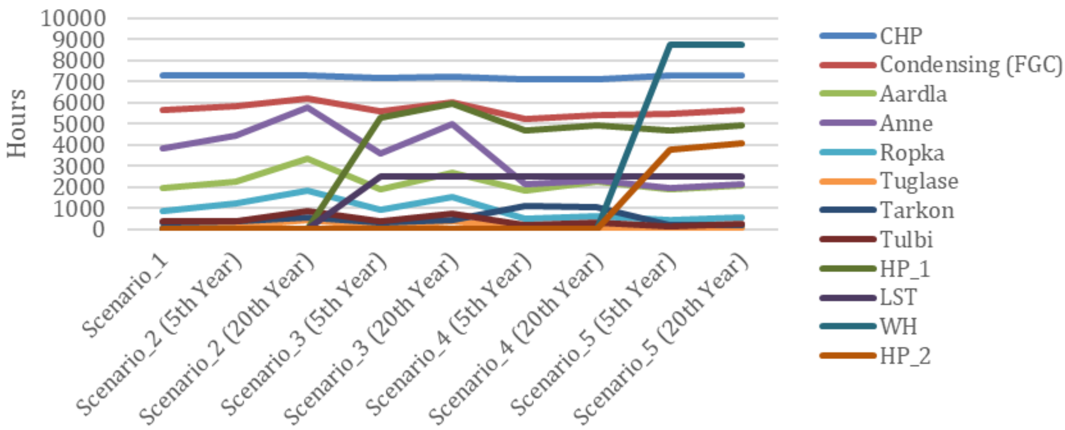

Figure 14: Evolution of the working hours in production plants along the scenarios 1-5 (Source: Fortum Tartu)

Regarding the economic overview, Figure 16 shows the total price of the heating energy in EUR/MWh for the different scenarios.

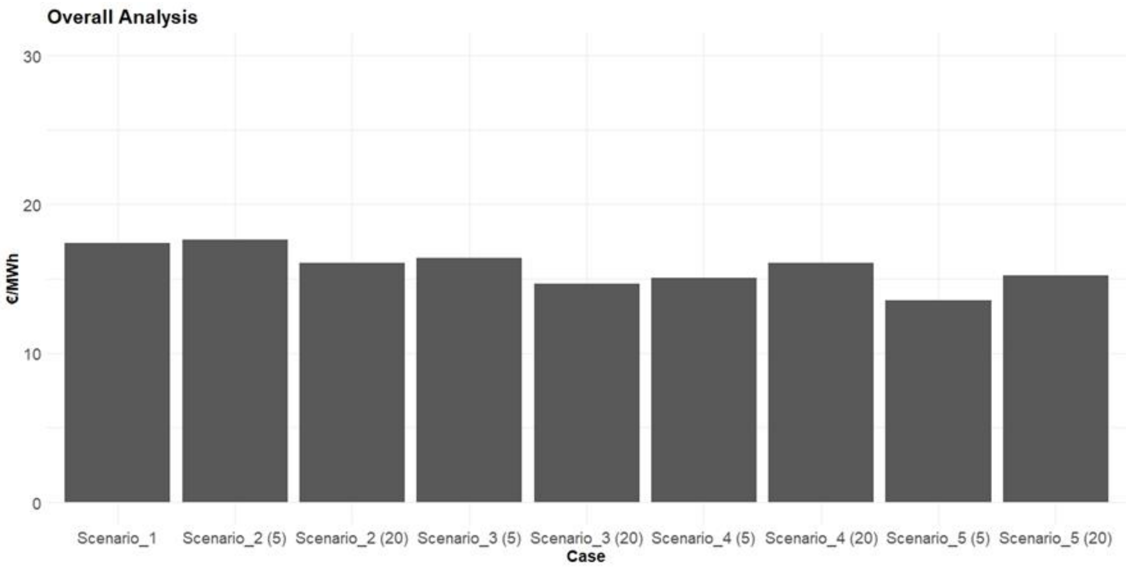

Figure 15: DH Total Price overview for all the scenarios in Tartu (Source: Fortum Tartu)

The trend that the previous economic figure shows is undoubtedly decreasing. As far as new producers that incorporates RES, the total price of the DH is reduced, since the price of the fuel sources for RES are free.

Finally, the table 4 below summarizes the overall conditions of the DH in Tartu for the different scenarios, showing the most critical factors.

Producer	RES Share %	Total Production GWh/year	Total Operational costs MEUR/Year	DH Price EUR/MWh
Scenario 1	95.23	551.01	9.58	17.38
Scenario 2 (5th Year)	93.40	596.48	10.51	17.62
Scenario 2 (20th Year)	87.04	741.02	11.91	16.08
Scenario 3 (5th Year)	94.69	612.79	10.05	16.41
Scenario 3 (20th Year)	88.82	753.39	11.05	14.66
Scenario 4 (5th Year)	96.72	541.53	8.17	15.09
Scenario 4 (20th Year)	95.67	569.71	9.14	16.04
Scenario 5 (5th Year)	97.61	570.18	7.73	13.56
Scenario 5 (20th Year)	96.83	597.85	9.10	15.22

Table 4: summary of scenarios 1-5 (Source: Fortum Tartu)

3.2 Karlova pilot area

The Karlova pilot testing measure aims to connect example buildings to LTDH. To find the buildings for developing the pilot testing measure, several meetings with citizens, the DH provider „Fortum" and the municipality were organized.

Karlova is one of historically wooden buildings district in Tartu. Most of the district's excisting buildings were completed in the early 1910´s, some in the 1920´s. Karlova buildings are characterized by "a lively bulky structure with numerous roof structures and slats and a unique Art Nouveau façade trim adapted to wood architecture, mainly created by dynamic mouldings of door and window enclosures and frames." (M.Siilivaks, architectural historian) In the backyard are many woodsheds.

Most of the buildings in Karlova are using local heating, mostly stoves and fireplaces.

The reasons for choosing Karlova were:

- Low number of DH users
- Deteriorating air quality and the city's strategic direction to reduce low-quality heating systems
- Most challenging buildings for connecting to grid

The DH grid in Karlova is shown in the figure below.

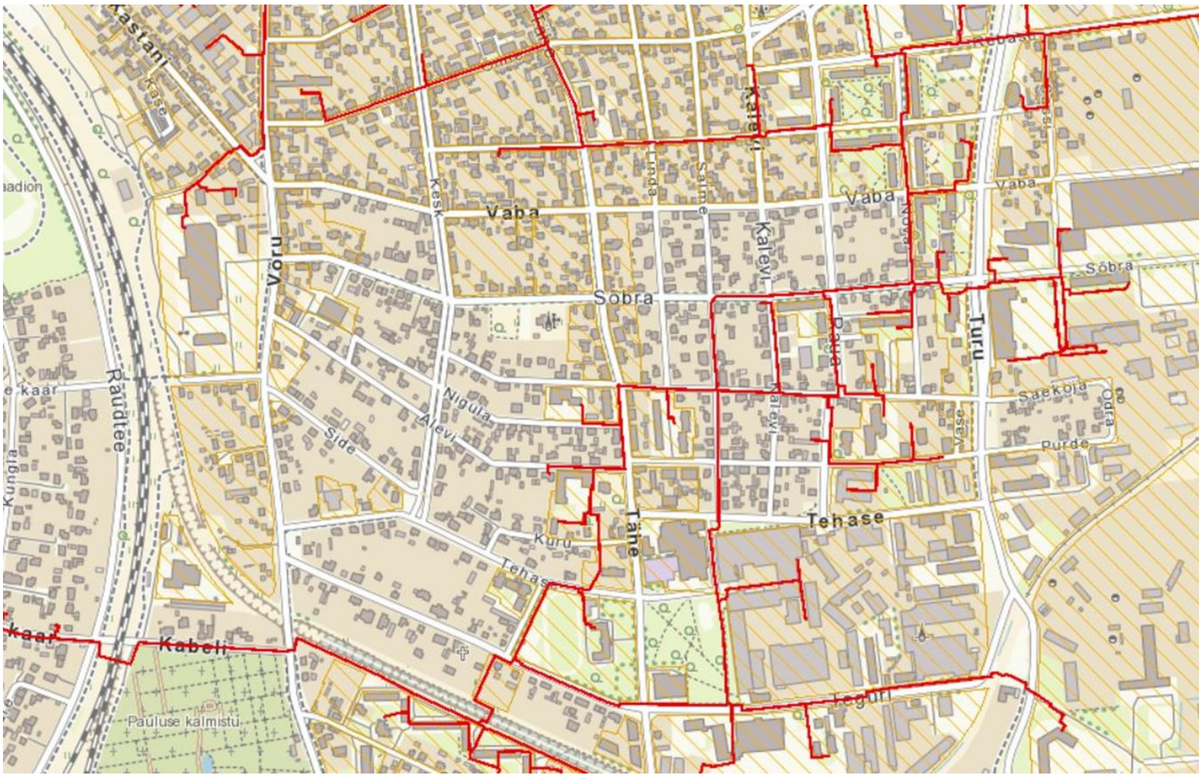

Figure 16: DH grid in Karlova (source: Fortum Tartu)

A technical solution was planned to connect several or at least one pilot building to the existing DH grid and to the backflow tube.

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The target is to test and monitor connections and the quality of the provided heat if the building is connected to the backflow grid. Today, the Karlova grid has temperautures of 90/60 °C.

Conditions for building owners to connect to the DH grid are:

- It is possible to join anywhere in Karlova
- Fortum Tartu develops the network according to consumers our applications
- Network development costs are covered by Fortum Tartu
- Joining takes 4 months to 1 year, as it is necessary to prepare a project, apply for a building permit and order materials.
- Advice will be provided for renovation of building including of connecting to DH grid and upgrade internal heating system.

To compare different sources of heat-energy for buildings, calculations were made by Fortum Tartu.

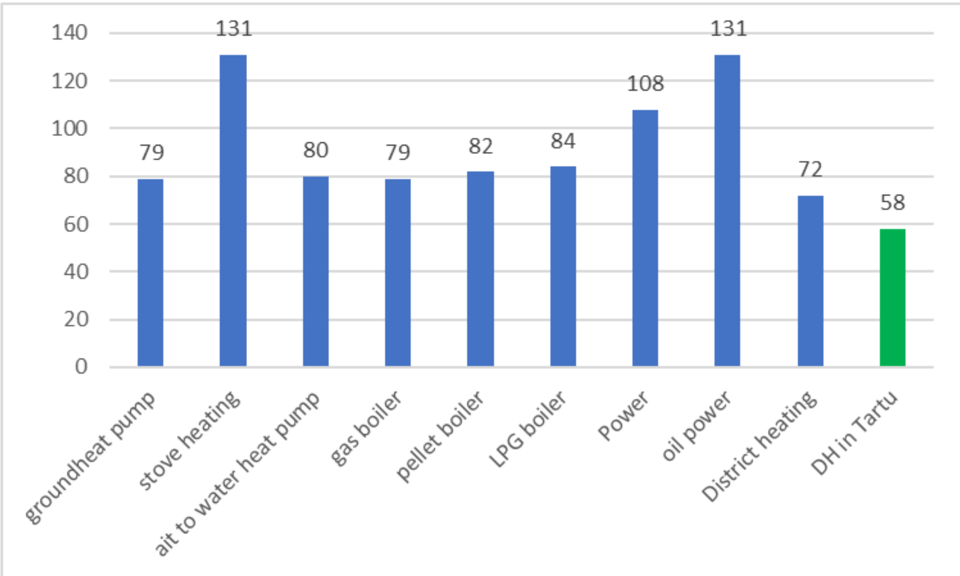

Figure 17: cost of heatenergy to consumer by different heat sources (Source: Fortum Tartu)

Based on the meetings with the citizens, discussions and results of a survey, it can be conluded that consumers are the most problematic aspect of the existing large DH transition. Consumers are not often ready to consume district heating and escpecially low-temperature heat and they have a very little understanding of the system's operation. As a result, they do not have enough knowledge and motivation to support technological improvements. In our case, they need to make deep renovations of buildings to be ready for DH.

First, consumers need to be educated in the way the system operates and a trusting relationship between all parties needs to be established. This will help the consumers to understand why technological improvements are necessary for their systems and how to get them done. In terms of technology, the following actions must be performed:

- reducing the temperature of heating devices

- substation automation configuration and parameter optimisation, e.g. temperature schedule, night temperature setback, hot water circulation timings, etc.
- new technologies must be implemented in substations to achieve ultra-low supply temperature, e.g. heat pumps, high-efficiency heat exchangers

It is important that consumers and DH companies cooperate, support and share knowledge all the way from the design stage of the heating system and until the demolition of the house [4]. Consumers and building owners in Karlova need to clear calculations and feasibility studies for deep renovations with upgrading internal heating systems to connect and use DH, especially LTDH.

4 SWOT analysis and risk analysis of Karlova pilot testing measure

4.1 SWOT analysis for Karlova pilot testing measure

Strengths	Weaknesses
• Stable and guaranteed security of supply • coordinated price • better air quality in the district • convenient use of DH • higher efficiency of DH system	• dependence on the district heating operator • choice of limited sources • high costs for reconstruction of houses or buildings' heating systems • not enough capacity in grid for all consumers
Opportunities	**Threats**
• energy policy favors energy efficiency and the use of renewables • new financing opportunities for reconstruction	• renovation of buildings reduces demand in system • lack of readiness for district heating or renovation • stricter requirements for the energy performance of buildings • banning the use of peat and wood

4.2 Risk analysis of Karlova pilot testing measure

Risk	Probability of risk	Impact of risk	Operational risk prevention
Consumers don't go for connection to LTDH	High	High	• Wider and clearer information on sharing of benefits (financial possibilities, covering connection costs etc.) • Pilot case implementation • Providing of feasibility study of renovation and connection to grid
Increasing DH price	Low	High	• More efficient operation of grid • Reducing energy demand in buildings
High renovation cost	High	High	Mobilization of available funds, new financial possibilities

5 CONCLUSIONS AND RECOMMENDATIONS

Two major challenges must be overcome for DH systems to remain competitive in the future: the first challenge is competing with local renewable energy sources such as heat pumps and the second deals with decreased heat demand of new and existing buildings.

It is hard to implement 4th generation district heating (4GDH) technology in district heating systems in small Estonian systems or subsystems in the coming years, as, on the one hand, the situation of many systems has deteriorated by now, because of district heating efficiency.

Secondly, in many places, only recently (or in the near future), either partially (cut) or in full, the networks are currently reconstructed with the best possible technology, i.e. currently the most suitable so-called 3rd generation DH.

Thus, it is possible to talk about 4 GDH, the technology of which can be applied in new district heating areas without problems, which is why from the current point of view, the new technology does not offer a simple, but above all, a cost-effective and sustainable solution for Estonian small-town network areas.

It is possible to upgrade existing networks to the 4th generation, as there are only a few technical issues that already have solutions, but the main barriers are the unwillingness to change and technical limitation preventing consumers from using low-temperature DH. Despite the fact that low-temperature solutions for consumers are well-designed and available on the market, high-temperature devices are still used in both renovated and new buildings. Most consumers/designers focus on analysing their house energy levels, disregarding any possibilities to improve the efficiency of the entire system, which could lead to more significant energy savings and a much better environmental situation.

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6 References

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[2] Estonian Power and Heat Association, https://epha.ee/tohus-kaugkute/

[3] Estonian District Heating Act https://www.riigiteataja.ee/akt/KK%C3%BCtS

[4] V, Mašatin "Obstacles for Implementation of 4th Generation District Heating for Large Scale Networks" Doctoral thesis, 2018