ESTONIAN UNIVERSITY OF LIFE SCIENCES
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A TRANSITION FROM FOSSIL FUELS TO BIOFUELS - A CASE STUDY OF ELVA DISTRICT HEATING NETWORK

Bachelor's Thesis
in Energy Application Engineering degree

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ABSTRACT

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Heat energy, its absence or overabundance, has always been an important issue in the Estonian energy situation. Since the price of fossil fuels is constantly rising, which in turn raises the price of the energy they provide, energy efficiency and reasonable use of energy is becoming more and more popular. In a situation, where almost 60% of the Estonian population uses district heating, a great attention must be paid to the energy source used and the efficiency of the system.

In the current thesis, the investments made into the district heating network of the town of Elva were analysed in order to discover their effect on the consumers of heat energy. For the analysis several national databases were used to find indicators for the influence and effectiveness of the results.

Since the current policy of European Union requires member states to reduce the energy consumption of buildings while increasing energy efficiency of different appliances, devices and facilities, it is not reasonable to presume that the requirement of heat energy from district heating boiler plants will remain at the same level. Regarding the previous statement, four future scenarios were made for analyzing the long-term effects of energy efficiency measures in the fully renovated district heating network of Elva.

In order to analyse the changes that might occur in coming years, load diagrams describing the calculated hourly consumption in the sections of the district heating network, were prepared. The basis of the calculation was the measured consumption and production data of the network for the years 2008...2010. Heating characteristics were calculated based on the data. A 40% reduction of the heat energy requirement in housing sector and buildings owned by the public sector and a 10% reduction in industry was assumed to have happened by the year 2025.

The results of the calculations showed that the losses in the distribution network that had dropped to 10,2% after renovations will increase to 13,4% after the assumed increase in energy efficiency.

The options of connecting the district heating networks of Elva, while constructing a combined heat and power plant were analyzed as well. Since economical calculations were not a part of this thesis, the results can be summarized as following: when co-producing electrical energy while heating households has its’ positive sides, there is an increase of 10...20 % in woodchip consumption. Therefore, continuing „business as usual“ scenario is the most feasible. The most accomplishable scenario in terms of building a CHP plant was evaluated to be the scenario, according to which the CHP would only be built in the Keskkatlamaja district heating network network.

Keywords: district heating network, heat consumption, load diagram, future scenarios, energy conservation, combined heat and power plant, biofuels.

TABLE OF CONTENTS

SYMBOLS AND APPREVIATIONS

CHP – Combined Heat and Power generation
EIC – Environmental Investment Centre
EPHA – Estonian Power and Heat Association
EU – European Union
EMHI – Estonian Meteorological and Hydrological Institute
K_0 – thermal conductivity coefficient of heat pipeline, W/°C·m²
KredEx – Credit and Export Guarantee Foundation KredEx
KRP – number of degree days in a reference period °C·d
KRT – number of degree hours in a reference period °C·h
KRT_N – number of degree hours during the heating period in a standard year °C·h
KRT_n – number of degree hours during the reference period in a standard year °C·h
kW_e – CHP plant's electrical output capacity kW
kW_h – CHP plant's heat output capacity kW
MEAC – Ministry of Economic Affairs and Communications
$m_{p.õli}$ – quantity of shale oil t
n_{kN} – number of planned heating days
n_{kuu} – number of days in a respective month
ORC – combined heat and power technology that uses organic oil as a working liquid
P_t – average monthly heat loss capacity of district heating network's heating pipeline MW
Q – annual expenditure of heating energy of a group of buildings MW·h/y
Q_{CHP} – heat energy produced in the CHP plant MW·h
Q_k^{pl} – planned heat requirement for heating a consumption point MW·h
Q_k^{pr} – heat load for heating a building MW
Q_{katel} – heat energy produced with a regular woodchip boiler MW·h
$Q_{küte}$ – heat quantity used for heating during a reference period (year) MW·h/y
$Q_{toodang}$ – heat quantity in a district heating pipeline produced by the boilers in a respective month MW·h/month
$Q_{õlikatel}$ – heat energy produced by shale oil boilers MW·h
$q_{ekspl.}$ – heating characteristics of a group of buildings W/°C·m³
q_k – heating characteristics of a group of buildings MW/°C
q_{lisa} – heating characteristics of an additional consumption point MW/°C
q_{trass} – heating characteristics of a planned district heating pipeline MW/K
S – external surface area of the heat pipeline m²
TAK_{hake} – lower calorific value of woodchips used in Elva MW·h/m³
$TAK_{õli}$ – lower calorific value of shale oil MW·h/t
t_B – estimated indoor temperature of the heated rooms in a group of buildings, i.e. balance temperature °C
t_i – measured hourly average temperature °C
$t_{n,i}$ – normalised hourly average temperature °C
t_v – planned average ambient air temperature °C
t_v^a – estimated minimum ambient air temperature °C

$t_{välis,i}$	–	ambient air temperature °C
V_{hake}	–	volume of required woodchips quantity m^3
$V_{köetav}$	–	cubature of heated group of buildings m^3
WMS	–	standard protocol for serving georeferenced map images using various GIS software (Web Map Service)
WP 5	–	*Wood Energy and Cleantech* project's fifth working package: *Technology and Production*
η_{CHP}	–	efficiency coefficient of CHP plant
η_h	–	heat efficiency coefficient of CHP plant
η_{katel}	–	efficiency coefficient of regular woodchip boiler
$\eta_{õlikatel}$	–	efficiency coefficient of regular woodchip boiler
τ_i	–	duration of a respective ambient air temperature h
τ_p	–	number of heating system's working hours per day h

INTRODUCTION

The case study of the district heating network of the town of Elva was prepared as part of the Interreg IVa *Wood Energy and Cleantech* project, whose objective is to increase the availability of information and offer support structure to stimulate the investments in bioenergy and the application and establishment of the so-called "clean technologies". At the end of the project, as part of the fifth working package (WP 5), support systems (as instruction material, for example) have been prepared to analyse the profitability and performance of procurements of respective investments in terms of economic, technical, climatic, and environmental aspects and its protection. Case studies like this document are a direct means to increase the knowledge through comparing the experiences of different regions and countries [1].

Renewing the devices of a district heating network and gradually performed renovation works in consumption points have entered on the agenda in a situation where end consumers' maximum reference prices in some smaller district heating network are approved by the Estonian Competition Authority after every couple of months. Unlike the expenditure associated with insulating outer structures, the capital investments in the district heating pipelines and boiler plants are paid off (without applying support mechanisms) by all the consumers, which makes the right investment decisions particularly important.

The results of previously conducted works and good examples from neighbouring regions are a good way to predict the effect of various activities. Conducting a case study is one opportunity to analyse the effect of renovations on a respective district heating network. The results cannot be transferred to other regions completely, but they are sufficient for raising awareness and helping with making relevant decisions.

As far as the author is aware, an overview analysis of benefits and problems associated with a thorough renewal of a district heating network on the example of one specific region has not yet been conducted in Estonia in such a capacity, and thus, this case study or its sections can be used to select a methodology for conducting similar analyses.

The first and second section of this thesis give an overview of the literature on the topic and the objectives, tasks, and used methodology of the work. It also describes the current situation of heat energy and its future tendencies arising from both Estonian and European Union's energy policy.

The third and fifth chapter focus on creating future scenarios for conducted calculations and analysing the results achieved by these.

The forth chapter gives an overview of the base situation in the district heating network of Elva and its parts. It presents an overview of conducted works and the effects and indicators of these that are used to come up with calculations of future scenarios.

The selection of data processing methodology for the calculations was guided by the Government of the Republic regulation "Methodology for calculating and dividing the expenditure of heat supply" and various heat technology articles and publications.

1. CASE STUDY: DEFINITION, OBJECTIVE, METHODOLOGY

1.1. Case study as a means to get a detailed overview of a situation

Case study by definition is an examination of an event or an example, whereas the usefulness of the case study is revealed in the early stages of substantial researches by giving inputs for creating hypotheses to be inspected later on [2].

Traditionally, case study has been primarily used in social sciences [3, pg. 3], but due to the close connection of social factors with other areas (e.g. energy) it has become a commonly applied method. Researching databases of academic articles (e.g. *Science Direct* [4]) revealed that a considerable number of articles have been published regarding conducting analyses on single cases in energy. However, even though by nature, heat network is a system, whose operating mechanisms are often incomprehensible to consumers, district heating loses its purpose without consumers, and thus much attention should be paid to them when developing a central heating system.

There is a wide-spread opinion that case study results give an overview of a specific problem or event, and because of that the results are not usable to make generalisations and thus applicable in some other situation. Dane B. Flyvbjerg refutes this claim by saying that opinions, according to which case studies are only useful for creating hypotheses and not checking them, are incorrect, insofar as sometimes you only need one result to prove the wrongness of a hypothesis [5]. Using and assuming tried technical solutions is a common practice in technical sciences. Therefore, by applying case study research when examining technical solutions and their social benefits, we can claim that the results arising from it give inputs to the regions that can be used to plan new investments and activity plans.

1.2. The nature and objective of the task to be solved

The objective of this Bachelor's thesis is to find indicators describing the volume, importance, and effect of works performed in the district heating network on the population. In addition, it analyses the effect of reducing energy consumption on the investments made in the district heating network to show the importance of optimising the system in urban communities where the increase of district heating consumers is unlikely. In order to do that, the thesis looks at a central heating network that has largely switched from fossil fuels to wood energy, on the example of a small town (Elva).

The result can be achieved by perusing the dynamics of a small town heating system, giving information about reaching the current situation, and offering different options for further development. The output of the work is to give smaller Estonian local governments a more detailed overview of switching central heating boiler plants from fossil fuels to biofuels.

Drawing on the results of previous investment, the thesis focuses on determining the future prospects of Elva central heating network, not increasing the effective exploitation time of the conducted works. The research takes the increase of consumer efficiency into account, which in reality means a situation where production volumes should rather be reduced due to the decrease of heat loss.

1.3. Analysing the situation

The following options have traditionally been considered as a version of conducting a case study [3, pg. 7, 8]:
1) investigative;
2) explanatory;
3) descriptive.

Insofar as the questions focused on are "how" and "why", this particular thesis is an explanatory case study [3, pg. 9]. When gathering the source data, focus was first on getting an overview of the current situation and then reasons and premises for the situation were analysed.

The task was solved in the following stages:
1) getting an overview of the regulations and tendencies associated with district heating;
2) researching databases and sources for gathering data;
3) processing data to analyse the current situation and create future scenarios.

Statistics Estonia [7], Building Registry [8], Estonian Land Board's public map server [9], and Procurement Registry [10] databases were used to get an overview of the current situation. Average ambient air temperatures as the most commonly used prediction methods of heat requirement were achieved by making an inquiry to the Estonian Meteorology and Hydrology Institute (EMHI) [11]. A more detailed overview of applying the datasets of the databases used in this Bachelor's thesis is presented in chapters three and four.

Analysing the behaviour of the system as a whole does not make use of the existing modelling programmes: in order to get a better understanding of the concurrence of the system's working parameters, necessary calculation formulas were entered in the software package MS Excel 2010, and necessary source data for environmental and economic analyses that were conducted parallel to this thesis were found by changing various parameters.

Data gathered for previous analyses as part of the Woodenergy project (annex A), information received at meetings with key persons of Elva heat sector, and research results ordered from various companies were used to analyse the situation and prepare future scenarios, in addition to various state databases. The respective companies were EnPro and Hendrikson & Co. EnPro conducted the Elva district heating system management analysis [6]. Hendrikson & Co was responsible for the effect of transition to wood fuel on the environment and economic analysis.

The calculations included in this thesis are largely based on the 2008...2010 data. 2011 consumer information was used to calculate later predicted consumption volumes. The reason for not using newer data are the substantial reconstruction works in district heating pipelines performed in 2011 and the connecting of new consumers during a heating period, the calculation of which would have inexpediently complicated the data processing and analysis.

2. DISTRICT HEATING MARKET AND ITS REGULATION

2.1. Overview of Estonian district heating market

In 2010, according to the data from Statistics Estonia, district heating networks produced 8139 GW·h of heat energy [7]. According to the report "State's efforts in ensuring the sustainability of heat supply" submitted to the Parliament of Estonia by the National Audit Office, 151 of 226 local governments consume district heating in Estonia. The consumers make up nearly 60% of all people living in Estonia. 44% of heat energy was produced from natural gas, followed by wood fuels with 25% and oil shale with 11% [12, pg. 7, 8]. More detailed overview of the percentage of fuels used for district heating can be seen on Figure 2.1.

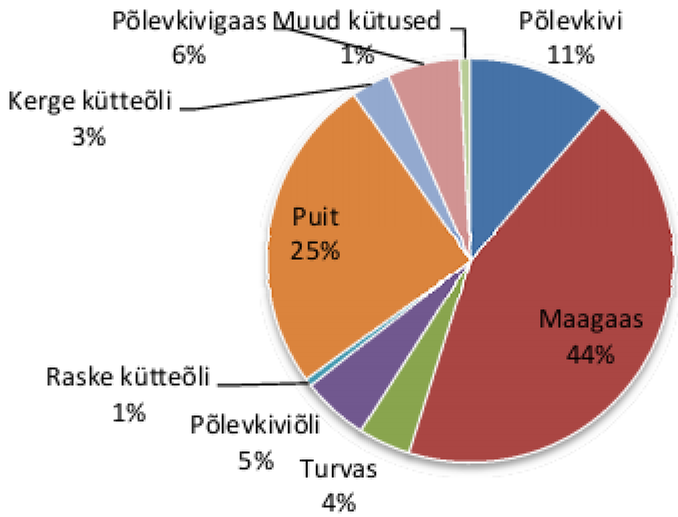

Figure 2.1. Percentage of fuels used for district heating [12, pg. 8]

Production, distribution, and sales activities of heating conducted in the district heating network are regulated by the District Heating Act that, in addition to aforementioned, prescribes that local governments can determine their district heating network on their administrative territory themselves [13]. This privilege is practically the only way for local governments to organise activities in the district heating system, because price regulation over all heating companies in the district heating sector is performed by the Estonian Competition Authority as of 1 November, 2010.

The approved maximum reference prices for end consumers issued by the Estonian Competition Authority on 8 May, 2012, are the maximum heat MW·h reference prices imposed on the consumer, without value added tax 90,28 €/(MW·h) and minimum 27,48 €/(MW·h). The average reference price is 68,7 €/(MW·h) [14]. Value added tax is added to the prices. The document reveals that in some regions, the price of heat energy on sale is changed as often as once a month. Insofar as this is due to the changes in the price of raw material and wood fuel delivery contracts are usually entered into for the duration of the entire heating period, it can be assumed that regions (where prices are above-average) produce heat energy in the district heating network on the basis of fossil fuels or the high price has arisen because of low energy efficiency.

According to the data of Statistics Estonia, 25349 GW·h of heat energy was produced in 1991, but the production only reached 9765 GW·h in 2010 [7]. Producing heat (and thus also consumption) has decreased 2,58 times in the given period. Insofar as most district heating networks were built before 1991, the major problems in the Estonian district heating networks are due to incorrect dimensions of the heat networks [15, pg. 22]. Therefore, the reason for the high reference price imposed in the district heating network may not be caused by the cost of raw material necessary for heat energy, but also by the optimisation of the system. Heat losses in the district heating networks calculated pursuant to various statistics gathered by the audit of the National Audit Office range from 11% to 20,6 % [12, pg. 14], and thus there is currently no reliable statistics available for assessing the data.

2.2. European Union regulations

European Union does not directly regulate district heating networks and their management, but several directives of the European Parliament and of the Council have a relatively strong effect on activities performed in district heating networks.

The current energy policy in the European Union was approved by the European Council in 2007, and as part of this, Europe's 20-20-20 targets were implemented for the year 2020 [16]:

a) raising the percentage of renewable energy to 20%;
b) 20% reduction of energy;
c) reduction of greenhouse gas emissions by at least 20%;
d) raising the percentage of biofuel in transport to 10 %;

On 23 April, 2009, Directive 2009/28/EC of the European Parliament and of the Council was passed with the objective to promote the use of energy from renewable energy sources to ensure that member states complete the aforementioned general goals. With this directive, European Union imposed legally binding objectives to increase the percentage of renewable energy in the end consumption of member states, basing it on the percentages of 2005 [17]. Estonia was set to aim to raise the percentage of renewable energy in the end consumption from 18% to 25% [17, pg. 46].

If the EU climate and energy package affects the district heating networks indirectly by setting the goal for the country to increase the production of renewable energy with the help of support schemes and legislative regulation, then the directive 2010/30/EC of the European Parliament and of the Council gives direct instructions for raising energy efficiency of buildings [18]. In addition to the obligation to impose minimum requirements for the energy efficiency, the directive also stipulates that as of 1 January, 2019, all public sector buildings must be nearly zero-energy buildings. This provision applies to all new buildings as of 1 January, 2021 [18, pg. 21].

In light of previously mentioned directives, it is appropriate to assume that renovating the district heating network's heating sources to use biofuels is an activity favoured by the European Union. At the same time, increasing energy conservation methods in buildings where district heating is consumed should be taken into account, and thus it is important that the system is properly optimised when being renovated.

2.3. Heat energy tendencies in Estonia

So far, Estonia's long-term energy policy has been regulated by the "National Development Plan of the Energy Sector Until 2020", passed in 2008. The development plan shows that the monopolistic situation on the district heating market creates circumstances where companies are not required to find alternative and cheaper heating solutions and invest in them. The consumer, however, has to also pay off the company's incorrect investment decisions. It also mentions low energy efficiency both in the buildings and district heating systems. As a solution, it suggests creating a national development plan and various support methods to modernise boiler plants and district heating networks [19].

The "National Energy Efficiency Action Plan 2007-2013" [20] was created with the aim to describe necessary activities for conserving fuel and energy. Required methods for achieving them were also determined [19, pg. 9]. The title of the document indicates that the programme is about to be concluded, and an overview of the results of methods described in it will certainly be given with defined indicators at the end of the period. Of activities related to the topic of this thesis, the activity plan mentions supporting the preparation of energy development plans of local governments, energy audits of the buildings [20, pg. 22] and heating supply of district heating systems, reconstruction and development of boiler plants and networks [20, pg. 30].

Minimum requirements were imposed on the energy efficiency values of new buildings to be constructed and existing ones to be substantially renovated with the help of "Minimum Energy Efficiency Requirements". Additionally, computational bases necessary for proving the requirements were also stipulated [21].

The aforementioned regulations are to be amended soon in relation to the expiration of validity period or new (and adjusted) tendencies in the energy policy of the European Union. Both the "Minimum Energy Efficiency Requirements" and "Format and Procedure of Issuing Energy-Performance Label" are soon to be amended in relation to the definition of nearly zero-energy buildings appearing in the EU directive of the energy efficiency of buildings. The tendency will still be to raise energy conservation and energy efficiency, as different support schemes managed by KredEx and EIC have shown.

Considering the maximum heat losses from the pipeline that can be reflected in the sales price of heat imposed in the regulation "Procedure of Imposing a Temporary Sales Price of Heat" [22] that the Estonian Competition Authority adopted in their principles of coordinating the reference price of heat [23, pg. 12], there is a reason to assume that the future national energy policy continues to increase the obligations for making the district heating networks more effective.

Even though the "Long-Term National Development Plan of the Energy Sector Until 2020" mentions low energy efficiency in district heating networks, explicit national instruction material for assessing the sustainability of heat sector has not been issued. EPHA research "Mapping Estonia's Small Heat Producers and Energy Development Priorities in Rural Areas" reveals two indicators: power density and building density. Both are calculated in relation to the length of district heating network and reflect the consumers' required heating capacity with respect to the length of district heating network pipeline (kW/m) and heated buildings' cubature in the total length of the district heating network pipeline (m^3/m). The research does not contain precise recommended values for Estonian conditions, but as indicators of Finland's conditions it mentions that the value of building density should be above 35...40 m^3/m and power density above 1.1 kW/m [24, pg. 10]. Book titled "Energy Planning for Local Governments" [25] and instruction material "Technical Recommendations of Energy Saving for Local Governments" [26] prepared by the Department of Thermal Engineering of Tallinn University of Technology give a general overview of energy planning.

3. CALCULATION METHODOLOGY

3.1. Temperature duration diagram and degree days

Heat requirement used for heating depends on external and internal factors [27, pg. 20]. If internal factors are related to people's behavioural habits (keeping windows and doors open, effective usage of average internal heat gain), then external factors are closely related to ambient air temperature and its distribution. Even though it is nearly impossible to predict ambient air temperatures as hourly or even daily averages, statistics do show the temporal duration [27, pg. 20] of average ambient air temperatures, which enables predicting yearly heat energy requirement, provided that the building's heat losses are equal to the difference between the room's indoor and ambient air temperature [27, pg. 21]. Figure 3.1 represents the duration curve of average ambient air temperatures in Tartu.

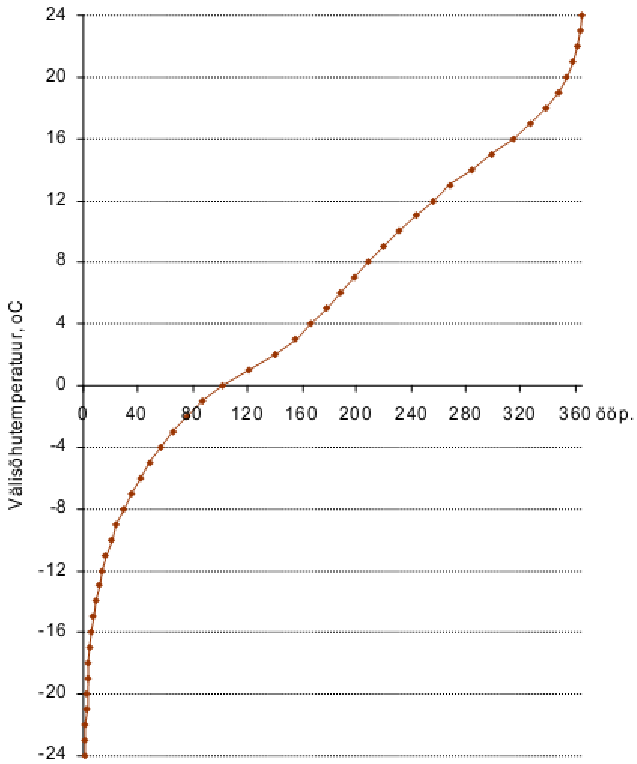

Figure 3.1. Duration curve of yearly average ambient air temperature and duration of temperatures lower than the given ambient air temperature (represented by the number of days) in Tartu [28, pg. 24]

The duration curve diagram (Figure 3.1) has been prepared on the basis of statistic processing of Tartu region's climatic data, the X-axis representing the number of twenty-four hour periods with a higher temperature than that of Y-axis.

Using degree days is common in energy calculations of today (and even required for receiving various subsidies endorsed by KredEx). The degree day represents a 1 °C difference between the ambient air temperature and estimated indoor temperature during a 24-hour period [28, pg. 4], whereas the estimated indoor temperature is a temperature up to which heat losses from the building's outer structures are covered by the heating system [28, pg. 8]. The actual room temperature is higher than estimated due to using the heat emanating from "average internal heat gain", i.e. from people, electrical appliances, lighting and solar radiation [28, pg. 30].

3.2. Annual heat energy requirement of buildings and heating characteristics

Yearly heat energy expenditure of a group of buildings can be assessed according to heating characteristics [29, pg. 16]

$$Q = V_{köetav} \cdot q_{ekspl.} \cdot KRT \cdot 10^{-6}, \tag{3.1}$$

where Q is annual expenditure of heating energy of a group of buildings MW·h/y;
$q_{ekspl.}$ – heating characteristics of a group of buildings W/ºC·m^3;
$V_{köetav}$ – cubature of heated group of buildings m^3
KRT – number of degree hours in a reference period ºC·h.

By definition, heating characteristics represent the amount of heat energy needed for one m^3 of building's volume, if the difference between indoor and ambient air temperatures is one degree (W/ºC·m^3). The values can be found both in the data referenced in literature [27, pg. 23] or by processing the measured consumption data [27, pg. 28]. It must be taken into account that preparing hot consumer water is not directly related to the difference between ambient air and indoor temperatures. Consumption data is processed with the formula [27, pg. 29]

$$q_{ekspl.} = \frac{10^6 \cdot Q_{küte}}{V_{köetav} \cdot KRT}, \tag{3.2}$$

where $Q_{küte}$ is heat quantity used for heating during a reference period (year) MW·h/y.

If degree days represented one °C difference between the ambient air temperature and estimated indoor temperature within a 24 h period, then degree hours (*KRT*) represent the same relation during a one hour period. The number of degree days during a reference period can be derived from the formula [29, pg. 16]

$$KRT = \sum \left[\left(t_B - t_{välis,i} \right) \cdot \tau_i \right], \tag{3.3}$$

where t_B is estimated indoor temperature of the heated rooms in a group of buildings, i.e. balance temperature °C;
$t_{välis,i}$ – ambient air temperature °C;
τ_i – duration of a respective ambient air temperature h.

The estimated indoor temperature or balance temperature t_B in this thesis is 18 °C [27, pg. 22], insofar as analysis of a group of buildings as a whole does not enable analysing every unit's outer structures and internal heat allocations, and thus it is reasonable to use a conservative approach by estimating the increase of temperature due to average internal heat gain to be lower rather than higher.

As actual heat sales data for three years was available for Elva's heating networks, one decided to use heating characteristics derived from actual consumption data. Instead of using a formula 3.2 found in literature, the calculations applied

$$q_k = \frac{Q_{küte}}{KRT}, \tag{3.4}$$

where q_k is heating characteristics of a group of buildings MW/°C.

It is reasoned that the heated cubature of the buildings and the added coefficient 10^x for converting units are cancelled out upon calculating yearly heat energy expenditure with formulas 3.1 and 3.2. Therefore, the planned heat energy expenditure of a group of buildings to cover the heating can be derived from formula

$$Q = q_k \cdot KRT. \tag{3.5}$$

Insofar as in 2011, three new consumers (annex B) joined the district heating network managed by AS Elva Soojus at different times and substantial renovation works took place in the Kesklinna district heating network region, 2008...2010 actual heat energy quantities sold to consumers were used to calculate the heating characteristics of the heating networks. The following formula was used to estimate the consumption volumes of joined consumers:

$$q_k = \frac{Q_{küte}}{KRT}, \tag{3.6}$$

where q_{lisa} is heating characteristics of an additional consumption point MW/°C;

Q_k^{pl} – planned heat requirement for heating a consumption point MW·h;

KRT_N – number of degree hours during the heating period in a standard year °C·h ($KRT_N = 95040$ °C·h).

Once usable measuring results regarding the building's consumption volume had been found, then Q_k^{pl} was derived by standardising actual consumption data, using degree days in a standard year [30]

$$Q_k^{pl} = Q_{küte} \cdot \frac{KRT_n}{KRT}, \tag{3.7}$$

where KRT_n is number of degree hours during the reference period in a standard year °C·h.

If there were no usable consumption data for the consumption point, the planned heat requirement for heating was derived according to the methodology found in Riigi Teataja [31]

$$Q_k^{pl} = Q_k^{pr} \cdot \frac{t_B - t_v}{t_B - t_v^a} \cdot n_{kN} \cdot \tau_p, \tag{3.8}$$

where Q_k^{pr} is heat load for heating a building MW;

t_v	–	planned average ambient air temperature °C ($t_v = -1,61$ °C);
t_v^a	–	estimated minimum ambient air temperature ° °C ($t_v^a = -23$ °C);
n_{kN}	–	number of planned heating days ($n_{kN} = 212$);
τ_p	–	number of heating system's working hours per day h ($\tau_p = 24$ h).

Degree days for aforementioned calculations have been derived using degree days for Tartu region [30] available on SA KredEx web page, whereas

$$KRT = KRP \cdot \tau_p , \tag{3.9}$$

where KRP is number of degree days in a reference period ºC·d.

Because there is no large hot water consumption in the Elva district heating network, monthly heating characteristics of the heating network, which were averaged to reduce the effect of various factors not related to ambient air temperature (malfunctions in the system), were derived pursuant to 2008...2010 data. Consumer heating characteristics not reflected in the data were added to the results, thereby achieving the computational heating characteristics of the "base year" of the group of buildings. Further changes to the heating characteristics arise due to the connecting/disconnecting of consumers and the effect of various renovations. The effect of different activities on the district heating network can be modelled according to the change of heat energy requirement (and thereby heating characteristics).

3.3. Hourly calculation model and load diagram

The task of this thesis is to model the behaviour of the district heating network as a whole without special software and thus an MS Excel-based calculation model was created where the formulas described in the thesis were entered. With these, the variation of consumption capacities in the event of various scenarios was assessed. Chapter five presents an overview of the scenarios and their source data. Load diagrams were created for every scenario, which is one possible method to analyse the power necessary for covering the heating period's consumption volumes. If the ambient air duration diagram reflected the duration of temperatures during a period of one year, then the heat load diagram reflects the temporal duration of the boiler's required output capacity. The standard heat load diagram is visible on the following figure (Figure 3.2).

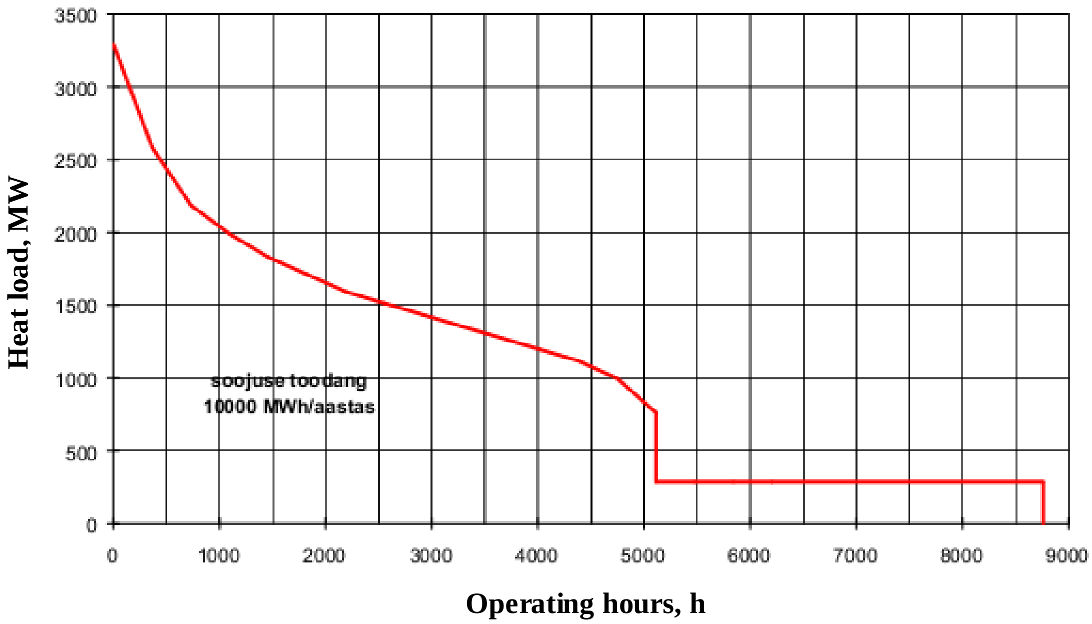

Figure 3.2. Illustrative heat load duration diagram of a boiler plant [25, pg. 66]

Figure 3.2 reveals that the required peak load for this particular boiler is 3250 MW, whereas summer load or permanent load after 5144 h is probably due to the requirement of hot consumer water.

The thesis uses the measurement data for hourly average temperatures in the Tõravere weather station issued by the EMHI [11] that form the basis for finding the degree days and thus also the degree hours in the Tartu region. The existence of hourly data enabled finding the required production capacities for every hour of the year with formula 3.5. Insofar as the author of this thesis could not use the hourly temperatures of a standard year as source data, the hourly temperature measurement data for the year 2010 were standardised in order to increase the comparability and transferability of the results, using the formula

$$t_{n,i} = t_i \cdot \frac{KRT_n}{KRT}, \quad (3.10)$$

where $t_{n,i}$ is standardised average hourly temperature °C;

t_i – measured hourly average temperature °C.

The smallest period of degree days (and also degree hours) available on the KredEx web page [30], one month, was chosen as the period of degree hours. Overview of the calculation results and bases is available in annex C.

By implementing the results of formula 3.10 in formula 3.3, computational heat energy requirement was derived in all analysed district heating networks with an hourly precision with the help of formula 3.5. The district heating network's heating period load diagram was achieved by summarising the results and sorting them from the largest unit to the smallest. Length of the modelled heating period both during the "base year" and years 2008...2010 is given in annex C. The prepared load diagrams are shown in chapter five.

3.4. Assessing the heat losses of district heating pipeline

In addition to practically no consumption of hot water in the Elva district heating network, the load diagram is made up of losses through the outer structure of the heating network. Insofar as the district heating pipeline has no direct contact with ambient air, monthly heat consumption capacities were derived in order to assess the losses of the existing pipeline by using the difference between energy quantities produced by the boiler plant and sold to the consumers

$$P_t = \frac{Q_{toodang} - Q_{küte}}{n_{kuu} \cdot \tau_p}, \tag{3.11}$$

where P_t is average monthly dissipated power of district heating network's heating pipeline MW;

$Q_{toodang}$ – heat quantity in a district heating pipeline produced by the boilers in a respective month MW·h/month;

n_{kuu} – number of days in a respective month.

The derived dissipated power was summarised in an hourly basis and added to the data massif created for preparing the load diagram of a boiler.

Insofar as future scenarios foresaw the construction of a new heat pipeline, the following formula was used to assess heat losses without knowing the actual losses of new pipelines:

$$q_{trass} = K_0 \cdot S \cdot 10^{-6}, \tag{3.12}$$

where q_{trass} is heating characteristics of a planned district heating pipeline MW/ºC;

K_0 – heat pipeline heat conductivity coefficient W/ºC·m^2 (K_0 =1,1 W/ºC·m^2[32, lk 278]);

S – external surface area of the heating pipeline m$^{2.}$

External surface area of the pipeline was found by using the external diameters of a typical pre-isolated heat pipe (annex D) and computational lengths of the utility pipelines, derived by measuring the distances using the public WMS-service [33] of the Estonian Land Board and freeware geographic processing program QGIS (annex E). The lengths and heating characteristics of pipelines to be added in the event of future scenarios are given in annex C.

4. BASE DATA FOR THE TOWN OF ELVA

4.1. Demographic data

Although perusing demographic data may seem inexpedient in a research about the development of heat sector, it must be remembered that the district heating network always has to have two parties: the producer and the consumer. It is therefore important to monitor migration trends when planning sustainable economic and investment activities in the heat sector. While choosing a smaller output capacity for a planned boiler due to the decrease in population may seem economically inexpedient in the first couple of years of the planning phase of the investment, the decrease in consumption that could have been predicted may cause the later monetary expenses to become inexpedient.

In order to have an overview of the effect of the town's development on the development of the heat sector (and vice versa), an overview of Elva's current situation and its background needs to be given. One indicator is the number of people living in the area. The data received from Elva City Government (annex F) has been used to graphically show the changes in the population during the period of 1996...2012. The basis for choosing the period of time was availability of data. Changes to the population during this period are shown on Figure 4.1.

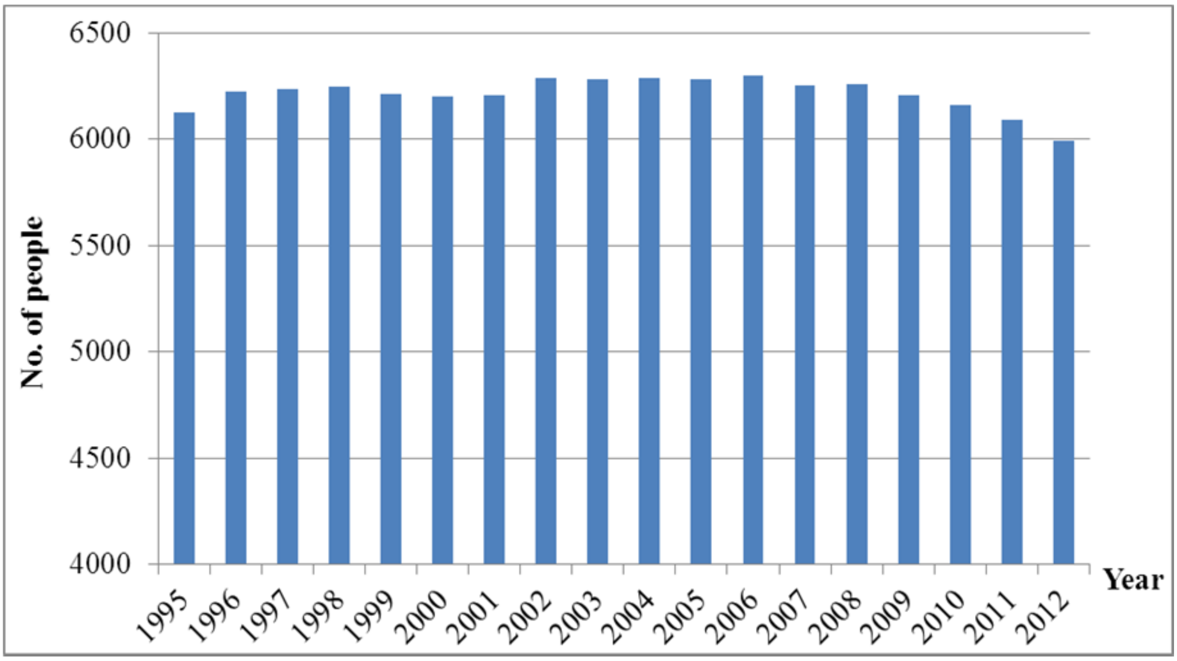

Figure 4.1. Number of people living in Elva in 1995...2012 (annex F)

The above-mentioned Figure shows that the population has remained above the limit of 6000 people in 1995...2011. The number of population started to decrease at the beginning of recession, however, reaching 5992 people as of 1 January, 2012. In order to get a better overview of the backgrounds of the decrease in population, we need to peruse migration and the changing of registered unemployment (Figure 4.2). Migration was derived from the difference between the change in the number of people and natural increase according to data from the city government (annex F), while data from the regional statistics database of Statistics Estonia [34] was used to describe registered unemployment.

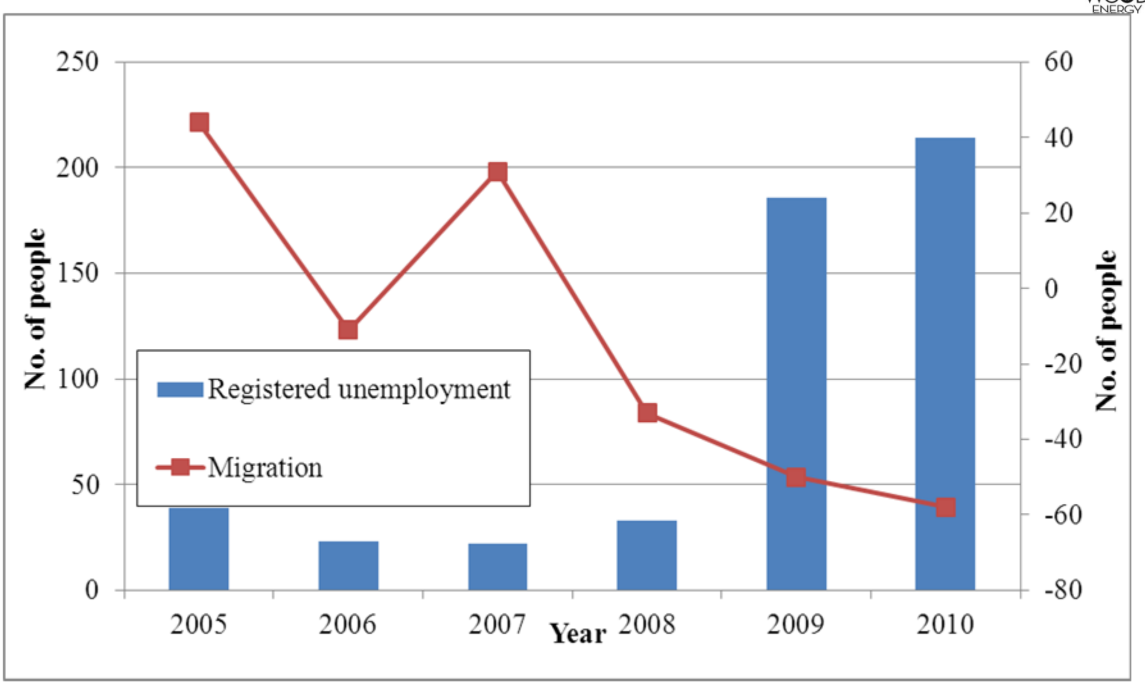

Figure 4.2. Balance of the registered unemployed and migrants in Elva in 2005...2010

The figure above shows that there was emigration in 2008...2010 when registered unemployment grew. Newer data was unavailable during the writing of this thesis, but based on the given tendency, we can assume that one of the reasons for emigration was unemployment: there may have been a need to change habitats due to loss of workplaces and being made redundant. Housing utility bills have a fairly large effect on economic coping and the fact that the price of heat energy in Elva is one of the lowest in Estonia was likely to help decrease emigration.

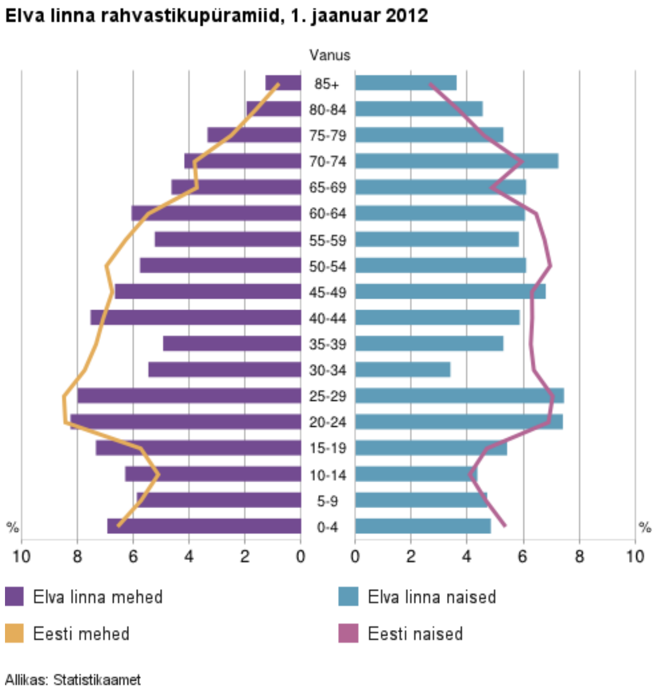

Figure 4.3. Elva estimated population pyramid as of 1 January, 2012 [34]

Figure 4.3 shows that the composition of age and gender in Elva is similar to the Estonian average. However, it must be admitted that the proportion of 30...40-year-old people is lower than average. This shows that a part of the age group has left the town at some point. In terms of the heat sector, this lower than average percentage does not have a significant effect for the next couple of decades, provided that the younger age group (ages 20...30) remains in Elva. One way to reduce the emigration in the region near Tartu is lower housing costs and long-term working opportunities.

4.2. Business and housing

Issuing building permits as a construction activity indicator was viewed as the indicator of business and housing development. Required data regarding the years 1995...2011 was taken from the Building Registry's database [8], gathering the results of conducted entries in yearly inquiries to a document management group 122, the subsets of which include building permits issued in categories. The results were generalised in four categories: erecting a new construction, expanding a structure, reconstruction, demolishing, and renovating, and were consolidated on a diagram (Figure 4.4).

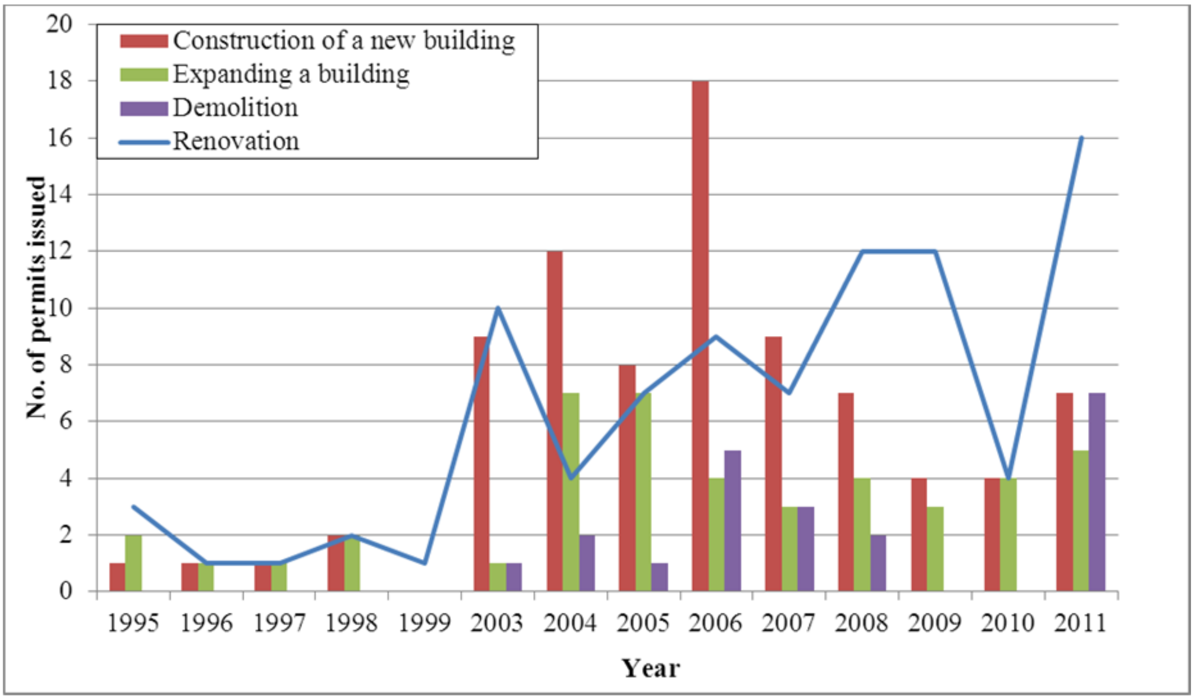

Figure 4.4. Number of building permits issued in Elva and entered in the Building Register in 995...2011

Lack of data during the period 2000...2002 visible on Figure 4.4 is due to the fact that there were no results in the Building Registry's database for this period of time. The reason is probably the issues due to renewal of various registry systems that took place at the same time. However, we can see on the above-mentioned diagram that while the building permits issued for renovation has generally increased, erecting and expanding existing buildings has been on a fairly low level in the last five years.

From the beginning of renovations, three new apartment blocks, two stores, two production facilities, and four public sector buildings have joined the district heating network, and its total consumption is computationally above 4000 MW·h. Heat energy requirement of production and trade sector buildings makes up the majority of the consumption volume (annex B) The two residential buildings that joined in 2010 and 2011 only consume 0.6% of consumption volumes of all consumers that have joined the district heating network from 2006, and because of that it is not economically expedient (at least for some time) to construct new pipelines to join residential buildings with the network.

A conversation with the director of Elva City Property Department Kalev Kepp, who has held the position throughout the heat network's renovation period, revealed that the 35% KredEx apartment building renovation subsidy has been used to renovate three apartment blocks already and the fourth one is in progress. Additionally, renovation of three apartment blocks is in the preparatory phase. It should therefore be concluded that the decrease of heat energy consumption due to renovations should be taken into account when planning future activities of heat sector in Elva.

4.3. Organisation of Elva heat sector

District heating service provider in Elva is OÜ Elva Soojus, a private body 100% of whose shares are owned by the Elva town. The company's main activities are producing, distributing, and selling heat, and the company manages three district heating boiler plants and one local boiler plant [35].

The district heating network of Elva consists of three district heating networks [36]:

1) Kirde boiler plant;
2) Keskkatlamaja;
3) Haigla boiler plant.

This thesis does not separately include aspects associated with managing the local boiler of a social house located at Pikk St. 26.

The aforementioned district heating networks were implemented in 2005...2006, whereas the only official amendments to the networks were made in 2009 [36] when the Keskkatlamaja network was expanded with four more consumers [37]. District heating networks and their expansion with new consumers are given in annex E.

The terms and conditions and procedure of connecting and disconnecting a district heating network and general quality requirements for district heating are provided in the regulation passed by the Elva city council. Although buildings that use renewable energy sources for heating [36] can break away from the district heating network, the author does not have data about consumers who have taken advantage of this opportunity. Elva City Council is no longer responsible for imposing reference prices: Estonian Competition Authority is now charge of this function (as of 1 November, 2010). However, it should be mentioned that even though the maximum reference price of heat energy MW·h on sale was imposed already on 30 September 2008, it was fully implemented on the consumer only on 1 October, 2011. The respective price for a natural person and building and apartment associations was 52,28 €/(MW·h) during the work and for legal person 56,56 €/(MW·h) (VAT is added to the prices) [35].

Different price of heat energy for legal persons and private persons was imposed with the aim to keep the population's tax burden lower. Maintaining such circumstances is only possible until there is a need to coordinate a higher reference price with the Estonian Competition Authority. Insofar as there are no plans to establish additional district heating boiler plants and networks [37], we may conclude that the town's and Elva Soojus OÜ's activity is optimising the district heating network in current circumstances. Furthermore, both the Keskkatlamaja and Kirde boiler plant's network boilers' capability to produce maximum quantities during maximum loads while requiring a fairly small amount of additional power from shale-derived oil boilers proves that the current system is sustainable even if consumption volumes decrease.

4.4. Investments in the heat sector

The basis for investments made so far in the district heating networks by Elva Soojus OÜ and Elva town was the "Development Plan of Heat Supply in the Town of Elva" drafted in 2000 by OÜ Märja Monte. The development plan identified the bottlenecks of the district heating network and recommended gradual replacement of district heating pipelines as a further development direction of the heat sector and demonstrated the environmental friendliness of wood waste and chips burning boilers compared to boilers operating with shale-derived oil. It also emphasised the prospect of wood burning and conducted various economic analyses according to future scenarios [38].

Pursuant to Elva's development plan for 2008...2018, the objectives of the heat supply development plan have been achieved and preparing a new development plan is being devised.

Substantial renovation works in Elva started in 2005 when a part of Kirde boiler plant's heating pipelines was renovated. Gradual renovation of heating pipelines enabled dispersing the investments for a longer period, thus avoiding accruing a large debt burden. Using different support systems for financing investments enabled to keep the price of heat energy low.

Procurement Registry's database was used to gather data [10], provided that a public procurement was organised for the largest investments. Data tables demonstrating the volume of investments and performed works were prepared with the help of processing tender documents reflected in the databases regarding the renovation and renewal activities in the Haigla boiler plant (Table 4.1), Kirde boiler plant (Table 4.2), and also Keskkatlamaja (Table 4.3; Table 4.4) district heating networks.

Work completion dates shown in the tables is taken directly from tender documents and may therefore somewhat differ from those on the instruments of delivery and receipt of the works. Information about completed projects available on the Environmental Investment Centre's web page [39] was also used to find the amount of the subsidy, in addition to the data in the Procurement Registry.

The reference time period chosen is 2000...2012, because there were no earlier entries about announced building procurements in the Procurement Registry. It should be noted that the following tables only reflect the largest renovation and construction works that required a public procurement to find a contractor.

Table 4.1. Most substantial renovation works performed in the Haigla boiler house's network [10, 39]

Indicator	Unit	Reconstructing Elva Haigla boiler plant	Reconstructing a boiler plant located at Supelranna 21, Elva	Total
Time of completion	-	2000	autumn 2012	-
Total cost	EUR	46655	268399	315054
Subsidy	EUR	19173	241565	260738
Own share	EUR	27482	26834	54316
Subsidy	%	41	90	83
Programme, as part of which the subsidy was received	-	Ministry of Economic Affairs and Communications energy conservation programme	EIC - Protection of atmosphere air	-
Description of works (pursuant to what is defined in the Procurement Registry)	-	Reconstructing the Haigla boiler plant to use shale-derived oil, replacing heating stations	Boiler plant reconstruction design and construction works, transition to using biofuels	-

Table 4.1 demonstrates that in 2000, transition to using shale-derive oil was still supported as an energy conservation activity. Therefore, there have been fairly substantial changes in the national energy policy in the last ten years.

Table 4.2. Most substantial renovation works performed in the Kirde boiler plant's district heating network [10, 39]

Indicator	Unit	Reconstructing Kirde boiler plant's heating pipelines	Reconstructing Kirde boiler plant	Renovating Kirde boiler plant's heating pipeline	Total
Time of completion	-	30.09.2005	31.01.2006	30.08.2006	-
Total cost	EUR	114807	327666	150775	593248
Subsidy	EUR	0	290007	118034	408041
Own share	EUR	114807	37659	32741	152466
Subsidy	%	0	89	78	69
Programme, as part of which the subsidy was received	-	Performed with own funds	EIC - Energy, 4.0202-0205	PHARE project "Energy Saving Support Scheme for Local Governments", subsidy from state budget	-
Short description of works	-	Replacing heating pipelines. Length of pipeline 460 lnm.	Demolishing depreciated devices and installing new ones. Connecting the boiler plant to the district heating network	Constructing a heating pipeline - 932 lnm of trench.	-

Table 4.3. Most substantial renovation works performed in the Keskkatlamaja network [10, 39]

Indicator	Unit	Renovating central boiler plant	Constructing Elva kindergarten Murumuna heating pipeline	Reconstructing Elva central boiler plant's heating pipelines	Total
Time of completion	-	10.10.2007	15.12.2008	15.11.2011	-
Total cost	EUR	600957	42769	703909	1347635
Subsidy	EUR	326867	0	351955	678822
Own share	EUR	274089	42769	351955	668813
Subsidy	%	54	0	50	50
Programme, as part of which the subsidy was received	-	- (see NOTE 1)	- (see NOTE 2)	EIC - Wider use of renewable energy	-
Description of works (pursuant to what is defined in the Procurement Registry)	-	- (see NOTE 1)	Constructing central heating pipeline.	Reconstructing and expanding Elva district heating network in the Keskkatlamaja network.	-
NOTE 1 –	Detailed description of renovating the central boiler plant in stages is shown in the Table 4.4 due to the difference in data available on EIC and Procurement Registry's web pages.				
NOTE 2 –	Performed with own funds				

Tables 4.2 and 4.3 show that the performed renovation works had large capital volumes. Investments made in boilers had, as a rule, a shorter pay-back period than investments in heating pipelines, and the fact that over 55% of total cost was spent on renovating the district heating pipelines therefore has large significance.

Table 4.4. Description of central boiler plant's renovation stages [10]

Performed work	Time of completion	Cost, EUR	Programme, as part of which the subsidy was received	Description of works
I stage of reconstructing the central boiler plant	15.10.2006	79826	European Regional Development Fund. NDP measure 4.2 "Developing Environmental Infrastructure" project "Reconstructing Elva Central Boiler Plant to Burn Biofuels".	Demolishing and utilising boiler plant's depreciated pipeline, constructing heat measurement station and water processing station
II stage of reconstructing the central boiler plant	31.05.2007	509285		Reconstructing the boiler plant, partially reconstructing the existing building, and procuring and installing heat energy production devices.

According to data presented in above-mentioned tables, the volume of investments directed into Elva district heating networks is 2.26 million euros, pursuant to Procurement Registry, of which 59.7% was accrued from various support mechanisms. Therefore, the town of Elva and Elva Soojus OÜ (insofar as the unit that received the subsidy took the responsibility of investment's own financing) only had to cover 1.35 million euros of the 2.26 million euro investment. There are no further large investments planned so far, and investment activity is thus conducted according to the necessity arising from routine business and economic activities.

4.5. District heating network in Elva

In the development plan of the heat supply in the town of Elva drafted by Märja Monte OÜ in 2000, the total length of pipelines was 4808 m, of which most were built in 1980 [38, pg. 6]. Thus, the heating pipelines were in a fairly bad condition. As a result of investment and renovation activities, only a 65 m segment of the 4930 m district heating pipeline located in the town is yet to be replaced by the time the works are completed. Table 4.5 shows the distribution of district heating pipelines in different regions.

Table 4.5. District heating pipelines in the town of Elva

District heating network	Length of two-pipe pipeline, m
Keskkatlamaja	3432
Kirde boiler plant	1358
Haigla boiler plant	140
Total	4930

The data presented in Table 4.5 was received from Kalev Kepp, the director of Elva City Property Department.

Following the 2006...2007 renovation works, two wood chip boiler plants started operating in the Kirde and Keskkatlamaja network. Insofar as previously operational shale-derived oil boilers were in a relatively good condition, they were kept in order to cover peak loads. The following table (Table 4.6) gives an overview of more powerful boilers located in Elva.

Table 4.6. Boilers servicing Elva district heating networks

Location of boiler plant	Type of boiler	Number	Age, y	Fuel	Power, MW	Yearly heat energy output, MW·h/y
Nooruse 8	BET 500	1	28	shale-derived oil	5,8	100,4
Nooruse 8		1	5	wood chips	4,0	10341,6
Kirde 6	RFW 1500	2	31	shale-derived oil	1,5	172,4
Kirde 6	HKRSV 1300	1	6	wood chips	1,3	3442,9
Supelranna 21	VIARDUS G500	1	11	shale-derived oil	0,5	1270,6
Supelranna 21		1	-	wood chips	0,75	
Valga mnt 7a	Wolf GT515	1	-	light fuel oil	0,87	not available
Valga mnt 7a	Wolf GT413	1	-	light fuel oil	0.745	

The yearly heat energy output of boilers shown in Table 4.6 is reflected as computational values derived according to the methodology provided in chapter three. Two boilers exploited by the company Enics, located at the address Valga mnt 7a [40], that are being used only during the summer period for hot consumer water after being connected to the Elva district heating network, and therefore the author of the thesis does not presently have information about the output of the boilers.

Pursuant to aforementioned data, production of heat energy in the Elva district heating networks has almost entirely switched to using biofuels by the start of 2012/2013 heating period. Fossil fuels (i.e. shale-derived oil and light fuel oil) are only used to cover peak loads and when boilers operating on biofuel are being cleaned or performed maintenance on.

4.6. Consumers of heat energy

37% of heat energy sold in Elva district heating network is sold to consumers in the residential sector. Public sector buildings and industrial and trade companies consume 29% and 34% respectively. The large percentage of public sector in the consumption increases Elva's, being the owner of Elva Soojus OÜ, motivation to keep energy prices low, because this helps to reduce their own fixed costs as well.

Elva City Property Department director mentioned two buildings in the city government administrative area, music school (Kalda 11) and social house (Pikk 26), as two potential consumers. OÜ Mareplex (Pikk 4a) working in the glass product industry has also expressed a wish to join. Chapter 5 includes calculations associated with connecting these consumers.

4.7. Effect of investments in the heat sector on consumers

Transition to boilers burning wood fuels has enabled to keep the prices of heat energy relatively low in the Elva district heating network. The following diagram (Figure 4.5) shows the comparison of average and maximum prices of heat energy MW·h with maximum prices of heat energy imposed by the Estonian Competition Authority for end consumers.

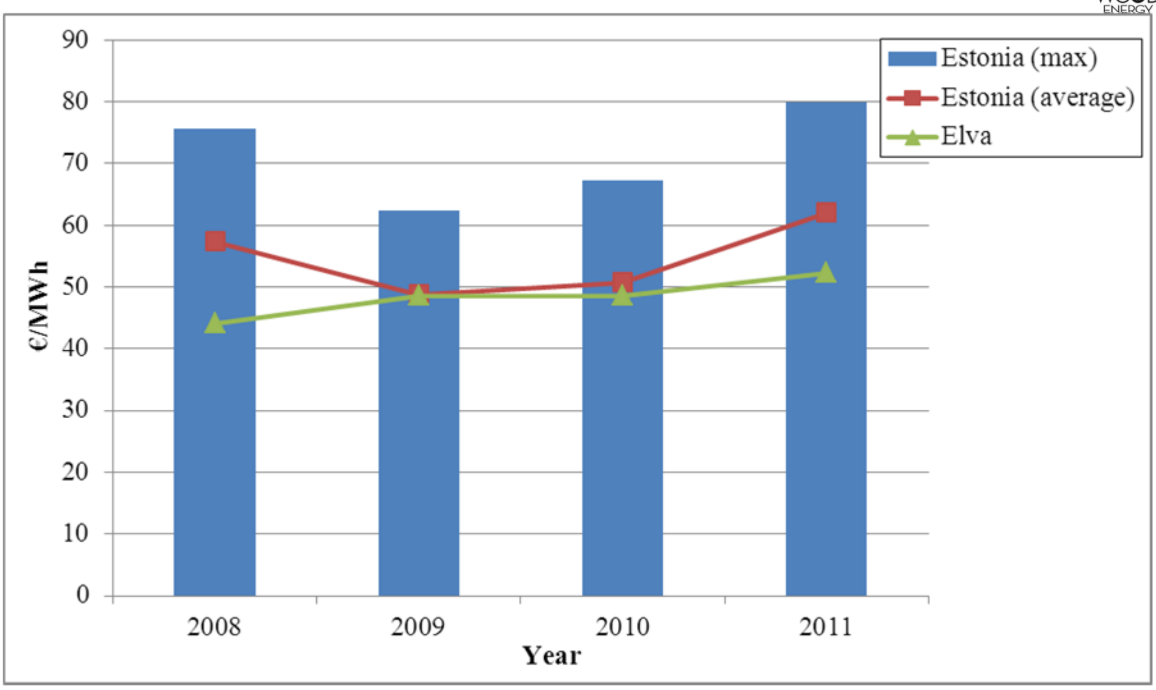

Figure 4.5. Price of heat energy in Elva compared to Estonian indicators [41]

Figure 4.5 shows that compared to the maximum reference prices for end consumers imposed by the Estonian Competition Authority, the price of heat energy for natural persons implemented by the Elva Soojus OÜ has remained below the imposed maximum reference price averages every year. It should be mentioned, however, that imposed maximum reference price does not automatically mean that it is implemented. Value added tax is added to the prices reflected on the diagram.

5. POTENTIAL FUTURE SCENARIOS IN THE REGION

5.1. General description of future scenarios

The previous chapter showed that the price of heat energy is one of the lowest in Estonia right now thanks to various investment and renovation activities: 52.28 €/(MW·h) for private persons and 56.56 €/(MW·h) for legal persons [35]. While chapter four analysed activities that helped to reach today's circumstances and the nature of the current situation, this chapter focuses on predicting various future opportunities of a district heating network and analysing them.

Future scenarios are divided into four categories:

1) continuing routine business and investment activity;
2) building a CHP plant and connecting Keskatlamaja and Kirde boiler plant’s network;
3) building a CHP plant and connecting Keskkatlamaja, Haigla, and Kirde boiler plant’s network;
4) building a CHP plant in the Keskkatlamaja district heating network.

Scenarios II and III include connecting potential consumers in the district heating network in addition to what is described in chapter 4.6.

Data tables describing the change of production volumes were prepared for every future perspective. If production volumes for a base year were calculated according to source data and formulas presented in chapter three, then future scenarios were prepared pursuant to the tendencies of EU and Estonian energy policy (see Ch. 2). A presumption that consumption of heat energy reduces 40% in both the residential and public sector and 10% in industrial and trade sector buildings thanks to renovations was created for the future scenario (year 2025).

In order to create value added, implementing the ORC-type CHP plant was considered in all future predictions that did not conform to routine business and economic activities.

In a CHP plant operating on the ORC-device or Organic Rankine Cycle principle, heat energy is transmitted with the help of organic oil as opposed to water-steam CHP plants. Temperature of organic thermal oil reaches up to 310 °C, which ensures a longer service life both for the oil and device as a whole. Other advantages for this CHP device are a high general efficiency (98%), small know-how requirements of permanent plant employees thanks to a high level of automatisation, and ability to operate with up to 10% nominal power. ORC-type CHP plants are relatively efficient with small output powers thanks to good electric efficiency factor (compared to other common CHP plants). Technology is suitable to be used with up to 2.5 MW electric output power [42].

5.2. Scenario I - routine business and investment activity

Creating a scenario "Continuing Routine Business and Investment Activity" was based on 2008...2010 consumer data, to which the estimated heat energy requirement of consumers that joined in 2011 was added (calculation methodology is provided in chapter three). Insofar as only 65 m of pipeline is yet to be renovated in Elva, but renovation works were completed only in the autumn of 2011, precise data regarding network losses in the Keskkatlamaja region were unavailable. Calculation results are consolidated in Table 5.1.

Table 5.1. Calculation results of routine business and investment activity

Indicator	Unit	Basis	2025
Selling heat energy to end consumers	MW·h/y	13803	9390
incl. residential fund 37%	MW·h/y	5097	2957
local government buildings 29%	MW·h/y	3942	2287
industry and service 34%	MW·h/y	4764	4146
Losses	MW·h/y	1559	1455
Total	MW·h/y	15362	10845
Heating period	h	5496	5088
Output of peak boilers	MW·h/y	273	186
Renovating heating pipeline	m	65	

The heating period was chosen to be 229 days instead of the regular 216 days by modelling heating characteristics with the help of output of May and September of different years. The chosen heating period for 2025 is 1 October - 30 April (i.e. 216 days), considering that the necessity for supplying additional heat to buildings reduces with the decrease of heat energy consumption thanks to better use of average internal heat gain when weather gets warmer.

Computational output of all boiler plants during a standardised base year can be seen on the following diagram (Figure 5.1).

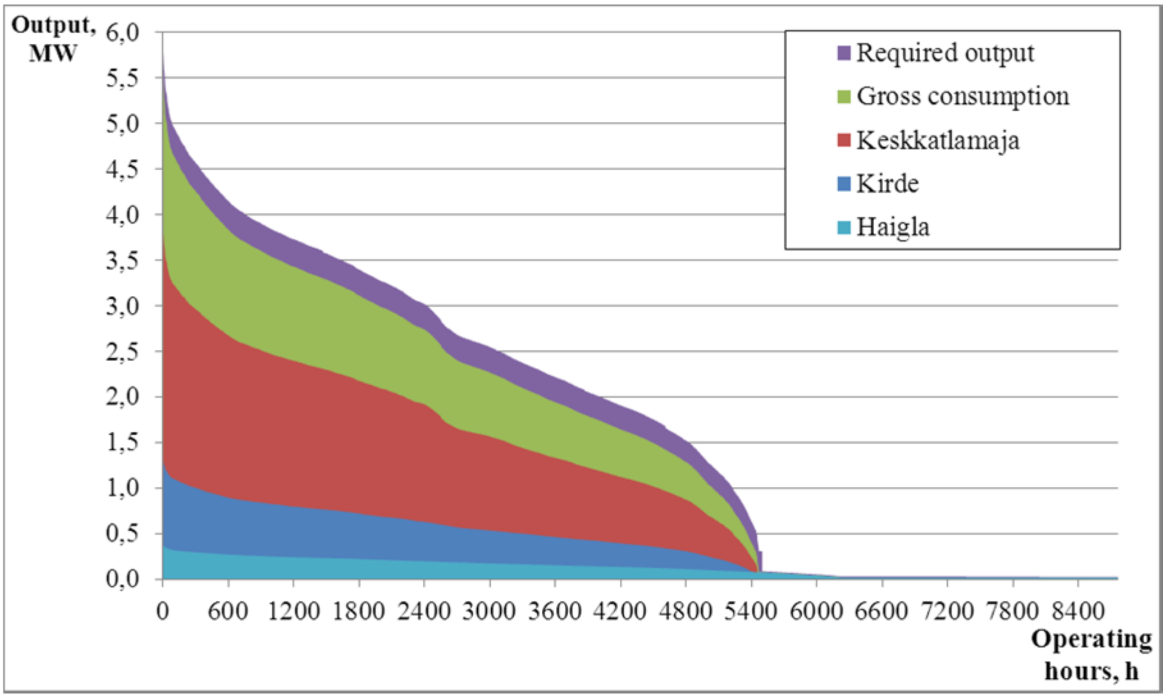

Figure 5.1. Heat load duration diagram of Elva district heating system during a standardised production period

Maximum gross summary production capacity approaches 5.77 MW during a base year, whereas the yearly consumption in the Haigla boiler plant's network is due to the requirement of hot consumer water.

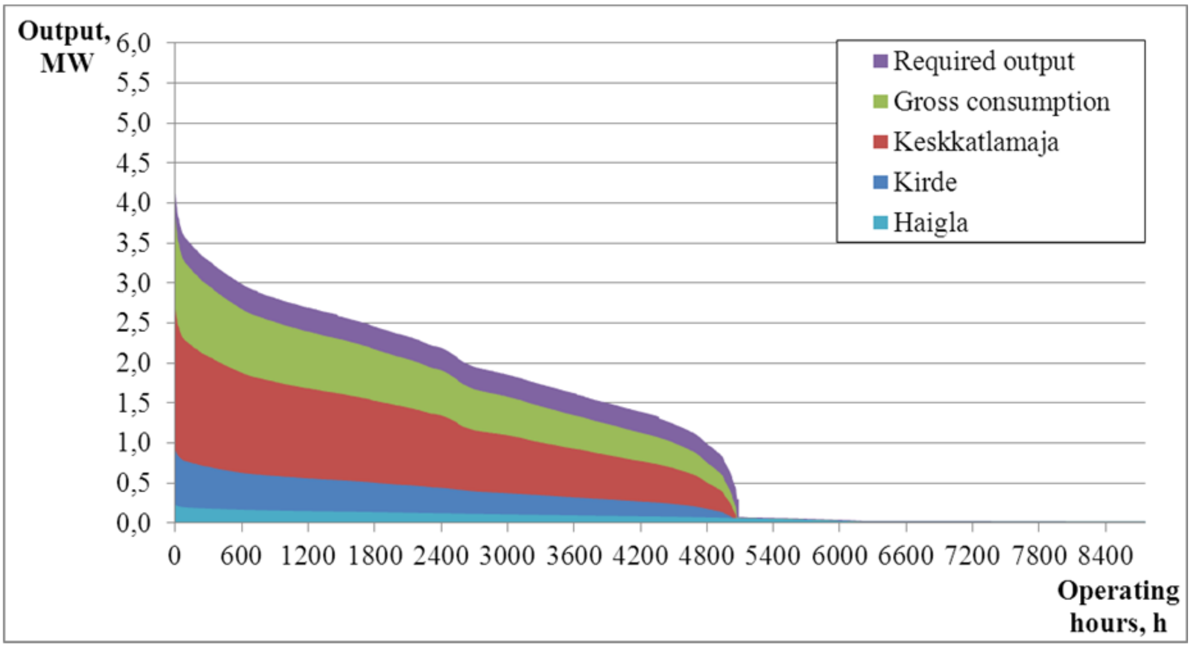

Figure 5.2. Computational heat load duration diagram of Elva district heating system in 2025

Compared to the base year, Figure 5.2 shows that the production capacity curve has become gentler, peaking at 4.11 MW. Average production capacity of the year still remains around 2 MW.

Decrease of production capacity is also described in chapter 5.1, where the 15362 MW·h production volume prediction during a base year has decreased to 10845 MW·h by 2025. It should be mentioned that such a decrease of consumption volume in the entire district heating network only happens if renovations are conducted and no new consumers join the network.

5.3. Scenario II – connecting the district heating networks of Keskkatlamaja and Kirde boiler plant

This scenario found production quantities and capacities in a circumstance where Kirde and Keskkatlamaja district heating networks were joined. ORC-type CHP plant is installed in the central boiler plant (Nooruse 8). The plant was chosen according to the estimated total production of Kirde and Nooruse boiler plants, additional consumers, and losses of heating pipeline to be constructed.

Haigla boiler plant remains as a stand-alone plant and is therefore not included in the diagrams illustrating the duration of computational production capacities (Figure 5.3; Figure 5.4).

According to the consumption prediction, the chosen production unit is Turboden TD 10 CHP with a maximum heat energy production capacity in district heating network of 4095 kW_h. By developing the capacity, the device is capable of providing 1000 kW_e production capacity into the power network [43].

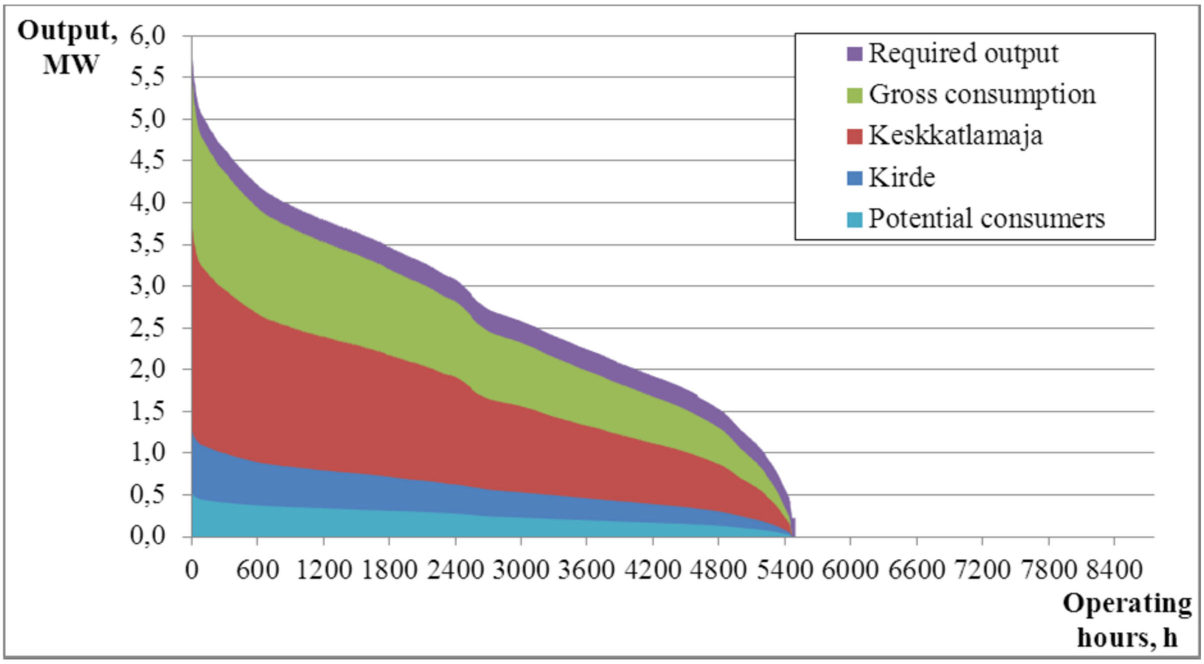

Figure 5.3. Predicted heat load duration diagram in Keskkatlamaja and Kirde boiler plant's district heating networks during a standardised production period

The above-mentioned table indicates that production volume necessary for heat energy consumption is larger than the total for all network thanks to new additional consumers, peaking at 5.87 MW.

CHP plant's heat capacity was chosen to be smaller than the maximum production requirement, insofar as the maximum production requirement will decrease to 4.29 MW according to the prediction (Figure 5.4). The circumstance that the demand for electricity will increase in the future (e.g. due to ventilation demand of renovated houses) and the production of electricity from fossil fuels will decrease or increase in price can be considered as a reason for building a larger CHP plant.

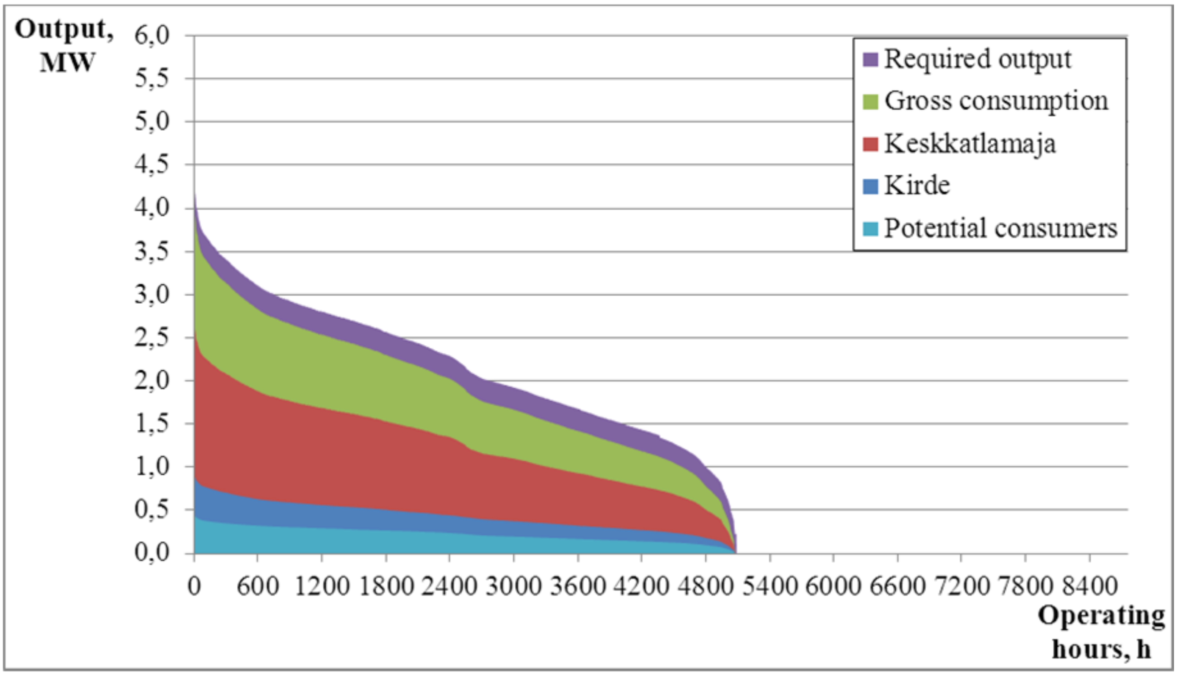

Figure 5.4. Predicted heat load duration diagram in the event of scenario II in Keskkatlamaja and Kirde boiler plant’s district heating networks in 2025

Insofar as the renovated Kesklinna heating pipeline was designed so that 1000 kW could potentially be joined, we presume that devices located in Kirde boiler plant will be operated during a time when load is larger than that provided. It was revealed in the calculations that 1990 h per year of pipeline's throughput is lacking at today's consumption volumes when the maximum load for a pipeline is 1000 kW. Calculation results for the future scenario are provided in Table 5.2

Table 5.2. Calculation results for scenario II

Indicator	Unit	Basis	2025
Selling heat energy to end consumers	MW·h/y	15176	10524
incl. residential fund 37%	MW·h/y	5604	3090
local government buildings 29%	MW·h/y	4334	2390
industry and service 34%	MW·h/y	5238	4332
Losses	MW·h/y	1605	1499
Total	MW·h/y	16769	12011
Heating period	h	5496	5088
Number of hours when pipeline's throughput is insufficient	h	1990	451
Quantity of heat energy deficit	MW·h/y	442	48

Number of hours when capacity of CHP plant is insufficient	h	788	58
Quantity of heat energy deficit	MW·h/y	405	12
Quantity of produced electricity	MW·h/y	3691	2713
Own consumption CHP plant	MW·h/y	280	260
Renovating, constructing heating pipeline	m	1718	

Presumption that the connection between heat and electric production capacity is linear and that electricity can be produced until heat capacity falls to 10% of maximum was used to calculate electricity throughput [42]. Therefore, the scenario presumes that electricity is produced as a by-product to heat energy to receive subsidies, not the other way around. CHP plant's own consumption was derived according to the consumption capacity and duration of heating period on the data sheet [43].

Although CHP plant's capacity is insufficient only during 788 hours, unlike the throughput of pipeline, the system must be optimised according to the maximum throughput of the heating pipeline in this instance. Based on the presumption that the boiler located in Kirde boiler plant is not completely depreciated by the time the CHP plant is completed, part of the required energy requirement (378 MW·h) is covered with a heating generator located there. The production requirement of peak boilers operating on shale-derived oil was assessed to be 64 MW·h.

In 2025, the entire deficit heat energy quantity is covered by peak boilers. The required heat energy quantity is therefore dictated by the maximum heat throughput of a pipeline, and the required heat energy quantity is 48 MW·h.

5.4. Scenario III - connecting Keskkatlamaja, Kirde, and Haigla boiler plants' district heating networks

For scenario III, changes in the network associated with connecting consumers to be supplied with heat by central, Kirde, and Haigla boiler plants were calculated. Like in scenario II, potential new consumers located near the pipeline used to connect network were joined. This scenario therefore has the largest investment volume. Limited heat energy throughput of an existing, already renovated pipeline has also been solved. ~500 m additional pipeline will be established from Nooruse boiler plant to increase the throughput of the respective pipeline's part.

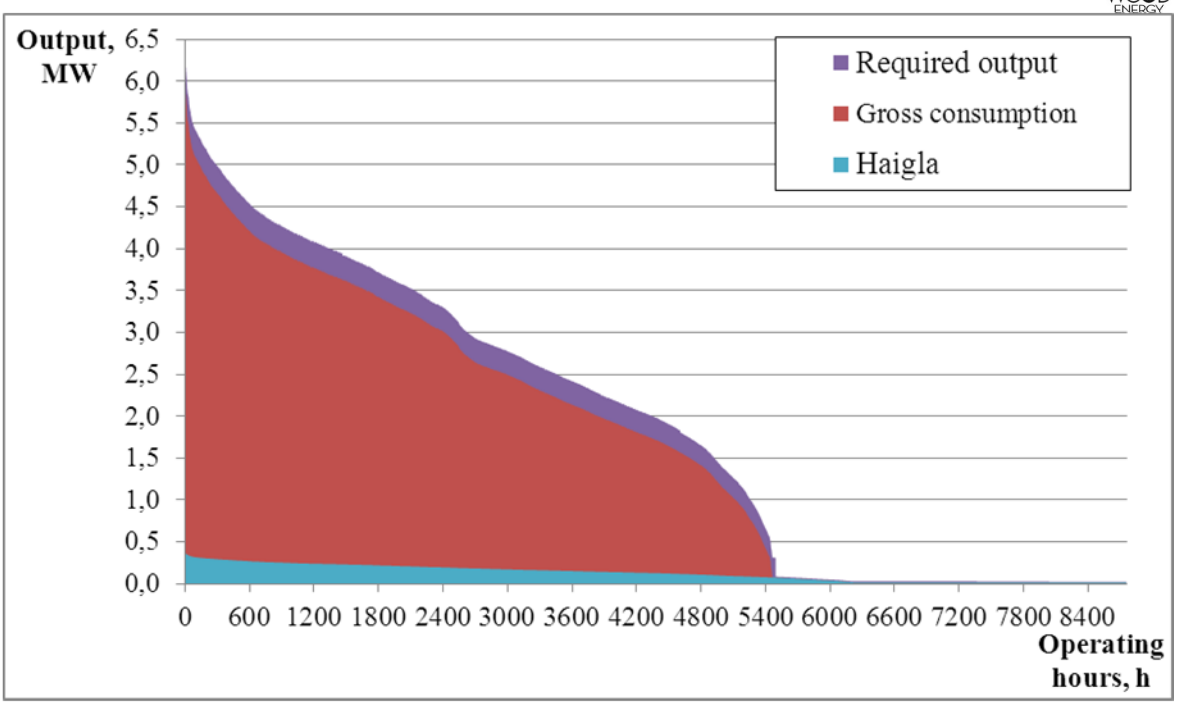

Figure 5.5. Heat load duration diagram of district heating networks located in Elva during a standardised production period in the event of connecting all heating networks

According to the information presented on Figure 5.5, the maximum consumption capacity is 6.28 MW in the event of connecting all consumers in a joint network and adding new consumers. At the same time, Figure 5.6 shows that by 2025 the required production capacity decreases to 4.57 MW pursuant to the defined decrease of consumption.

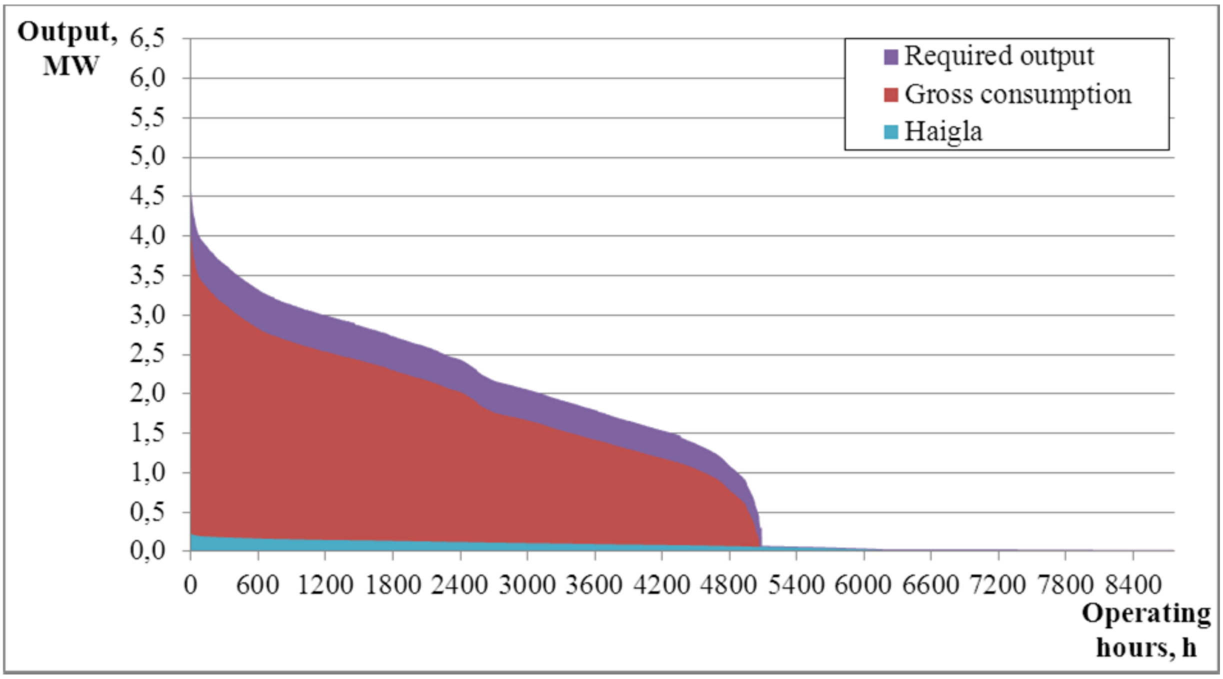

Figure 5.6. Predicted heat load duration diagram of district heating networks in 2025 in the event of connecting all heating networks

Summary of calculations made for scenario III are presented in Table 5.3.

Table 5.3. Base data for scenario III

Indicator	Unit	Basis	2025
Selling heat energy to end consumers	MW·h/y	15176	10524
incl. residential fund 37%	MW·h/y	5604	3090
local government buildings 29%	MW·h/y	4334	2390
industry and service 34%	MW·h/y	5238	4332
Losses	MW·h/y	1605	1499
Total	MW·h/y	16781	12022
Heating period	h	5496	5088
Number of hours when capacity of CHP plant is insufficient	h	1260	76
Quantity of heat energy deficit	MW·h/y	739	16
Produced electricity	MW·h/y	3901	2900
Own consumption of CHP plant	MW·h/y	280	260
Renovating, constructing heating pipeline	m	2328	

Pursuant to above-mentioned Table we can say that even though the initial efficiency seems larger according to this scenario because there are no issues arising from the throughput of district heating pipelines, a relatively large portion (739 MW·h) of heat energy required in the first few years must be produced with a boiler located in Kirde boiler plant.

Circumstance that the renovation of the Haigla boiler plant will be completed this autumn decreases the sensibility of this scenario, however, which is why there is no actual investment necessity for renewing or reconstructing this boiler plant in the next 15 years.

5.5. Scenario IV - building a CHP plant in the Keskkatlamaja network

This section only looks at the Keskkatlamaja district heating network where 65 m pipeline is renovated and a CHP plant with a smaller capacity is installed in boiler plant located at Nooruse 8: Turboden TD 7 CHP with 3146 kW_h and 729 kW_e [43].

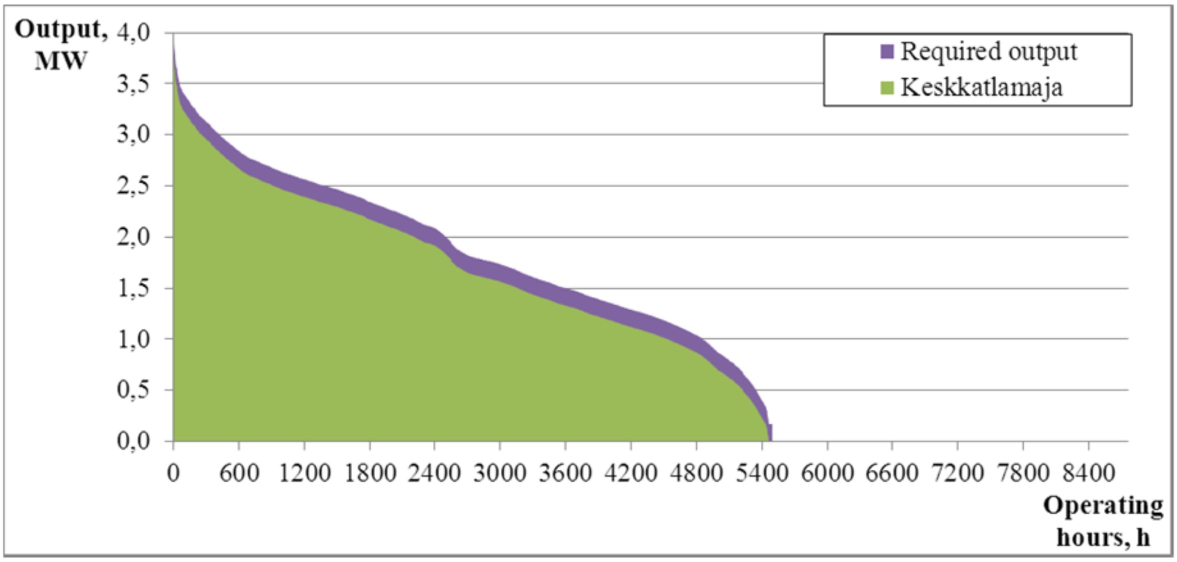

Figure 5.7. Load duration diagram of CHP plan in the Keskkatlamaja district heating network during a standardised production period

Figure 5.7 describes production capacity necessary for covering the consumers' heat energy requirement during a base year. As we can see, the CHP plant needs to develop 3.96 MW of heat capacity already during the base year: a smaller CHP plant is also chosen because of that.

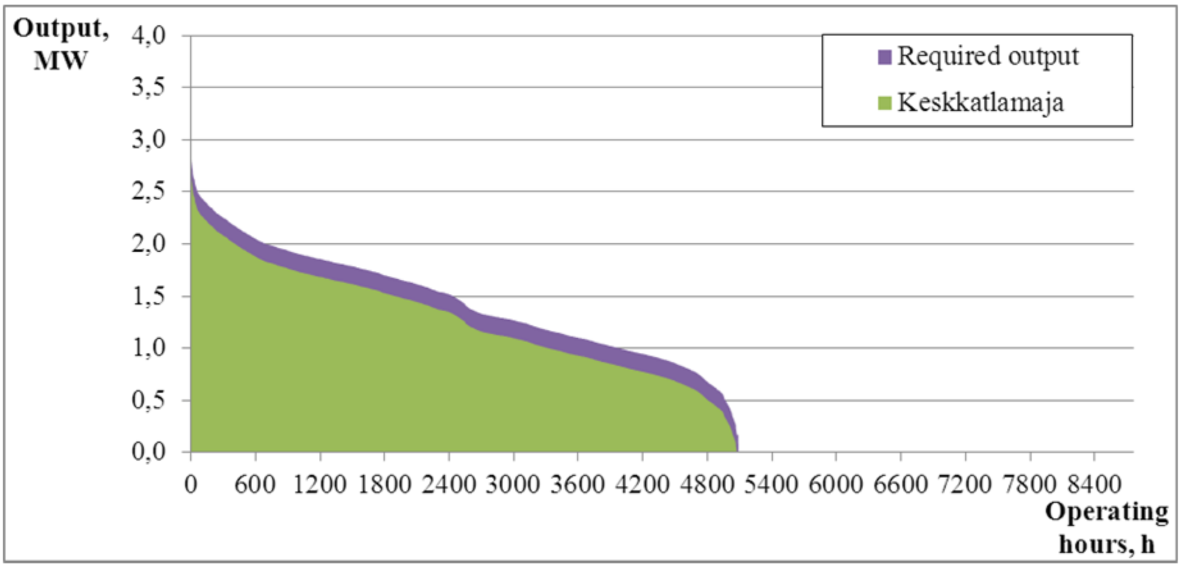

Figure 5.8. Predicted heat load duration diagram of Keskkatlamaja district heating network in 2025

By 2025, the maximum required CHP plant's production capacity indicated on the load diagram has changed to 2.84 MW, due to which the chosen plant can cover the entire heat energy requirement and there is no need to use peak boilers (Table 5.4).

Table 5.4. Source data for scenario IV

Indicator	Unit	Basis	2025
Selling heat energy to end consumers	MW·h/y	13803	9390
incl. residential fund 37%	MW·h/y	5097	2957
local government buildings 29%	MW·h/y	3942	2287
industry and service 34%	MW·h/y	4764	4146
Losses	MW·h/y	1559	1455
Total	MW·h/y	15362	10845
Heating period	h	5496	5088
Number of hours when capacity of CHP plant is insufficient	h	332	0
Quantity of heat energy deficit	MW·h/y	79	0
Produced electricity	MW·h/y	2520	1795
Own consumption of CHP plant	MW·h/y	219	204
Renovating, constructing heating pipeline	m	65	

According to the information presented in Table 5.4, we can say that in the event of consumption volumes predicted for 2025 the boiler does not reach its maximum production capacity, and the production of electricity decreases by 29%. However, this scenario has the smallest start-up investment and is therefore the likeliest in terms of feasibility.

5.6. Comparison of future scenarios

The future scenarios prepared while drafting different load diagrams and modelling heat energy requirements reflect production volumes that the boilers in Elva district heating network should put out during a standardised year. Insofar as the economic analysis was not part of the framework of this thesis, the comparison of future scenarios is conducted based on energy and volume units. Table 5.5 gives and overview of required fuel quantities and production volumes for different scenarios.

Table 5.5. Summary of calculation results of future scenarios

Year	Indicator	Scenario I	Scenario II	Scenario III	Scenario IV
Basis	Required wood fuel quantity, m3/y	29118,6	35893,2	36318,8	32453,7
	Required shale-derived oil quantity, t/y	25,2	5,9	5,9	7,3
	Produced heat energy MW·h/y	15362,4	16768,7	16781,4	15362,4
	Losses in heat network, %	10,2	9,5	9,6	10,2
	Produced electricity MW·h/y	-	3691,1	3900,6	2520,2
2025	Required wood fuel quantity, m3/y	20571,4	25872,6	26036,6	23124,3
	Required shale-derived oil quantity, t/y	17,2	4,4	4,4	0,0
	Produced heat energy MW·h/y	10845,5	12010,6	12023,1	10845,5
	Losses in heat network, %	13,4	12,4	12,5	13,4
	Produced electricity MW·h/y	-	2712,7	2900,0	1795,1

Quantities of wood and fossil fuels presented in the Table were derived with formula

$$V_{hake} = \left(\frac{Q_{katel}}{\eta_{katel}} + \frac{Q_{CHP}}{\eta_{CHP} \cdot \eta_h} \right) \cdot TAK_{hake}^{-1}, \tag{5.1}$$

where V_{hake} is volume woodchips m^{3};

Q_{katel} – heat energy produced with a regular woodchip boiler MW·h;

η_{katel} – efficiency of regular woodchip boiler $(\eta_{katel} = 0{,}8)$;

Q_{CHP} – heat energy produced in the CHP plant MW·h;

η_{CHP} – efficiency of the CHP plant $(\eta_{CHP} = 0{,}98\,[43])$;

η_h – heat efficiency of CHP plant $(\eta_{CHP} = 0{,}805\,[43])$;

TAK_{hake} – lower calorific value of woodchips used in Elva boiler plant MW·h/m^3 $(TAK_{hake} = 0{,}648\ \text{MW·h/m}^3)$.

$$m_{p.õli} = \frac{Q_{õlikatel}}{\eta_{õlikatel} \cdot TAK_{õli}}, \tag{5.2}$$

where $m_{p.õli}$ is quantity of shale oil t;

$Q_{õlikatel}$ – heat energy produced by shale-derived oil boilers MW·h;

$\eta_{õlikatel}$ – efficiency of regular woodchip boiler $(\eta_{õlikatel} = 0,9)$;

$TAK_{õli}$ – Lower calorific value of shale-derived oil MW·h/t $(TAK_{õli} = 10,8$ MW·h/t [21]).

The results of Table 5.5 show that even though the consumption volumes and pipelines losses of scenario I and IV and scenario II and III are equivalent respectively, the quantity of wood fuel used to get the required amount of energy is different for each scenario. Using the CHP plan increases the costs on raw material, even though the efficiency coefficient of the device is nearly 18% higher than that of a regular boiler. The reason for that is the quantity of energy required for producing electricity. When building a CHP plant it is therefore important to make sure that the raw material cost does not exceed the value added from selling electricity.

Although scenarios II and III have the highest potential of producing electricity, the large start-up investment certainly makes the capital investments more unprofitable than resuming routine business and investment activities, and therefore the most sensible option for establishing a CHP plant is scenario IV. In the event of this scenario, the production volume decreases from 153632 MW·h to 10846 MW·h, while producing electricity reduces from the base year's 2520 MW·h level to 1795 MW·h by 2025. The result is 33...35% lower than the electricity production of scenario II and III, while the requirement of wood chips is only 10.6...9.4% smaller. Scenario II and III are thus more profitable considering the volumes of energy sales and ratio of additional wood chip quantity, however the necessity for building heating pipelines and high pressure pumping stations increases the required start-up capital.

According to the calculation results of scenario I, the town of Elva has managed to make its district heating network sustainable with investments, because even in the event of decrease of consumption volumes defined in chapter 5.1, the heat losses in the network will not exceed the 15% imposed by the Estonian Competition Authority. Boilers also operate with a relatively high load even in the event of decreased consumption, and we can therefore presume that a sharp increase of heat energy prices is not anticipated with the regular increase of wood chip prices.

SUMMARY

When planning the development of a district heating network, many regulations and acts that may not necessarily be associated with the heat sector need to be considered in addition to the current situation in the region. Laws, regulations, and development plans that direct people to implement energy conservation methods affect both the consumer and supplier of district heating.

Elva is one of the few local governments in Estonia that has maintained the role of a district heating network owner in a public limited company managing the heating network through sole shares and has managed to renovate nearly all district heating pipelines in addition to boiler plants with the help of various investment activities. The current situation has become possible only through the use of various support mechanisms, as reflected in a circumstance that only 1.3 million euros of the total investment of 2.26 euros have been covered with own funds in economic activity during the last decade. As a result, the district heating price for consumers has been kept relatively low, while increasing the quality and reliability. Elva achieved a situation with renovations where the heat losses from the pipeline remain within 15% of production volume with the predicted volume of decrease in consumption, which is the maximum allowed heat loss from the pipeline in 2017, according to the price model of the Estonian Competition Authority.

When creating future scenarios, it is impossible to steer away from predicting the yearly energy requirement. Predictions can be created by implementing the connection between indoor and ambient air temperatures of a heated building and heat losses. Heating characteristics found when processing consumption data is one indicator of such a connection, enabling adding the consumption volumes of consumers potentially connecting the district heating network, in addition to existing consumers, to the heat requirement calculation. This enables preparing load duration diagrams for production capacities required for a respective region. Source data for future scenarios can be derived by changing the parameters associated with the consumption and production activities in the district heating network as a whole.

The thesis analyses four different future scenarios, three of which include the construction of a CHP plant. Decreasing consumption volume of heat energy (28.4...29.6%) and its effects in a district heating network on already completed renovations and new investment opportunities were at the centre of the scenarios. Comparison of calculation results reveals that Elva district heating networks can be exploited sustainably by continuing routine business and economic activity even when the requirement of heat energy decreases due to the increase of energy efficiency of buildings. Building CHP plants and connecting district heating networks is limited by the capacity of start-up investments and lack of summer consumption.

The most feasible scenario of building a CHP plant is scenario IV, because the required start-up capital is the smallest of the respective future prospects. In the event of this scenario, the production volume decreases from 153632 MW·h to 10846 MW·h, while producing electricity reduces from the base year's 2520 MW·h level to 1795 MW·h by 2025. Scenario II and III are thus more profitable considering the quantities of energy sales and ratio of additional wood chip quantity, but the necessity for building heating pipelines increases the required start-up capital.

Investments already made, low heat losses in district heating pipelines, flexibility of the system in the event of a decrease in energy consumption, and price of raw material contribute to the continuing of routine business and economic activity. According to EL energy tendencies, building a CHP plant becomes both energetically and economically more profitable by the time the currently operational boilers have completely been depreciated.

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ANNEXES

Annex A. Elva Soojus OÜ business and economic activity data in different years

Table A.1. Quantity of heat energy produced and sold to consumers in the Kirde boiler plant's network

Month	Heat energy output in boiler plant, MW·h			Measured heat energy consumption, MW·h		
	2008	2009	2010	2008	2009	2010
I	558	631	802	503	557	700
II	543	550	642	481	488	541
III	460	471	491	415	408	413
IV	287	338	254	259	279	208
V	61	4	78	54	3	66
VI	0	0	0	0	0	0
VII	0	0	0	0	0	0
VIII	0	0	0	0	0	0
IX	207	68	96	172	53	60
X	299	444	364	247	356	294
XI	453	408	463	391	339	387
XII	553	564	624	487	490	546
Total	3421	3478	3814	3009	2973	3215

Table A.2. Quantity of heat energy produced and sold to consumers in the Keskkatlamaja network

Month	Heat energy output in boiler plant, MW·h			Measured heat energy consumption, MW·h		
	2008	2009	2010	2008	2009	2010
I	1169	1367	1996	1002	1220	1632
II	1072	1152	1545	908	1019	1264
III	977	1021	1152	832	864	931
IV	604	624	578	464	492	465
V	143	100	175	108	60	124
VI	0	0	0	0	0	0
VII	0	0	0	0	0	0
VIII	0	0	0	0	0	0
IX	467	154	176	348	112	126
X	645	906	706	505	741	555
XI	973	897	952	818	730	783
XII	1094	1320	1415	931	1079	1175
Total	7144	7541	8695	5916	6317	7055

Table A.3. Quantity of heat energy produced and sold to consumers in the Haigla boiler plant's network

Month	Heat energy output in boiler plant, MW·h		Measured heat energy consumption, MW·h	
	2009	2010	2009	2010
I	175	231	154	211
II	159	191	136	185
III	142	157	115	140
IV	95	90	84	87
V	63	71	52	54
VI	19	50	11	41
VII	9	20	9	12
VIII	14	24	12	15
IX	40	85	40	54
X	123	138	112	102
XI	129	144	113	130
XII	184	185	148	174
Total	1152	1386	986	1205

Table A.4. Price of heat energy in 2008...2010

Year	Price of heat energy for population, €/(MW·h)	Price of heat energy for companies, €/(MW·h)
2008	44,10	47,81
2009	48,57	52,66
2010	48,57	52,66

Table A.5. Lengths of heating pipelines in Elva district heating networks at the beginning of 2012

District heating network	Length of two-pipe pipeline, m
Keskkatlamaja	3432
Kirde boiler plant	1358
Haigla boiler plant	140
Total	4930

Annex B. New consumers in Elva district heating network 2000...2011

Table B.1. Consumers who joined Elva district heating network in 2000...2011

	Joined consumer	Year of joining	Max. heating capacity, kW	Consumption in 2011, MW·h	Building's volume, m^3	Address	Application	Comment
1.	Kinnisvara valdus AS	2001	-	100	3536	Kesk 7, Elva	store	
2.	Shopping Centre Elva TÜ	2003	-	152	-	Kesk 1	store	
3.	Dentist	2003	50	20	-	Kirde 4a	medical institution	
4.	Ludvig Svensson	2005	85	94	2956	Kesk 12	store	
5.	Social house	2005	-	122	-	Pikk 26	apartment building	
6.	Apartment block	2006	75	109	-	Kirde 1	apartment building	
7.	Apartment block	2007	-	19	-	Jaani 5	apartment building	
8.	Camping centre	2007	-	64	-	Pargi 2	public building	
9.	Shopping Centre Elva TÜ	2007	-	218	-	Kirde 3	store	
10.	Production facility	2007	105	128	4014	Kirde 2a	office building	
11.	SA Elva Haigla	2008	-	734	10861	Supelranna 21	hospital	
12.	LPK Õnneseen	2008	-	233	4650	Kaja 4	kindergarten	
13.	Day centre	2008	-	37	ca 2000	Supelranna 21/23	day centre	
14.	Apartment block	2009	73	19	2540	Ujula 19	apartment building	
15.	Residential building	2010	25	10	-	Soo 2	residential building	
16.	Enics	2011	1000	1094	ca 54000	Valga mnt 7a	production facility	as of 01.04.2011
17.	Maxima	2011	250	10	-	Valga mnt 5a	store	as of 01.10.2011
18.	Residential building	2011	25	4	-	Puiestee 9	residential building	as of 01.11.2011

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Annex C. Results of data processing

Table C.1. Heating characteristics of central boiler plant in 2008...2010

Month	2008			2009			2010			Basis (see NOTE 1)
	Measured consumption, MW·h	Number of degree days, °C·h	q_{ekspl}, MW/°C	Measured consumption, MW·h	Number of degree days, °C·h	q_{ekspl}, MW/°C	Measured consumption, MW·h	Number of degree days, °C·h	q_{ekspl}, MW/°C	q_{ekspl}, MW/°C
I	1002	593	0,07040	1220	654	0,0778	1632	982	0,0692	0,0960
II	908	497	0,07612	1019	635	0,0669	1264	714	0,0738	0,0965
III	832	537	0,06458	864	589	0,0612	931	597	0,0649	0,0890
IV	464	318	0,06072	492	353	0,0580	465	348	0,0556	0,0830
V	108	225	0,06651	60	193	0,0587	124	169	0,0582	0,0846
VI	0	103	0	0	122	0	0	96	0	0
VII	0	48	0	0	40	0	0	1	0	0
VIII	0	71	0	0	71	0	0	51	0	0
IX	348	238	0,07415	112	146	0,067	126	202	0,0567	0,0880
X	505	294	0,07161	741	426	0,073	555	419	0,0552	0,0896
XI	818	466	0,07320	730	463	0,066	783	525	0,0622	0,0901
XII	931	584	0,06645	1079	708	0,064	1175	806	0,0608	0,0883
Total	5916	3973	-	6317	4399	-	7055	4912	-	-
NOTE 1 – Maximum and minimum values were excluded from 2008...2010 calculation results of heating characteristics to find the data in the "Basis" column										

Table C.2. Heating characteristics of Kirde boiler plant in 2008...2010

Month	2008			2009			2010			Basis (see NOTE 1)
	Measured consumption, MW·h	Number of degree days, °C·h	$q_{ekspl,}$, MW/°C	Measured consumption, MW·h	Number of degree days, °C·h	$q_{ekspl,}$, MW/°C	Measured consumption, MW·h	Number of degree days, °C·h	$q_{ekspl,}$, MW/°C	$q_{ekspl,}$, MW/°C
I	503	593	0,0353	557	654	0,0355	700	982	0,0297	0,0327
II	481	497	0,0403	488	635	0,0320	541	714	0,0316	0,0320
III	415	537	0,0322	408	589	0,0289	413	597	0,0288	0,0290
IV	259	318	0,0339	279	353	0,0329	208	348	0,0249	0,0291
V	54	225	0,0333	3	193	0,0029	66	169	0,0310	0,0323
VI	0	103	0	0	122	0	0	96	0	0
VII	0	48	0	0	40	0	0	1	0	0
VIII	0	71	0	0	71	0	0	51	0	0
IX	172	238	0,0366	53	146	0,0318	60	202	0,0270	0,0296
X	247	294	0,0350	356	426	0,0349	294	419	0,0292	0,0322
XI	391	466	0,0350	339	463	0,0305	387	525	0,0307	0,0308
XII	487	584	0,0348	490	708	0,0289	546	806	0,0282	0,0287
Total	3009	3973	-	2973	4399	-	3215	4912	-	-
NOTE 1 –	Maximum and minimum values were excluded from 2008...2010 calculation results of heating characteristics, exc. from data regarding May where processing consumption data for 2009 gave an unrealistic result with the chosen duration of heating period.									

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Table C.3. Heating characteristics of Haigla boiler plant in 2009...2010

Month	2009			2010			Basis (see NOTE 2)
	Measured heat energy consumption for heating, MW·h (see NOTE 1)	Number of degree days, °C·h	q_{ekspl}, MW/°C	Measured heat energy consumption for heating, MW·h (see NOTE 1)	Number of degree days, °C·h	q_{ekspl}, MW/°C	q_{ekspl}, MW/°C
I	142	654	0,0091	199	982	0,0084	0,0088
II	124	635	0,0081	173	714	0,0101	0,0091
III	103	589	0,0073	128	597	0,0089	0,0081
IV	72	353	0,0085	75	348	0,0090	0,0087
V	40	193	0,0087	42	169	0,0104	0,0095
VI	0	122	0	0	96	0	0
VII	0	40	0	0	1	0	0
VIII	0	71	0	0	51	0	0
IX	28	146	0,0080	42	202	0,0087	0,0083
X	100	426	0,0098	90	419	0,0090	0,0094
XI	101	463	0,0091	118	525	0,0094	0,0092
XII	136	708	0,0080	162	806	0,0084	0,0082
Total	847	4399	-	1030	4912	-	-

NOTE 1 – Derived by subtracting the requirement of hot water from total consumption

NOTE 2 – Data was derived by averaging 2009 and 2010 calculation results

Table C.4. Heat losses in Elva heating network's district heating pipelines

Month	Kirde boiler plant				Central boiler plant	Haigla boiler plant
	2008	2009	2010	Basis	Basis	Basis
	Dissipated power, MW (see NOTE 1)	Dissipated power, MW (see NOTE 1)	Dissipated power, MW (see NOTE 1)	Dissipated power, MW (see NOTE 2)	Dissipated power, MW (see NOTE 3)	Dissipated power, MW (see NOTE 4)
I	0,0739	0,0995	0,1371	0,0867	0,1710	0,0269
II	0,0891	0,0833	0,1358	0,0862	0,1710	0,0081
III	0,0605	0,0847	0,1048	0,0726	0,1710	0,0228
IV	0,0376	0,0793	0,0618	0,0497	0,1710	0,0040
V	0,0653	0,0867	0,1099	0,0760	0,1710	0,0228
VI	0	0	0	0	0	0,012097
VII	0	0	0	0	0	0,010753
VIII	0	0	0	0	0	0,012097
IX	0,0806	0,1035	0,1004	0,0905	0,1710	0,0417
X	0,0699	0,1183	0,0941	0,0820	0,1710	0,0484
XI	0,0833	0,0927	0,1022	0,0880	0,1710	0,0188
XII	0,0887	0,0995	0,1048	0,0941	0,1710	0,0148

NOTE 1 – Dissipated power of May and September has been derived as the average heat loss capacities of months preceding and succeeding these

NOTE 2 – Maximum and minimum values were excluded from 2008...2010 calculation results to achieve the results

NOTE 3 – Based on an assessment that there is a yearly loss of 959.78 MW·h heat energy in newly renovated heat pipeline

NOTE 4 – Computational dissipated power of 2010 were used

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Table C.5. Computational heating characteristics of district heating pipelines to be built when implementing future scenarios II and III

Marker	External diameter of heat pipe, m	Scenario II				Scenario III			
		Length of pipeline, m	Length of pipeline, m	External surface area of the heat pipe, m^2	q_{trass}, MW/ºC	Length of pipeline, m	Length of pipeline, m	External surface area of the heat pipe, m^2	q_{trass}, MW/ºC
DN 200	0,355	1320	2640	261,31	0,002874	1820	3640	360,29	0,003963
DN 150	0,28	110	220	13,55	0,000149	220	440	27,09	0,000149
DN 50	0,14	223	446	6,87	0,000076	223	446	6,87	0,000076
Total	-	1653	3306	281,72	0,003099	-	4526	394,25	0,004188

Table C.6. Modelled data regarding months partially in the heating period in Elva heating district

Month	2008	2009	2010	Basis
	h	h	h	h
V	240	144	216	168
IX	480	240	288	240
Total	720	384	504	408

Table C.7. Heating characteristics of potential and of consumers already connected tot the district heating network

Consumer	Yearly heat energy requirement, MW·h	Maximum consumption capacity, MW	$q_{lis\,a}$, MW/°C
Valga mnt 7a	2434,09	1	0,02561
Valga mnt 5a	39,96	0,01611	0,00042
Soo 2	10,85	0,00437	0,00011
Puiestee 9	16,90	0,01152	0,00018
Kalda 11	68,49	0,02814	0,00072
Pikk 26	132,83	0,05457	0,00140
Pikk 19a	1050,00	0,39935	0,01105

Table C.8. Standardisation results of 2010 monthly average temperatures

Month	Monthly average temperature, °C	Number of degree days, °C·h	Number of degree days in a standard year, °C·h	Reduced monthly average temperature, °C
I	-13,69	23576	17112	-9,94
II	-7,50	17133	16032	-7,01
III	-1,27	14339	14352	-1,27
IV	6,39	8358	9336	7,14
V	12,82	4063	5064	15,97
VI	14,97	2314	2472	-
VII	22,56	29	1248	-
VIII	18,45	1229	1968	-
IX	11,26	4852	5280	12,25
X	4,49	10053	9216	4,11
XI	0,51	12594	12792	0,52
XII	-7,99	19338	16200	-6,70
Total	-	117878	111072	-

Annex D. Extract of the information sheet on pipes manufactured by Wehoterm.

Wehotherm ® KWH TECH

1-torusüsteem

02.02

2.1.1 ISOLATSIOONIKLASS 2

ISOLATSIOONIKLASS 2							
DN	d · s [mm]	D · s [mm]	L (m)	Kaal (kg/m)	Isolatsiooni paksus	Veemahutavus (l/m)	Toru K-väärtus (W/m°C)
20	26,9 · 2,3	110 · 3,0	6	3,1	39	0,30	0,134
25	33,7 · 2,6	110 · 3,0	6,12	3,7	35	0,64	0,161
32	42,4 · 2,6	125 · 3,0	12	4,6	38	1,09	0,175
40	48,3 · 2,6	125 · 3,0	12	4,9	35	1,46	0,201
50	60,3 · 2,9	140 · 3,0	12	6,4	37	2,33	0,227
65	76,1 · 2,9	160 · 3,0	12	7,9	39	3,88	0,257
80	88,9 · 3,2	180 · 3,0	12	9,9	43	5,35	0,270
100	114,3 · 3,6	225 · 3,5	12,16	14,6	52	9,01	0,281
125	139,7 · 3,6	250 · 3,9	12,16	17,7	51	13,79	0,329
150	168,3 · 4,0	280 · 4,4	12,16	23,1	51	20,18	0,380
200	219,1 · 4,5	355 · 5,6	12,16	34,7	62	34,67	0,402

Markeering: WTS (Isolatsiooniklass) P (DN-L)
Näide: WTS 2 P 150-16

Eritellimuse korras valmistatakse ka muude mõõtmetega torusid.
Arvutustes kasutatakse toru seina soojusjuhtivustegurit 0,029 W/m°C

Figure D.1. Parameters of 1-pipe system pre-insulated pipes in the Wehoterm product range

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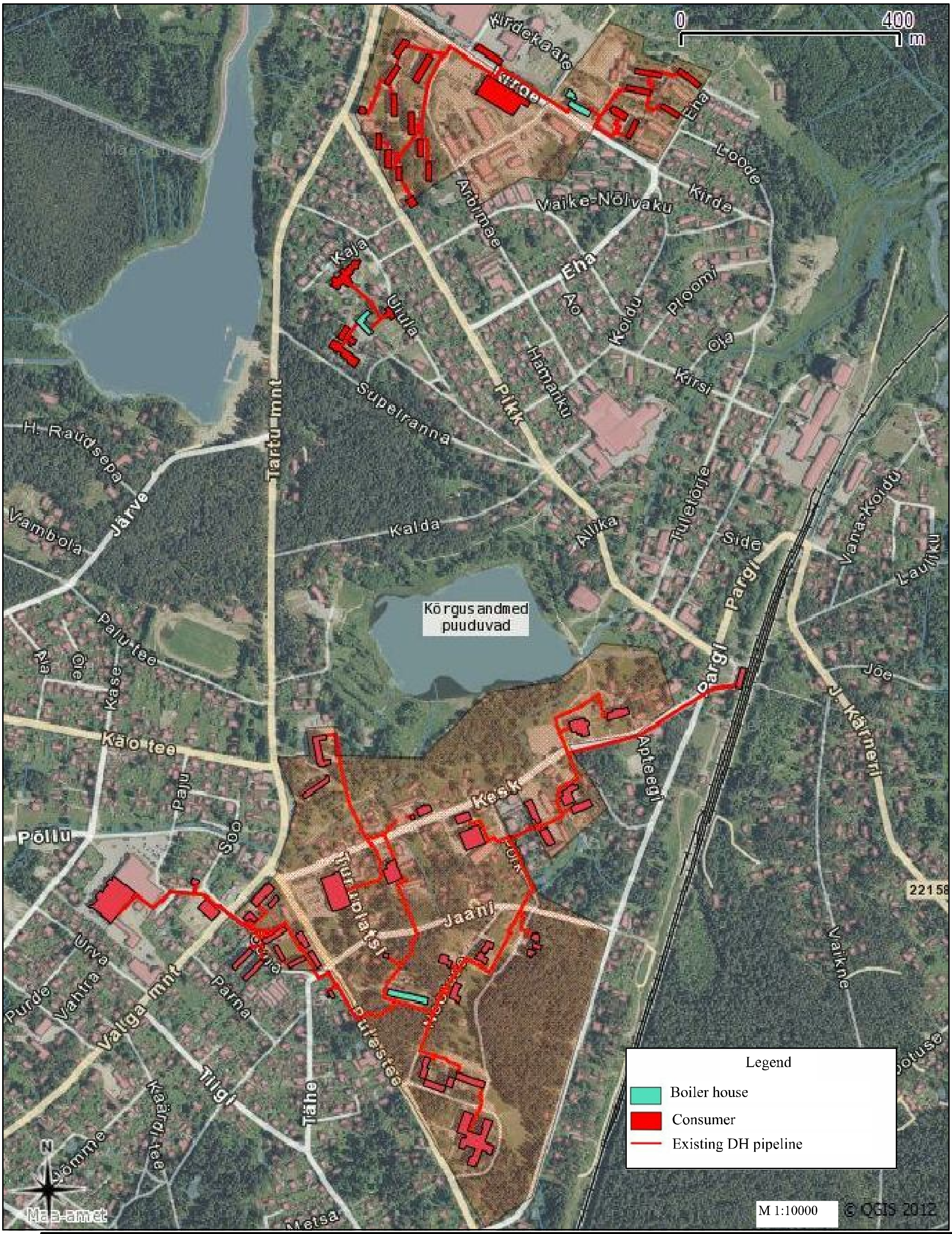
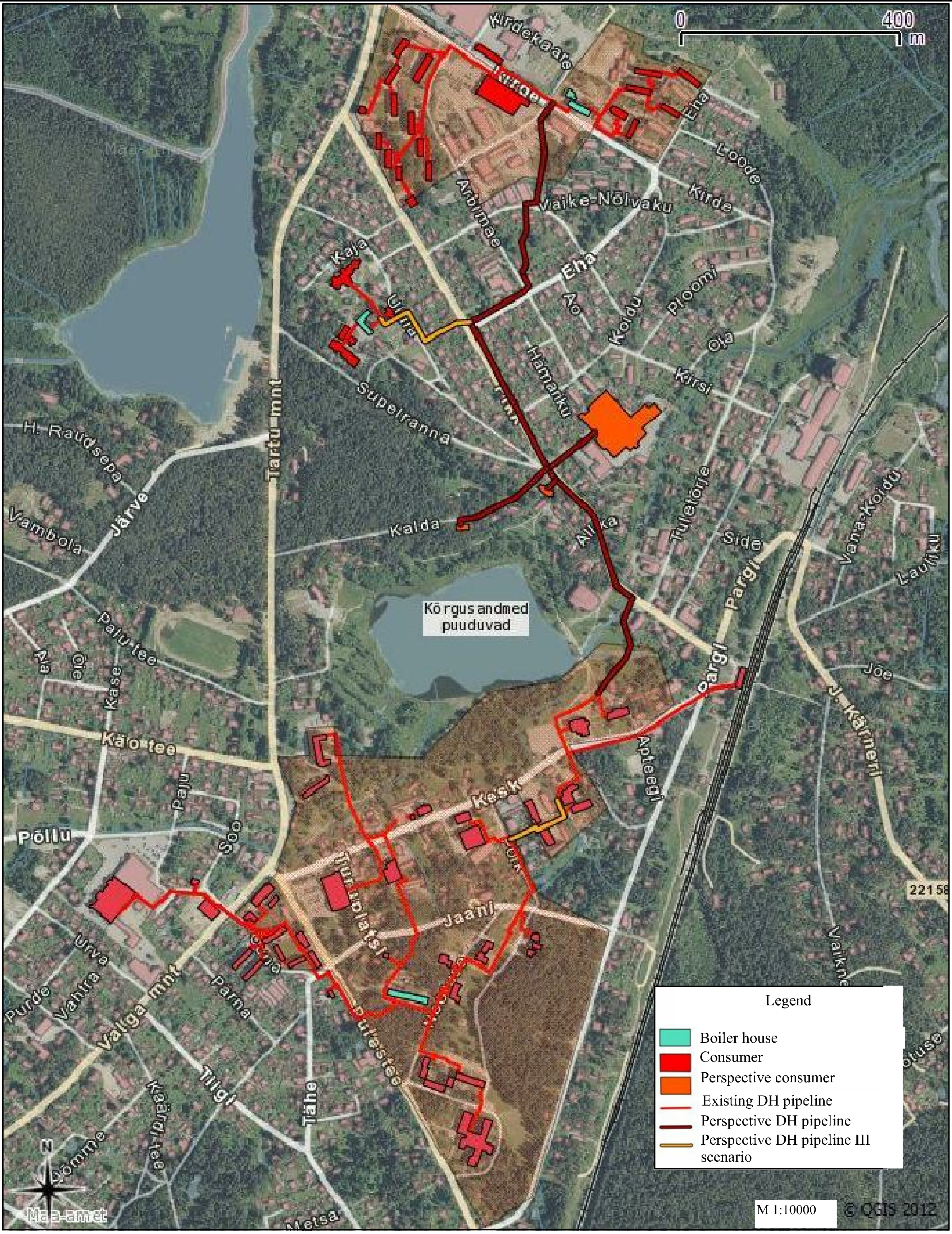
Annex E. Indicative location of district heating pipelines



Tellija		Objekt, seade Elva linn	
Teostas	Jaanus Uiga	Nimetus Elva linna kaugküttetrasside indikatiivne paiknemine	
Kontr.	Alo Allik		
Kinnitas			
EMÜ TE-EK		Leht 1/2	Tähis EK 12/090513 E S



Tellija		Objekt, seade
		Elva linn

Teostas	Jaanus Uiga	Nimetus
Kontr.	Alo Allik	Kaugküttetrasside indikatiivne paiknemine II ja III stsenaariumi korral
Kinnitas		

EMÜ TE-EK	Leht	Tähis
	2	EK 12/090513 E S

Annex F. Demographic data presented by Elva City Government.

Table F.1. Changes in Elva population in 1995...2012

MUUTUSED ELVA ELANIKE ARVUS

Aasta	Aasta algul elanikke	Sündis	Suri
1995	6214		
1996	6222	64	81
1997	6234	58	95
1998	6246	55	62
1999	6215	57	74
2000	6199	44	66
2001	6208	42	59
2002	6287	43	91
2003	6283	55	97
2004	6289	54	75
2005	6280	49	76
2006	6297	47	80
2007	6253	62	88
2008	6258	68	84
2009	6209	81	81
2010	6159	68	79
2011	6090		
2012	5992		

Annex G. Maximal reference prices for end consumers coordinated by the Estonian Competition Authority

Konkurentsiametiga kooskõlastatud soojuse piirhinnad lõpptarbijatele (käibemaksuta) aastatel 2009 -2011

Soojusettevõtja	otsuse kp	otsuse nr	kooskõlas-tatud piirhind €/MWh
AS Eraküte			
Haapsalu võrgupiirkond	6/30/2008	026/08S	**49.70**
	1/30/2009	7.1-3/09-0008	**42.08**
	2/20/2009	7.1-3/09-0016	**41.43**
	9/21/2009	7.1-3/09-0061	**41.24**
	1/28/2010	7.1-3/10-004	**42.70**
	5/21/2010	7.1-3/10-032	**41.71**
	9/23/2010	7.1-3/10-054	**47.38**
	3/18/2011	7.1-3/11-024	**51.22**
	8/30/2011	7.1-3/11-056	**57.21**
Jõgeva võrgupiirkond	10/31/2008	077/08S	**61.88**
	2/18/2009	7.1-3/09-0014	**55.28**
	4/1/2009	7.1-3/09-0027	**49.74**
	12/1/2009	7.1-3/09-0079	**49.84**
	12/30/2009	7.1-3/09-0084	**52.12**
	3/1/2010	7.1-3/10-022	**54.94**
	9/2/2010	7.1-3/10-050	**59.00**
	1/20/2011	7.1-3/11-012	**55.09**
	8/1/2011	7.1-3/11-043	**63.41**
	9/30/2011	7.1-3/11-071	**66.61**
Keila võrgupiirkond	6/30/2008	026/08S	**42.91**
	2/20/2009	7.1-3/09-0016	**42.24**
	10/16/2009	7.1-3/09-0066	**39.22**
	3/9/2010	7.1-3/10-023	**40.48**
	5/21/2010	7.1-3/10-033	**39.87**
	9/23/2010	7.1-3/10-054	**44.82**
	1/31/2011	7.1-3/11-019	**43.84**
	3/18/2011	7.1-3/11-024	**44.11**
	8/30/2011	7.1-3/11-056	**48.31**
Kärdla võrgupiirkond	6/30/2008	026/08S	**47.50**
	9/2/2010	7.1-3/10-050	**52.96**
	3/18/2011	7.1-3/11-024	**53.28**
	8/30/2011	7.1-3/11-056	**55.12**
Tartu võrgupiirkond	6/30/2008	025/08S	**60.54**
	2/18/2009	7.1-3/09-0014	**52.13**
	4/1/2009	7.1-3/09-0027	**48.59**
	9/4/2009	7.1-3/09-0057	**47.62**
	12/30/2009	7.1-3/09-0084	**50.35**
	3/1/2010	7.1-3/10-022	**52.27**
	5/18/2010	7.1-3/10-031	**46.11**
	9/23/2010	7.1-3/10-054	**49.12**
	3/18/2011	7.1-3/11-024	**48.95**
	4/29/2011	7.1-3/11-029	**49.15**
	8/1/2011	7.1-3/11-043	**50.34**
	8/30/2011	7.1-3/11-056	**51.40**
	10/28/2011	7.1-3/11-080	**51.72**
Tiskre-Hansu võrgupiirkond	12/5/2008	087/08S	**63.06**
	2/18/2009	7.1-3/09-0014	**59.94**
	4/1/2009	7.1-3/09-0027	**55.04**

	9/28/2009	7.1-3/09-0063	**55.92**
	12/30/2009	7.1-3/09-0084	**59.17**
	3/1/2010	7.1-3/10-022	**61.65**
	9/2/2010	7.1-3/10-050	**65.17**
	10/22/2010	7.1-3/10-055	**65.17**
	4/29/2011	7.1-3/11-029	**67.56**
	8/1/2011	7.1-3/11-043	**70.77**
	9/30/2011	7.1-3/11-071	**70.33**
Valga võrgupiirkond	7/23/2008	039/08S	**46.75**
	1/30/2009	7.1-3/09-0008	**42.53**
	11/25/2009	7.1-3/09-0076	**39.87**
	1/28/2010	7.1-3/10-005	**40.76**
	5/21/2010	7.1-3/10-034	**40.84**
	9/23/2010	7.1-3/10-054	**45.82**
	1/31/2011	7.1-2/11-019	**44.69**
	3/18/2011	7.1-3/11-024	**44.93**
	4/29/2011	7.1-3/11-029	**47.89**
	8/30/2011	7.1-3/11-056	**49.53**
AS Rapla Küte	10/1/2008	061/08S	**72.95**
	2/18/2009	7.1-3/09-0015	**60.64**
	4/1/2009	7.1-3/09-0027	**54.97**
	12/30/2009	7.1-3/09-0084	**57.17**
	3/1/2010	7.1-2/10-020	**60.74**
	9/2/2010	7.1-2/10-050	**64.81**
	1/20/2011	7.1-3/11-012	**62.58**
	4/21/2011	7.1-3/11-026	**65.86**
	8/1/2011	7.1-3/11-042	**69.57**
	9/29/2011	7.1-3/11-068	**72.85**
AS Esro			
Viljandi ja Jämejala võrgupiirkond	11/20/2008	080/08S	**61.05**
	1/23/2009	7.1-3/09-003	**53.54**
	3/24/2009	7.1-3/09-0022	**52.68**
	3/25/2009	7.1-3/09-0039	**48.29**
	11/2/2009	7.1-3/09-0070	**49.78**
	12/22/2009	7.1-3/09-0082	**48.32**
	2/12/2010	7.1-3/10-014	**50.29**
	6/11/2010	7.1-3/10-039	**52.22**
	12/27/2010	7.1-3/10-071	**49.72**
	4/28/2011	7.1-3/11-028	**50.72**
	5/20/2011	7.1-3/11-032	**52.61**
	8/15/2011	7.1-3/11-050	**55.04**
Fortum Termest AS			
Väike-Maarja võrgupiirkond	10/30/2008	074/08S	**68.20**
	5/29/2009	7.1-3/09-0038	**48.41**
	10/7/2011	7.1-3/11-073	**64.74**
Narva-Jõesuu võrgupiirkond	5/28/2010	7.1-2/10-035	**65.91**
	9/23/2011	7.1-3/11-064	**70.72**
Haabneeme võrgupiirkond	5/30/2008	016/08S	**64.71**
	8/31/2009	7.1-3/09-0049	**62.20**
	11/29/2011	7.1-3/11-095	**66.23**
Laagri võrgupiirkond	1/25/2008	003/08S	**49.21**
	5/29/2009	7.1-3/09-0037	**49.91**
	9/13/2011	7.1-3/11-061	**66.88**
Loo võrgupiirkond	12/23/2008	088/08S	**70.69**
	2/11/2009	7.1-3/09-0012	**67.39**
	5/29/2009	7.1-3/09-0038	**57.55**
	11/9/2011	7.1-3/11-087	**76.48**
Kostivere võrgupiirkond	12/23/2008	088/08S	**72.10**

	7/2/2008	030/08S	**76.53**
	2/11/2009	7.1-3/09-0012	**61.62**
	5/29/2009	7.1-3/09-0038	**52.50**
	11/28/2011	7.1-3/11-094	**67.49**
Põltsamaa võrgupiirkond	8/28/2008	050/08S	**55.04**
	1/27/2009	7.1-3/09-0006	**51.97**
	7/16/2009	7.1-3/09-0044	**48.95**
	3/23/2010	7.1-3/10-024	**49.23**
	6/30/2010	7.1-3/10-043	**51.03**
	11/5/2010	7.1-3/10-060	**52.00**
	12/1/2010	7.1-3/10-068	**53.53**
Saue võrgupiirkond	10/31/2008	078/08S	**69.64**
	5/29/2009	7.1-3/09-0038	**50.26**
	6/11/2010	7.1-3/10-0039	**65.11**
	9/23/2011	7.1-3/11-064	**68.11**
Sõmeru võrgupiirkond	7/2/2008	030/08S	**73.89**
	5/29/2009	7.1-3/09-0037	**51.54**
	11/28/2011	7.1-3/11-093	**75.14**
Tõrva võrgupiirkond	10/24/2008	068/08S	**50.71**
	7/27/2011	7.1-3/11-039	**55.48**
Viiratsi võrgupiirkond	7/2/2008	030/08S	**75.54**
	5/29/2009	7.1-3/09-0037	**57.82**
	7/15/2010	7.1-3/10-044	**69.04**
	12/6/2010	7.1-3/10-070	**65.31**
	9/30/2011	7.1-3/11-066	**68.19**
Viimsi võrgupiirkond	10/28/2008	071/08S	**71.69**
	5/29/2009	7.1-3/09-0038	**51.63**
	8/31/2009	7.1-3/09-0053	**52.26**
	11/22/2011	7.1-3/11-091	**68.01**
Kesklinna-Pirita võrgupiirkond	10/30/2008	074/08S	**64.41**
	5/29/2009	7.1-3/09-0038	**45.82**
	9/16/2011	7.1-3/11-063	**60.80**
Kunda võrgupiirkond	7/2/2007	030/08S	**72.67**
	5/29/2009	7.1-3/09-0037	**55.62**
	10/21/2011	7.1-3/11-077	**74.73**
Nõmme Linnaosa võrgupiirkond	10/31/2008	078/08S	**58.86**
	5/29/2009	7.1-3/09-0038	**43.29**
	10/28/2010	7.1-3/10-057	**51.21**
	10/12/2011	7.1-3/11-076	**61.62**
Põhja-Tallinna Linnaosa võrgupiirkond	12/30/2008	074/08S	**64.46**
	5/29/2009	7.1-3/09-0038	**44.85**
	9/27/2011	7.1-3/11-065	**61.66**
Püssi võrgupiirkond	8/7/2008	044/08S	**65.16**
	5/29/2009	7.1-3/09-0037	**50.51**
Pärnu võrgupiirkond	7/18/2008	037/08S	**37.86**
alates 22.06.2011 Fortum Eesti AS	12/30/2009	7.1-3/09-0083	**39.15**
	6/30/2010	7.1-3/10-042	**41.49**
Aluvere võrgupiirkond	10/30/2008	075/08S	**73.00**
	5/29/2009	7.1-309-0038	**51.90**
Adavere võrgupiirkond	11/24/2008	082/08S	**53.14**
	1/27/2009	7.1-3/09-0005	**51.35**
	1/28/2010	7.1-3/10-006	**49.60**
	11/1/2010	7.1-3/10-058	**50.99**
	12/1/2010	7.1-3/10-067	**51.26**
Vändra võrgupiirkond	8/7/2008	044/08S	**67.44**
	5/29/2009	7.1-3/09-0037	**60.45**
AS Kuressaare Soojus	10/1/2008	059/08S	**45.00**
	1/23/2009	7.1-3/09-0002	**42.30**

	3/24/2009	7.1-3/09-0021	**40.16**
	8/25/2009	7.1-3/09-0046	**38.66**
	11/30/2009	7.1-3/09-0077	**39.27**
	11/8/2010	7.1-3/10-061	**42.15**
	8/25/2011	7.1-3/11-054	**46.46**
AS Narva Soojusvõrk	11/25/2008	084/08S	**30.21**
	4/30/2009	7.1-3/09-0032	**28.46**
	8/31/2009	7.1-3/09-0054	**27.48**
Sillamäe SEJ	9/30/2008	056/08S	**36.33**
	5/25/2009	7.1-3/09-0035	**34.02**
	11/19/2009	7.1-3/09-0074	**34.90**
	2/12/2010	7.1-3/10-015	**35.93**
	5/11/2010	7.1-3/10-029	**36.71**
	8/19/2010	7.1-3/10-047	**37.31**
	11/30/2011	7.1-3/11-098	**38.58**
AS Tallinna Küte	7/3/2008	031/08S	**65.42**
	1/26/2009	7.1-3/09-0004	**59.52**
	6/30/2009	7.1-3/09-0043	**47.34**
	8/3/2009	7.1-3/09-0047	**48.95**
	8/31/2009	7.1-3/09-0055	**50.86**
	11/30/2009	7.1-3/09-0078	**50.34**
	2/1/2010	7.1-3/09-008	**53.17**
	3/1/2010	7.1-3/10-021	**54.41**
	9/1/2010	7.1-3/10-049	**56.90**
	9/2/2011	7.1-3/11-058	**57.51**
	9/29/2011	7.1-3/11-067	**59.73**
	11/30/2011	7.1-3/11-099	**61.94**
AS Võru Soojus	10/9/2008	062/08S	**47.57**
	2/27/2009	7.1-3/09-0017	**46.40**
	11/9/2009	7.1-3/09-0072	**43.47**
	9/17/2010	7.1-3/10-053	**45.13**
	10/27/2010	7.1-3/10-056	**45.87**
	9/16/2011	7.1-3/11-062	**50.03**
	12/1/2011	7.1-3/11-100	**51.19**
WTC Tallinn Kinnisvara AS	10/30/2008	073/08S	**60.87**
	2/26/2010	7.1-3/10-018	**51.29**
	4/1/2011	7.1-3/11-025	**52.67**
VKG Soojus AS			
(endine AS Kohtla-Järve Soojus)	5/28/2008	014/08S	**30.75**
	9/14/2009	7.1-3/09-0058	**33.00**
	2/25/2011	7.1-3/11-022	**39.46**
	9/6/2011	7.1-3/11-059	**43.69**
AS Tartu Keskkatlamaja	10/28/2008	070/08S	**47.60**
VKG Energia OÜ	12/1/2008	086/08S	**34.60**
AS Rakvere Soojus			
Näpi võrgupiirkond	4/20/2011	7.1-3/11-027	**59.63**
	8/8/2011	7.1-3/11-048	**67.53**
Rakvere võrgupiirkond	5/4/2011	7.1-3/11-030	**60.18**
	8/8/2011	7.1-3/11-047	**66.19**
Avoterm OÜ			
Abja-Paluoja võrgupiirkond	1/7/2011	7.1-3/11-002	**64.30**
	7/29/2011	7.1-3/11-040	**74.10**
	8/31/2011	7.1-3/11-057	**75.77**
	12/8/2011	7.1-3/11-103	**80.16**
Rõngu võrgupiirkond	1/10/2011	7.1-3/11-003	**62.33**
	7/29/2011	7.1-3/11-040	**71.69**

	8/31/2011	7.1-3/11-057	**73.28**
	12/8/2011	7.1-3/11-103	**77.45**
Oisu võrgupiirkond	1/10/2011	7.1-3/11-004	**64.04**
	7/29/2011	7.1-3/11-040	**73.46**
	8/31/2011	7.1-3/11-057	**75.07**
	12/8/2011	7.1-3/11-103	**79.24**
Tarbja võrgupiirkond	1/10/2011	7.1-3/11-005	**60.95**
	7/29/2011	7.1-3/11-040	**71.21**
	8/31/2011	7.1-3/11-057	**72.85**
	12/8/2011	7.1-3/11-103	**74.38**
Turba võrgupiirkond	1/11/2011	7.1-3/11-006	**64.86**
	7/29/2011	7.1-3/11-040	**74.52**
	8/31/2011	7.1-3/11-057	**76.16**
	12/8/2011	7.1-3/11-103	**77.66**
Keila-Joa võrgupiirkond	1/12/2011	7.1-3/11-007	**64.79**
	7/29/2011	7.1-3/11-040	**74.71**
	8/31/2011	7.1-3/11-057	**76.39**
	12/8/2011	7.1-3/11-103	**77.94**
Laekvere võrgupiirkond	1/12/2011	7.1-3/11-008	**53.75**
	7/29/2011	7.1-3/11-040	**62.33**
	8/31/2011	7.1-3/11-057	**63.79**
	12/8/2011	7.1-3/11-103	**65.14**
Märjamaa võrgupiirkond	1/13/2001	7.1-3/11-009	**65.20**
	7/29/2011	7.1-3/11-040	**75.19**
	8/31/2011	7.1-3/11-057	**76.88**
	12/8/2011	7.1-3/11-103	**78.45**
Päinurme võrgupiirkond	1/14/2011	7.1-3/11-010	**67.10**
	7/29/2011	7.1-3/11-040	**76.84**
	8/31/2011	7.1-3/11-057	**78.48**
	12/8/2011	7.1-3/11-103	**80.00**
Kaerepere võrgupiirkond	1/14/2011	7.1-2/11-011	**67.38**
	7/29/2011	7.1-3/11-040	**77.61**
	8/31/2011	7.1-3/11-057	**79.35**
	12/8/2011	7.1-3/11-103	**80.96**
Järva-Jaani võrgupiirkond	1/24/2011	7.1-3/11-014	**57.38**
	7/29/2011	7.1-3/11-040	**66.85**
	8/31/2011	7.1-3/11-057	**68.48**
	12/8/2011	7.1-3/11-103	**69.98**
Klooga võrgupiirkond	1/21/2011	7.1-2/11-013	**62.58**
	7/29/2011	7.1-3/11-040	**71.96**
	8/31/2011	7.1-3/11-057	**73.53**
	12/8/2011	7.1-3/11-103	**74.99**
Türi-Alliku võrgupiirkond	1/26/2011	7.1-3/11-018	**62.16**
	7/29/2011	7.1-3/11-040	**71.95**
	8/31/2011	7.1-3/11-057	**73.63**
	12/8/2011	7.1-3/11-103	**75.17**
Märja võrgupiirkond	2/2/2011	7.1-3/11-020	**66.02**
	7/29/2011	7.1-3/11-040	**76.04**
	8/31/2011	7.1-3/11-057	**77.72**
	12/8/2011	7.1-3/11-103	**79.28**
Kiili võrgupiirkond	1/25/2011	7.3-3/11-015	**67.63**
	7/29/2011	7.1-3/11-040	**77.91**
	8/31/2011	7.1-3/11-057	**79.66**
	12/8/2011	7.1-3/11-103	**81.26**
Vana-Võidu võrgupiirkond	1/25/2011	7.1-3/11-016	**64.65**
	7/29/2011	7.1-3/11-040	**74.89**
	8/31/2011	7.1-3/11-057	**76.64**
	12/8/2011	7.1-3/11-103	**81.19**

Roosna-Alliku võrgupiirkond	3/4/2011	7.1-3/11-023	**62.82**
	7/29/2011	7.1-3/11-040	**72.16**
	8/31/2011	7.1-3/11-057	**73.68**
	12/8/2011	7.1-3/11-103	**75.09**
Aravete võrgupiirkond	8/1/2011	7.1-3/11-041	**68.21**
	8/31/2011	7.1-3/11-057	**69.85**
	12/8/2011	7.1-3/11-103	**74.16**
Rummu võrgupiirkond	8/30/2011	7.1-3/11-055	**71.88**
	12/8/2011	7.1-3/11-103	**76.01**
Loksa võrgupiirkond	11/1/2011	7.1-3/11-082	**64.39**
	12/8/2011	7.1-3/11-103	**66.56**
AS TTP			
Padriku võrgupiirkond	12/1/2010	7.1-3/11-069	**59.26**
	11/11/2011	7.1-3/11-088	**70.44**
Par-cal OÜ	7/7/2011	7.1-3/11-035	**53.99**
Karksi-Nuia Soojus Oü			
Karksi-Nuia võrgupiirkond	8/2/2011	7.1-3/11-044	**54.43**
Aseri Kommunaal OÜ	8/5/2011	7.1-3/11-045	**58.36**
	11/3/2011	7.1-3/11-086	**62.12**
AS Nissi Soojus	8/5/2011	7.1-3/11-046	**71.34**
OÜ Puiga Soojus	8/18/2011	7.1-3/11-053	**47.69**
Termoring Grupp OÜ			
Tapa võrgupiirkond	9/9/2011	7.1-3/11-060	**67.61**
AS Termox			
Nõo võrgupiirkond	9/30/2011	7.1-3/11-069	**74.17**
Tõravere võrgupiirkond	9/30/2011	7.1-3/11-070	**80.00**
AS Revekor			
Linte võrgupiirkond	10/11/2011	7.1-2/11-075	**51.55**
Ruusa võrgupiirkond	10/11/2011	7.1-2/11-075	**51.55**
OÜ Sanva			
Keeni võrgupiirkond	10/26/2011	7.1-3/11-078	**50.01**
OÜ Vee-Ekspert			
Väimela aleviku võrgupiirkond	11/2/2011	7.1-3/11-083	**68.48**
	12/9/2011	7.1-3/11-104	**70.10**
AS Entek	11/2/2011	7.1-3/11-084	**65.56**
OÜ Kuldala Soojus	11/3/2011	7.1-3/11-085	**66.75**
Põlva Soojus AS			
Põlva võrgupiirkond	11/15/2011	7.1-3/11-089	**65.30**
Koeru Kommunaal AS			
Koeru Alevi võrgupiirkond	11/29/2011	7.1-3/11-096	**63.67**
Soojusenergia OÜ			
Paldiski võrgupiirkond	11/30/2011	7.1-3/11-097	**51.82**
OÜ Lavassaare Kommunaal			
Lavassaare võrgupiirkond	12/7/2011	7.1-3/11-102	**44.68**
Silikaat AS			
Järve Keskuse võrgupiirkond	5/12/2011	7.1-3/11-031	**52.27**
OÜ Tiskre Kommunaal	5/31/2011	7.1-3/11-033	**65.60**
	10/28/2011	7.1-3/11-081	**73.20**
OÜ Pääsküla Maja			
Rapla Võsa tn võrgupiirkond	12/9/2011	7.1-3/11-105	**69.07**
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