KPMG

Possibilities of using waste heat and waste cooling in the heating and/or cooling sector and the assessment of Estonia's potential for efficient district heating and cooling

Final report

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1 Preface

This report presents the results of the analysis in accordance with the terms of reference of the Ministry of Economic Affairs and Communications' tender ‘Possibilities of using waste heat and waste cooling in the heating and/or cooling sector and the assessment of Estonia's potential for efficient district heating and cooling’ The analysis is based on the structure set out in Annex VIII to Directive 2012/27/EU of the European Parliament and of the Council (hereinafter the Energy Efficiency Directive) and answers the questions set out in points 1—4 and 7 and 8 of Annex VIII to the Directive.

The analysis has been prepared by KPMG Baltics OÜ, in cooperation with energy sector advisors OÜ Pilvero (Ülo Kask), Arton Energy OÜ (Siim Link) and Tepsli OÜ (Siim Meeliste). Entrepreneurs who participated in the survey and interviews contributed to the completion of the analysis.

2 Abstract

This analysis is part of the assessment of the possibilities for the application of efficient cogeneration and efficient district heating and cooling referred to in Article 14 of the Energy Efficiency Directive. In addition, issues related to the use of waste heat and cooling and their potential, as well as efficient district heating and cooling and their potential have been further analysed. This report deals with waste heat generated in housing, commercial real estate, service economy and industrial enterprises. The authors based the threshold on the capacity limit of the waste heat source starting from the capacity of 5 MW.

Major conclusions:

1. There are no simple and quick solutions for the use of waste heat sources in district heating and cooling, but today's fundamental decisions and long-term meaningful work will lead to this result. Solutions must be comprehensive, especially in terms of support measures, i.e. in addition to a suitable transmission infrastructure, the development of infrastructure capable of receiving low-temperature heat in housing should be encouraged.
2. The surveys and interviews that supplemented the surveys revealed that district heating companies are probably in the best position to utilise in-house waste heat and that investments are self-remunerative thanks to lower costs. The initial investment for the use of waste heat, converted into energy units, was in the range of EUR 60—80 (per MWh in the first year) for companies, while for industrial companies it was EUR 120-300. District heating companies also had a good chance of benefiting directly (less frequently) or indirectly from the utilisation of waste heat. As a result of this analysis, the possibilities of district heating companies to utilise additional waste heat of 485 GWh/year have been assessed. The calculations performed in the study show that based on the unit price of energy, the implementation of flue gas condensers in district heating boiler houses and combined heat and power plants is cost-effective.
3. The extensive data collection carried out in this study was not sufficient to provide a nationwide assessment of the potential for untapped waste heat by sectors. Should detailed data prove necessary, this issue should be addressed in further analysis. In various other unspecified industries, an accurate assessment of the waste heat potential is not possible due to the absence of data, but is likely to exceed 400 GWh/a.
4. In individual cases, waste heat from companies has already been used or can be used in Estonia, where its parameters are suitable for transmission to the district heating network (either directly via a heat exchanger or heat pump), uniform and year-round availability is guaranteed and the company is located close to the district heating network. Collecting and utilising waste heat requires effort, work and financial resources, but it still has potential. Unfortunately, the availability of waste heat for use in district heating is often not continuous or sufficient, or it is technically difficult to route waste heat to the district heating network. In addition, it may not make economic sense because of the high investment cost and the remoteness of the network. This makes is all the more important for waste heat to be used internally.
5. Wastewater treatment plants, data centres, flue gas condensing and the development of low-temperature district heating areas (islands) have the greatest potential for low-temperature waste heat if it is supplied from the return line of existing district heating networks.
6. It is more promising to develop low-temperature heat sources and to develop networks in housings. There are both final and transitional solutions for this. The wider use of waste

heat in district heating systems requires the existence of a suitable infrastructure, i.e. a low-temperature district heating network. Reconstruction of existing district heating systems is a lengthy but potentially positive process for society, which would require a separate, more detailed analysis of how to lower the network temperature on existing infrastructure, connect consumers to the return pipeline, and build a low-temperature network in new development areas on the basis of existing pipelines. The analysis of the research confirmed that the existing housing stock, especially consisting of larger apartment buildings, is partly transferable to efficient solutions based on heat pumps (HP) (ventilation air HP). According to the present research, such a transfer could be undertaken gradually along with the reconstruction of buildings, during which the buildings will be insulated and modernised. Converting the existing housing stock to efficient heating would require a good deal of investment and would not be economically viable, the latter being primarily due to the reconstruction part of the building. Investment in heat pumps and associated equipment would theoretically be self-paying if the income target is the average price of heat (this is taken to be EUR 65 per MWh in this report) and the costs for modernisation of buildings are considered separately. Depending on how actively the investment is made, 39.7 to 85.21 MWh/a of primary energy could be saved by improving the efficiency of residential housing heating solutions. The investments are not cost-effective in any of the scenarios, and in the most aggressive scenario, the costs of district heating network and heat storage solutions have not been taken into account.

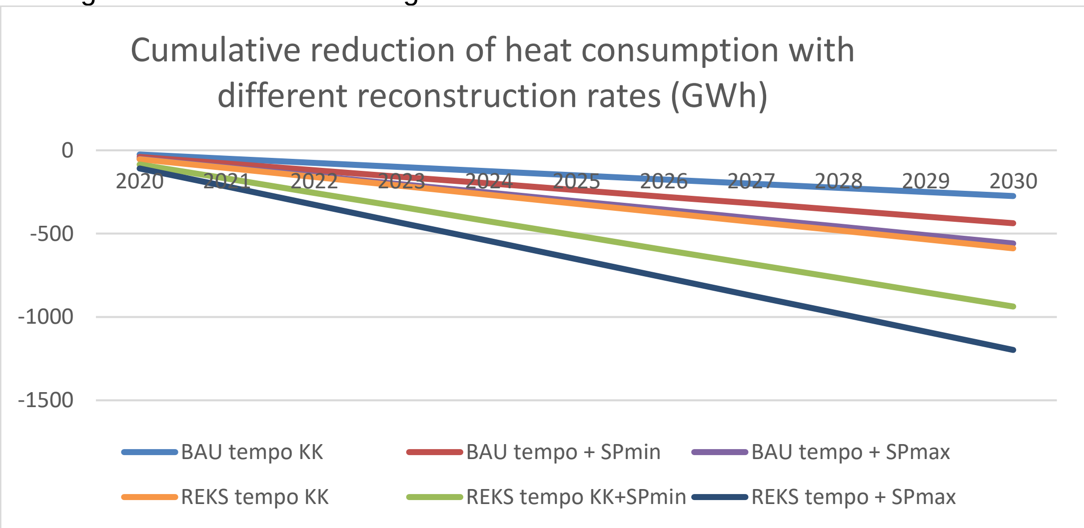


Figure 2.1. Cumulative reduction of heat consumption with different reconstruction rates (GWh)

This is a much simpler and more cost-effective situation for completely new residential buildings and also for larger buildings for low-intensity economic activities. This study is based on research that thoroughly deals with heating solutions for one of Tallinn's new development areas and calculates that a high-efficiency heating solution based on a combination of gas heating and heat pumps is economically cost-effective. In the initial phase, more expensive 'smart heating solutions' as compared to classic heating systems, will become self-paying after a few years thanks to high fuel savings.

7. Low-temperature (below 100 °C) waste heat has mostly been unused or used to a lesser extent in industry, service companies and housing. The predominant uses are heat recovery for heating the ventilation air being sucked into the building, waste water heat recovery and domestic water heating. In this study, the use of certain high-potential low-temperature waste heat has been modelled and the resulting energy savings, cost-effectiveness and the impact on the share of CO_2 emissions and renewable energy have been assessed.

8. In connection with the resource efficiency measure, of which part (up to 50 %) of companies' resource efficiency projects are financed, waste heat has been used mainly internally.
9. Wood fuel boilers, starting with a capacity of 5.1 MW (all sectors combined), already use 253 GWh/a of waste heat and the theoretical total potential of free waste heat would be 234 GWh/a. It is known that 333 GWh/a of waste heat is already used in natural gas boilers, starting with a capacity of 5.1 MW (all sectors combined) and the theoretical total free waste heat potential would be 251 GWh/a. The amount of waste heat already obtained from the combustion of both fuels (from flue gas condensation) is estimated at 586 GWh and the total theoretical potential still available would be 485 GWh per year.
10. Theoretically, a total of 5 276 TJ/a or 1 466 GWh/a of waste heat could be obtained from Estonian wastewater treatment plants (the corresponding saving of wet wood chips would be estimated at 2.3 million pm^3 per year). Based solely on the quantities and properties of wastewater from Tallinna Vesi AS, up to 450 GWh/a of potential waste heat can be obtained, for example, to supply heat to nearby future residential development areas or to direct in the Tallinn district heating network. This is low-temperature waste heat that requires heat pumps. As for heat pumps in general, such projects can be considered cost-effective if the projects generate sufficient revenue. In this case, the average calculated wholesale heat price (estimated at EUR 20 to EUR 25 per MWh) is appropriate. In this case, the investment is economically viable without taking into account possible investments in the district heating network.
11. In terms of Estonia, a very large data centre (server park) will be built in Harju County. The initial electrical capacity is planned to be 6 MW (~50 GWh of waste heat per year if operating evenly at full capacity all year round), which will later be increased to 20 MW if necessary, with the possibility of further additions (up to 32 MW). In principle, it would be possible to direct this waste heat to the district heating network of the city of Tallinn (Õismäe) through almost 5 km of pipeline. The data centre presented one sample case, which shows that the amount of heat generated annually is 150 GWh/a, and the conditions are there for the establishment of such centres in the future. Based on the feasibility study shared with the authors of this report by the owner of the data centre, we find that the utilisation of the waste heat is self-sustaining. An NPV based on the data centre data is positive as long as the lack of connections to a suitable district heating network is ignored. In the feasibility study already mentioned, estimates of the costs of connecting to different district heating networks have been made and they show that the NPV is strongly negative in each scenario.
12. The approaches using the heat pumps described above, both in industry (water management, cloud data management) and in households (existing and new housing stock), allow the more efficient use of lower temperature heat sources and reduce energy consumption, but they do not necessarily reduce the share of renewable energy, because heat pumps have a significant electricity self-consumption ratio.
13. According to the current regulation, the addition of a waste heat source to the existing district heating network is considered as the purchase of heat by a heating company. This approach does not take into account the cross-economic need to increase the use of waste heat. The issue of waste heat should be reflected in more detail in the District Heating Act and/or related regulations, starting with the definition of waste heat in the legislation and the establishment of uniform and transparent basic principles for third parties to connect to the district heating network.
14. In order to increase the share of renewable energy/waste heat by at least one percentage point per year, consideration should be given, as a minimum, to designating a competent authority with limited powers to implement additional measures. This competent authority could also develop and publish the non-discriminatory and transparent criteria referred to in the previous point for connecting waste heat sources to the district heating network.

3 Introduction

3.1 Background of the study

This analysis is part of the assessment of the possibilities for the application of efficient cogeneration and efficient district heating and cooling referred to in Article 14 of the Energy Efficiency Directive.

3.2 Purpose of the study

The purpose of the study was to prepare an analysis that meets the requirements set by the European Commission. The analysis follows the structure set out in Annex VIII to the Energy Efficiency Directive and answers the questions set out in points 1 to 4, 7 and 8 of Annex VIII. During the analysis, the tenderer assessed the national heating and cooling potential by following the below points:

- Heating and cooling overview
- Analysis of the economic potential of heating and cooling potential

Among other things, the analysis reveals:
1. the amount of exhaust heat and cooling energy actually used in Estonia as at 2019;
2. the realistic untapped potential of waste heat and cooling in the heating or cooling sector and the impact of the implementation of this potential on primary energy savings;
3. the share of efficient district heating and cooling in the total district heating and cooling sector as at 2019;
4. the untapped potential for efficient district heating and cooling and the impact of realising this potential on primary energy savings;
5. the economic impact of realising the potential mentioned in points 2 and 4 on the consumer price of heating and cooling.

3.3 Structure of the report

The report is structured as follows:

Chapter 4:	Covers the definition and sources of waste heat
Chapter 5:	Describes waste heat sources in more detail
Chapter 6:	Summarises the survey and interviews
Chapter 7:	Analyses heating and cooling demand
Chapter 8:	Studies heating and cooling suppliers and delivery volumes
Chapter 9:	Visualises a map of the entire territory of the country

Chapter 10: Forecasts trends in heating and cooling demand

Chapter 11: Evaluates the waste heat and waste cooling energy actually used in Estonia as at 2019

Chapter 12 2. Introduction of untapped potential of waste heat and cooling in the heating or cooling sector and the impact of the implementation of this potential on primary energy savings

Chapter 13: 3. Describes the share of efficient district heating and cooling in the total district heating and cooling sector as of 2019

Chapter 14: 4. Evaluates untapped potential for efficient district heating and cooling and the impact of realising this potential on primary energy savings

Chapter 15: An analysis of the economic potential of heating and cooling efficiency performed

The analysis has the following annexes:

ANNEX 1 Abstract

ANNEX 2 Waste heat utilisation technologies and equipment

ANNEX 3 Examples of waste heat use in other countries

ANNEX 4 Spreadsheets of economic potential

ANNEX 5 Map Heat consumption intensity

ANNEX 6 Map Heat consumption intensity in business

ANNEX 7 Map Cooling requirement

ANNEX 8 Map Waste heat map

3.4 Glossary of abbreviations and terms

Terms used in the work:

Waste heat is all forms of heat (both latent and obvious) that are released from the system and cannot be used in the system for their intended purpose.

CO_2 is the emission equivalent of one tonne of CO_2 or equivalent global warming factor for any other greenhouse gas listed in Annex A to the Kyoto Protocol.

Natural gas is a mixture of gaseous hydrocarbons formed as a result of the decomposition of organic matter, which is located in the voids and porous layers of the Earth's crust. Natural gas consists largely of methane (CH4). Natural gas is an odourless, colourless and tasteless gas mixture. A special fragrance (THT, 10—15 mg/m³) is used to scent natural gas.

Biogas is a gaseous fuel obtained by anaerobic fermentation consisting of 50—70 % methane (CH_4), 30—40 % carbon dioxide (CO_2) and other components such as N_2, O_2, NH_4, H_2S. Biogas can be obtained in a natural process from swamps, bogs and landfills, and by special fermentation using manure, wastewater, herbaceous biomass and other biodegradable waste.

Biomethane is a purified biogas that contains 96—99 % methane and has the same calorific value as natural gas, used wherever natural gas is used today.

Woodchips are wood chips produced from shrubs, felling waste or other wood unfit for consumption, comminuted fuel.

Milled peat is crushed peat produced by a milling machine.

Shale oil is a mixture of various saturated and unsaturated aliphatic, cyclic and aromatic hydrocarbons and other organic compounds obtained, and which is obtained by burning oil shale, i.e. semi-coking and oil shale coking.

Adjusted NPV is the net present value (in euros) adjusted for the amount of waste heat produced or sold during the lifetime of the waste heat generating installation (in MWh) or the amount of heated surface (in m^2).

Abbreviations used in the work:

°C	–	degrees Celsius
CH_4	–	methane
CO_2	–	carbon dioxide
BGJ	–	biogas plant
COP		coefficient of performance, or heat factor
DN	–	pipe diameter (mm)
DH		district heating
EJKÜ	–	Estonian Power Plants and District Heating Association
EL	–	European Union
ENMAK	–	Energy Economy Development Plan until 2030, with a vision for 2050
EnKS	–	Energy Management Organisation Act
ESA	–	Estonian Statistical Office
ETEK	–	Estonian Renewable Energy Chamber
GWh	–	gigawatt hour
IEA	–	International Energy Agency
K	–	for district heating
KV	–	district heating network
KWh	–	kilowatt-hour
mln	–	million
Mt_{oe}	–	million tonnes of oil equivalent (toe)
MTK	–	low temperature district heating network area
MWh	–	megawatt-hour
MW_{el}	-	megawatt of electrical power
NPV	–	net present value (*net present value)*
O	–	for personal use
CHP	–	combined heat and power production
S	–	heat pump
TWh	-	terawatt-hour
V	–	water heating
Õ	–	air heating

4 Definition and sources of waste heat

This paper deals with waste heat generated in housing, commercial real estate, service economy and industrial enterprises.

Industry uses ~38 % of final energy consumption worldwide, or over 58,600 TWh (2010).[1] Therefore, the energy consumption in industrial processes should be reduced as much as possible. However, even in optimised systems, waste heat is released, which in some cases can still be used to carry out processes with lower temperature requirements. In addition to such direct recovery, there is also the possibility of using industrial waste heat for the production of cold and cooling, heat and electricity using a number of technologies and equipment, as it is done in power plants. Industrial waste heat has been neglected for a long time due to the fact, that the companies are scattered and the amounts and parameters of the waste heat obtained are very different as compared to the amount of waste heat generated in electricity generation plants. As long as the industrial sector uses 38 % of final energy, the potential of waste heat is significant and its potential should be explored. The largest amounts of waste heat are usually found in the following industries: metallurgy, chemicals, non-metallic minerals, food and tobacco products, and pulp and paper. There is practically no metallurgy and non-metallic mineral industry in Estonia and the cement industry has stopped burning clinker.

The generation and use of waste heat in dwellings can be considered in relation to heat production, air exchange and domestic hot water use. The implementation of ever-increasing energy efficiency requirements in the residential sector has created a situation where the erection of new buildings and the reconstruction of existing buildings seeks to achieve the most energy-efficient result possible, therefore, there is a growing potential for solutions that help to collect and use waste heat at source. As a result, the amount of additional energy supplied to the building is reduced and the energy class on the building's energy label is improved. Talking about housing, the present work has also addressed the situation where residential buildings can use stable waste heat and in times when there is no local consumption, it could be directed to the district heating network. The preconditions for the realisation of such a scenario and the possible effects are described in the work below.

4.1 Waste heat definition

In the foreign literature and in different languages, excess heat from technological processes and technical equipment is referred to in various ways (e.g. in English. *waste heat, residual heat and excess heat*, similar in other languages, see below). In Estonian, we would recommend using only one term - **heitsoojus – waste heat**, because in essence these

[1] Sarah Brueckner, Laia Miró, Luisa F. Cabeza, Martin Pehnt, Eberhard Laevemann (2014) Methods to estimate the industrial waste heat potential of regions – A categorization and literature review. Elsevier. Renewable and Sustainable Energy Reviews 38 (2014) 164—171.

terms are relatively similar and starting to distinguish between them can lead to inconsistencies in legislation and make it difficult to understand even in ordinary language.

- **Heitsoojus** (*waste heat, excess heat, Abwärme (f), hukkalämpö, бросовое тепло)* – heat released during the production process and not used there. The generation of waste heat is thermodynamically inevitable in any energy conversion. Redirecting waste heat to production, using it for heating or water heating saves natural resources (mainly fuels) and reduces overall pollution.[2]

- **Jääksoojus** (*residual heat, Restwärme, остаточное тепло*) - **j**residual heat is generated (dominated) in the shutdown mode of nuclear reactors. The term 'residual heat' has been introduced to understand post-reactor shutdown processes.[3]
- **Liigsoojus ehk üleliigne soojus** (*excess heat, überschüssige Wärme, избыток тепла)* – in Estonian it is essentially the same as waste heat. Some examples of how this phrase is used in English: *The excess heat from combustion can efficiently be used for the drying process* (Põlemisel tekkivat liigset soojust e heitsoojust saab tõhusalt kasutada kuivatusprotsessis); *Recovery of excess heat from the cooling zone is applicable when grate coolers are used* (Jahutustsooni liigsoojust e heitsoojust saab taaskasutusse võtta vastavate restjahutitega); *Cooling the photovoltaic constraints to store the excess heat in the garden* (Fotogalvaaniliste elementide (PV-elementide) ülekuumenemise piiramiseks jahutatakse neid ja seda üleliigset soojust e heitsoojust saaks salvestada aias (pinnases) ning taaskasutada maasoojuspumpade abil).[4]

In this work, waste heat is considered to be all forms of heat (both latent and obvious) that are released from the system and cannot be used in the system for their intended purpose. Exhaust heat sources in industries can be individual machines or entire systems that release heat to the environment. Such sources include, for example, furnaces, including waste water from washing, drying or cooling processes and from domestic use, cooling systems, engines or production exhaust air from production premises[5]. The waste heat is released either by thermal conduction as radiation, or by convection, or by a heat carrier such as exhaust gas, coolants or steam.[6] In this work, waste heat released by thermal conductivity (scattered heat) is not taken into account.

4.2 Sources of waste heat

Exhaust heat is released as a by-product of various processes, for example: atmospheric combustion gases (from internal combustion engines of cogeneration plants, turbines, boilers, etc.), heated water released into the environment, air and condensed steam (industrial and non-condensed or condensed steam, cooling air and water, etc.) leaving

[2] http://www.seit.ee/sass/print.php?keel=ee&type=tapne&word=heitsoojus

[3] *Reactor physics* https://www.reactor-physics.com/what-is-residual-heat-definition.

See also /https://glosbe.com/en/en/residual%20heat

[4] Note: The translation into Estonian is free and explained at length for better understanding.

[5] De Beer J., Worrel E., Blok K. Long-term energy efficiency improvements in the paper and board industry. Energy 1998;23:21–42.

[6] Pehnt M, Boedekery J, Arens M, Jochem E, Idrissora F. Die Nutzungindustrieller Abwärme-technisch-wirtschaftliche Potenziale und energiepolitische Umsetzung Wissenschaftliche Begleitforschung zu uebergreifenden technischen, oekologischen, oekonomischenundstrategischen Aspektendes nationalen Teilsder Klimaschutzinitiative FKZ03KSW016A und B; 2010

industrial processes (bricks from kilns, steel products from kilns, etc.), and heat transfer from surfaces of hot equipment (e.g. cement and lime kilns, etc.). As such, waste heat sources differ in states of matter (mainly liquid and gas (air) flows), temperature range (between source and ambient), temperature change and heat content (amount of heat).

Among the industries and economic sectors, the following could be considered as a source of waste heat in Estonia:

1. Energy production (electricity and heat), including the use of return water heat from district heating networks to supply heat to low temperature network areas in order to lower the return water temperature in the district heating network. Condensation of water vapour in flue gases, use of condensate heat
2. Mineral oil refining, shale oil production
3. Production of cement clinker (clinker burning suspended in Estonia in March, 2020)
4. Lime production
5. Glass production
6. Pulp production
7. Paper and paperboard production
8. Ceramic product production
9. Production of chemical products (ammonia, Nitrofert AS suspended production in August, 2013)
10. Production of construction materials
11. Food and beverage industry
12. Wood and furniture industry (dryers)
13. Wastewater treatment (use of wastewater heat (via heat pumps (HP)) in low temperature district heating networks)
14. Service sector (hotels, spas, large trade and sports halls and other buildings with a lot of ventilation waste heat)
15. Agriculture (e.g. cooling of milk at barns, biogas plants, manure storage facilities)
16. Data centres (server parks)

These sectors in Estonia include installations of the EU Emissions Trading Scheme, the activities of which comply with the requirements set out in Section 2 of Government of the Republic Regulation No. 134[7] of 1 December 2016. In total, there are almost 50 Estonian installations in the system and their rated thermal input is over 20 MW (the first 9 areas on the list). The last seven areas have been added by the authors, where there may be heat sources with a rated thermal input exceeding 5 MW.

The number of all companies considered in this work in Estonia is between 1 000 and 2 000.

Only energy producers (heat, electricity and cogeneration), shaded dark blue and industrial plants, shaded light blue with an estimated unit capacity (s) of more than 20 MW are listed in Table 4.1 below. The equipment of the companies presented here should also be included in the table of Economics and Statistics Administration (ESA) (KE044 Boilers). Table 4.1 the following companies will transfer waste heat to district heating networks: Enefit Energiatootmine AS (Balti EJ) to the district heating network of the city of Narva; OÜ VKG Energia to the district heating network of Kohtla-Järve, Ahtme and Jõhvi; Enefit Green AS (Iru EJ) to the district heating network of Tallinn and Maardu; Silpower AS (Sillamäe EJ) to

[7] Government of the Republic Regulation No. 134 of 01.12.2016, List of Activities of Operators Included in the Greenhouse Gas Emissions Trading Scheme, RT I, 07.08.2018, 3.

the district heating network of Sillamäe City; AS Utilitas Tallinn (Mustamäe KM and CHP) to the district heating network of the city of Tallinn, OÜ Utilitas Tallinna Elektrijaam to the district heating network of Tallinn; Fortum Eesti AS (Pärnu CHP station) to the district heating network of the city of Pärnu; AS Anne Soojus (Tartu CHP station) to the district heating network of the city of Tartu; OÜ Utilitas Tallinna Elektrijaam, Part II to the Tallinn district heating network. From industrial enterprises, the heat of Kiviõli Keemiatööstuse OÜ SEK (CHP) is used to supply heat to the city of Kiviõli. O-I Estonia AS supplies waste heat to the consumers of the district heating network of Järvakandi settlement. It is not possible to use the waste heat of Eesti Elektrijaama and Auvere Elektrijaama in district heating networks today, secondly, it is not certain how long oil shale plants will operate. Industrial companies other than the above are also located relatively far from the district heating networks of cities/towns or have not had an interest/need to sell waste heat (AS Nordkalk (Rakke); Wienerberger AS (Aseri small town); Horizon Cellulose and Paper AS (Kehra)).

Table 4.1 Recipients of free CO_2 emission units in Estonia

Name and location of energy producer/industrial company
Enefit Energiatootmine AS (Balti EJ), Narva
Enefit Energiatootmine AS (Eesti EJ), Auvere
Enefit Green AS (Iru EJ), Maardu
OÜ VKG Energia (Kohtla-Järve, Ahtme, Jõhvi)
Liwathon E.O.S. AS (Maardu)
VKG Oil AS (Kohtla-Järve)
Kiviõli Keemiatööstuse OÜ (KKT Oil OÜ) (Kiviõli)
Silpower AS (Sillamäe EJ), Sillamäe
Fortum Eesti AS (Pärnu KM), Pärnu
AS Anne Soojus (Anne KM, Tartu)
AS Utilitas Tallinn (Mustamäe KM and SEK (CHP)), Tallinn
AS Utilitas Tallinn (Kristiine KM), Tallinn
AS Nordkalk (Rakke)
O-I Estonia AS (Järvakandi)
Horizon Tselluloosi and Paberi AS (Kehra)
AS Estonian Cell (Kunda lähedal)
Wienerberger AS (Aseri alevik)
OÜ Utilitas Tallinna Elektrijaam (Tallinn, Väo)
Fortum Eesti AS (Pärnu SEK (CHP) station), Pärnu
AS Anne Soojus (Tartu SEK (CHP) station), Tartu, Lohkva
VKG Oil AS, Kohtla-Järve
OÜ Utilitas Tallinna Elektrijaam, II osa, Tallinn, Väo
Enefit Energiatootmine AS (Õlitööstus), Auvere
Enefit Energiatootmine AS (Auvere EJ), Auvere

4.3 Waste heat in housing

Heat is supplied to apartment buildings primarily from the district heating network, which is why opportunities for extracting waste heat should be sought primarily on the heat production side. This has been addressed in other chapters of the work on waste heat from power plants. The consumer may consider the heat in the exhaust air (exhaust air) from the ventilation system as waste heat. (See Figure 4.1). A large part of the existing building stock has been built without heat recovery ventilation. The air exchange in the rooms takes place with either natural or mechanical ventilation and the exhaust air temperature corresponds to the indoor temperature, approx. 21—23 °C.

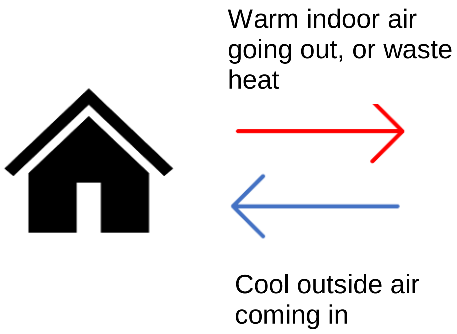


Figure 4.1. Exhaust heat generation from ventilation air in the residential sector

Usage options of ventilation air exhaust heat

In order to use the exhaust heat, it is necessary to install devices that partially recover the heat contained in the exhaust air. There are two most common technical solutions:

- heat recovery exhaust ventilation system with heat pump;
- heat recovery supply-exhaust ventilation system;

Heat pumps draw heat from the extract air and with such a solution it is possible to use the heat to preheat the supply air, to heat the domestic water (to preheat the cold water) or to heat it (in a heating system) (Figure 4.2). In order to build a supply air and cold water preheating solution, a competent specialist must be involved, reconstruction work must be carried out and space must be found in the common areas for additional technical equipment, and from the point of view of the energy system, this is a relatively simple and problem-free solution if the generated waste heat is used locally without being added to the district heating network. However, the use of heat pumps in the basements of buildings can cause low frequency noise problems. The quality of life of people living in apartments on top of a utility room may be disturbed by the noise.

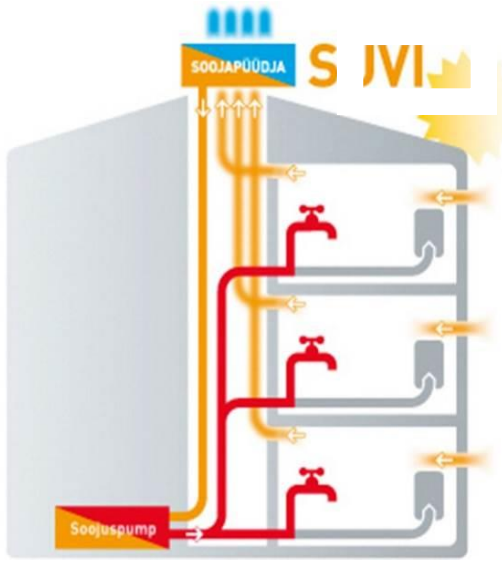


Figure 4.2. Using a heat pump to heat domestic water

When controlling the exhaust heat heating system, a technical solution is usually used, which raises the temperature of the water returning to the district heating network and therefore decreases the efficiency of the district heating system. District heating companies have therefore generally opposed the use of such a solution.

Installing **heat recovery ventilation** is the most common practice for using waste heat. Heat recovery ventilation is usually installed during the construction of new buildings or during thorough reconstruction works (e.g. during reconstruction works carried out with the support of KredEx measures). In such a ventilation system, the heat contained in the exhaust air is used to preheat the incoming air. Heat exchangers can be divided into three main types: rotary heat exchangers (Figure 4.3), plate heat exchangers (Figure 4.4) and heat exchangers with intermediate heat carrier (Figure 4.5). The first two types of heat exchangers are more common because they are more efficient and require less maintenance to operate. The heat exchanger with intermediate heat transfer medium is used in particular when the use of a rotor or plate heat exchanger is not technically possible (e.g. supply and exhaust fans are located in different parts of the building or the extract and supply air flows must not be mixed).

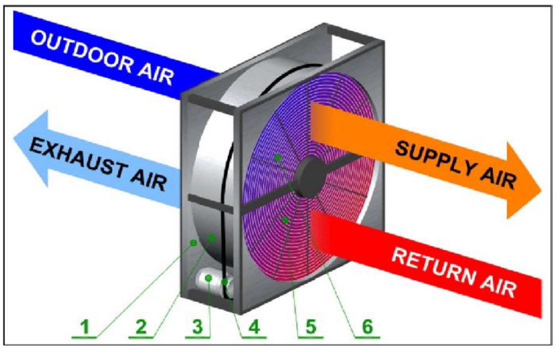


Figure 4.3. Working principle of rotary heat exchanger

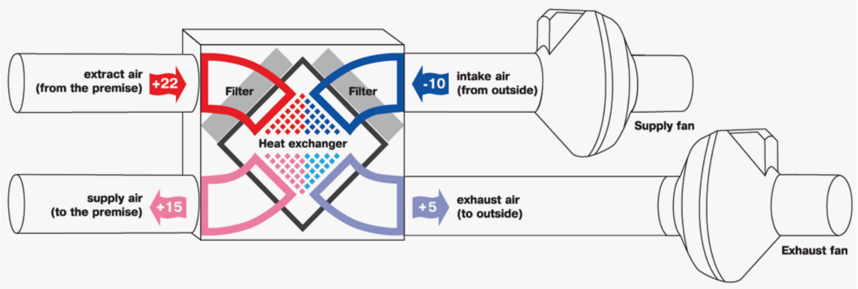


Figure 4.4. Working principle of plate heat exchanger

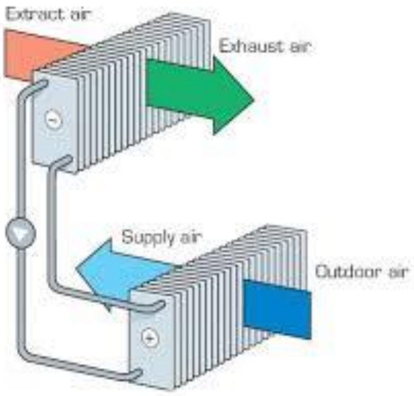


Figure 4.5. Working principle of a heat exchanger with an intermediate heat carrier

Utilisation of heat obtained from waste heat

In addition, domestic hot water entering the sewerage system can be considered as waste heat generated at the level of the final consumer. Technical solutions and equipment operating at the level of both the apartment building and individual water intake equipment (e.g. shower staircase, bath drain or floor drain) have been developed to recover the heat contained in the wastewater (Figure 4.6, Figure 4.7).

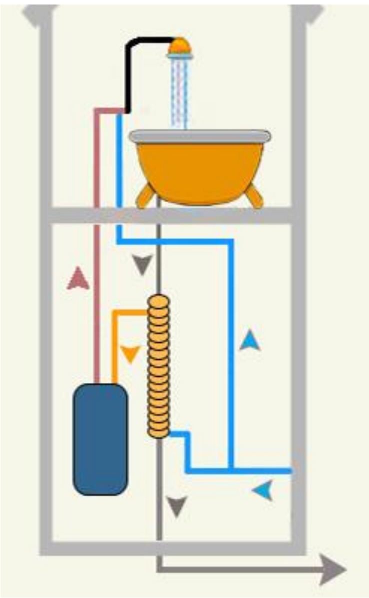


Figure 4.6. Possible use of wastewater heat at the building level for preheating cold domestic water

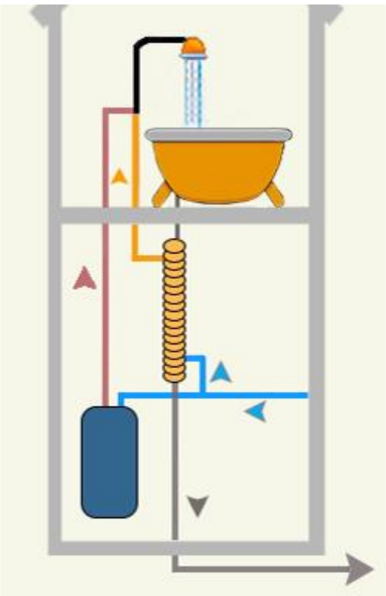


Figure 4.7. Possible use of waste water heat at the level of one device (e.g. shower, bath)

In the first case, the wastewater is collected in a tank and the heat is used to preheat the domestic hot water. In the case of heat exchangers in the aforementioned drainage units, sewage water (up to 40 °C) is used to preheat the cold water (~5 °C) entering the mixer. The cold water temperature can be raised by approx. 10 °C. In both cases, the heat extracted from waste water is used to preheat the domestic hot water. Such solutions are economically justified, especially in buildings with more intensive use of water than usual, such as hotels and barracks.

The use of waste heat is generally problem-free. Problems can occur if the heat exchanger is in direct contact with the waste water. This can cause blockages and the efficiency of the heat exchanger can be drastically reduced. This problem can be prevented by using a so-called pipe-in-pipe solution (Figure 4.8).

Figure 4.8. The so-called pipe-in-pipe heat exchanger type for utilising the heat of the waste water. Sewage flows around the cold domestic water pipe

However, it is not sensible to promote or encourage the mass use of waste water waste heat in buildings, as its income per dwelling is not high. It is more important if the collection of wastewater waste heat before the wastewater treatment plant starts to affect (lower) the temperature of the wastewater arriving at the wastewater treatment plant. This interferes with the activity of bacteria in activated sludge cleaners. In the worst case, activated sludge basins should be heated. For individual larger water users, such as spas, swimming pools, hotels, the use of waste heat from the wastewater could be considered on a case-by-case basis and the benefits calculated.

However, the introduction and treatment of wastewater heat treated in wastewater treatment plants into district heating networks would certainly be worth calculating in every location. This will be discussed in more detail in the following chapters (e.g. Chapter 8.3).

4.4 Industrial waste heat[8]

In many situations, excess heat can be partially used both inside and outside the company. There are several definitions and concepts for this, e.g. waste heat, surplus heat, secondary heat, low quality heat, black, white or green waste heat. To overcome this confusing situation, the following definitions have been suggested in the literature[9]:

Industrial waste heat (*excess heat* – is the heat content of all streams (gas, water, air, etc.) released from an industrial process at a given time. Part of this can be heat used both inside and outside the company *usable heat*) technically and economically. If the heat generated during the process is used externally and cannot be used internally as an alternative to the heat produced or purchased (see below for real excess heat/warmth), it may be referred to as *white excess heat*. If it is obtained from the conversion of biomass, it can be called *green excess heat*) (a mixture is also possible). If the heat could have been used technically and economically inside the company, it could be called *black excess heat*. *Non-usable excess heat* is the remainder of the heat after deducting parts used inside and outside the plant. It is suggested that this part may be called *waste heat*. The commonly used term *true excess heat* can be defined as white or green waste heat, depending on the origin of the fossil or biomass.

True waste heat can be used as heat outside the company if the justified (re)use of heat takes place through heat exchangers, heat pumps or if suitable new process equipment is installed. Reasonable (re)use of heat means a level of recovery that is in line with the

[8] ANNEX XV: Industrial Excess Heat Recovery –Technologies and Applications. Final report Phase 1, 5 May 2015. Prepared by Thore Berntsson CIT Industriell Energi AB, Sweden, Anders Åsblad CIT Industriell Energi AB, Sweden. Supported by Denmark, Germany, Norway, Portugal, US and Sweden.
[9] Idem.

industry's return on investment practices and traditions. One way of proving this could be for an industrial company to carry out and demonstrate the breakpoint analysis results *pinch analysis* and to declare the principles of the investment to be made.

The definitions of waste heat were discussed in a workshop organised by the IEA (*Industry Strategy Group*) on 19 February 2015 as a webinar. The IEA Secretariat's report used *waste heat* with the same meaning as *excess heat*, although the terms 'green', 'white', 'black' and 'true heat' were not covered. The ECES Implementing Agreement also used the term *industrial waste heat*, but defined it as heat generated by machinery, electrical equipment and industrial processes for which no direct application can be found in the plant itself.

In order to correctly interpret the above definitions, it is important to provide a definition of the word ‘industry’. This refers to any industry that produces materials, from small to medium-sized enterprises. There are other companies in society that produce waste heat. One obvious example is combined heat and power (CHP) plants. They are designed to generate both electricity and heat together. In some countries with high electricity prices, such CHP stations smaller than condensing stations can be used in condensing mode at least part-time. In such cases, the excess or waste heat of such plants may be used in equipment using low-temperature technologies, which will be reviewed in later subsections of the same report. Heat from large condensing power plants can be used in the same way, for example in district heating or cooling systems, if somewhat lower electricity generation efficiencies can be accepted (the share of electricity in a CHP is lower than in a condensing plant), but waste heat is used, which increases the overall efficiency of energy conversion, i.e. the more efficient use of primary energy. Another example is the excessive heat of municipal wastewater treatment plants, the temperature of which can be raised by means of district heating heat pumps. This type of system is relatively common in cities with large district heating systems, except for when the wastewater treatment plant is located very far from the CHP station.

There is therefore a great need to develop a common language, definitions and specifications in this area.

The literature cited is to show how multifaceted the field is and how many concepts are to be dealt with. We recommend that we initially stick to one concept in Estonia – **waste heat** – whether it comes from industrial companies or elsewhere, from fossil or renewable energy sources.

4.5 Data centre waste heat

4.5.1 General overview of some studies

It is estimated that data centres (server parks – *DCs*) already accounted for 1.1—1.5 % of global electricity consumption in 2010; and in 2013, the IT sector accounted for 10 % of global electricity consumption. In addition to the direct electricity consumed by information and communication technology (ICT) hardware and basic infrastructure, data centres require enormous cooling, which is typically produced by air conditioners. The electricity consumed in data centres is almost completely converted into heat. However, heat is usually not used, although various solutions already exist. Modern data centres can contain thousands of server shelves (individual servers) and the nominal capacity of the data centre can exceed

400 MW. It also means that the floor area of data centres is increasing and computing power is increasing, resulting in increasing energy consumption of data centres[10].

The cold climate in the Nordic countries has proven to be extremely suitable for data centres, providing natural and cheap cooling. In addition, there is a high demand for heat in these countries, and industrial waste heat is already widely used in various processes and *DH – district heating*, especially in Finland and Sweden. Waste heat was 3.3 %[11] in Finland in 2015 and 8 % in Sweden in 2014[12]. Highly efficient cogeneration of heat and electricity *CHP – combined heat and power* is extremely common in Finland and Sweden. As the housing stock and other buildings become better insulated from year to year, district heating companies strive for lower temperatures, which would allow lower quality heat to be transferred to the district heating network at lower costs. Therefore, there may be even more potential for the use of waste centre waste heat in the future.

A relatively large number of studies have recently been carried out on the energy efficiency of data centre facilities, but most of these studies relate to the integration of efficient cooling systems, electricity consumption and renewable electricity. Instead, less research is being done on waste heat recovery from data centres. However, in recent years, studies have become more relevant and some case studies have been carried out.

There is no uniform method for waste heat recovery, so various applications and temperature ranges have been studied. Marcinichen et al.[13] showed that low-temperature waste heat from data centres can be used to preheat feedwater in power plants. The use would lead to fuel savings in the power plant and increase the efficiency of the power plant by up to 2.2 %. Ebrahimi[14] studied the use of waste heat using absorption cooling systems. The study showed that the payback period for upgrading an absorption system can be low for a data centre with an electrical capacity of 10 MW, estimated at 4—5 months.

Lu et al. study[15] assessed the energy efficiency and waste heat collection potential of existing data centres in Finland. The study showed that 97 % of electricity consumption can be converted into heat and could be used as waste heat. The study concluded that a data centre with an electrical capacity of 1 MW, operating at half the nominal load, would be able to satisfy the heat demand of non-residential buildings with more than 30 000 m^2 of waste each year. Sorvari[16] studied the recovery of waste heat for heating spas and rental houses in northern Finland. The results showed that the waste heat from the data centre would almost

[10] Wahlroos, M. *et al*. Future views on waste heat utilisation – Case of data centres in Northern Europe. Renewable and Sustainable Energy Reviews 82 (2018) 1749—1764.

[11] Finnish Energy Industries. Energiavuosi 2015 - Kaukolämpö (In Finnish, Energy year 2015 - District Heating) 2016. http://energia.fi/tilastot-ja-julkaisut.

[12] Fjärrvärme Svensk. Industriell spillvärme (In Swedish, Industrial waste heat); 2016. http://www.svenskfjarrvarme.se/Medlem/Fokusomraden-/Energitillforsel-ochproduktion/Spillvarme/.

[13] Marcinichen JB, Olivier JA, Thome JR. On-chip two-phase cooling of data centres: Cooling system and energy recovery evaluation. In: Proceedings of the 13th Braz Congr Therm Sci Eng; 2012. 41:36–51. doi:10.1016/j.applthermaleng. 2011.12. 008.

[14] Ebrahimi K, Jones GF, Fleischer AS. Thermo-economic analysis of steady state waste heat recovery in data centres using absorption refrigeration. Appl Energy 2015;139:384–97. http://dx.doi.org/10.1016/j.apenergy.2014.10.067

[15] Lu T, Lü X, Remes M, Viljanen M. Investigation of air management and energy performance in a data center in Finland: case study. Energy Build 2011;43:3360–72. http://dx.doi.org/10.1016/j.enbuild.2011.08.034.

[16] Sorvari J. Konesalin ylijäämälämmön hyödyntäminen Levin Koutalaella (In Finnish, Utilization of waste heat from data center in Koutalaki Levi) Master's thesis Espoo,
Finland: Aalto University; 2015.

completely satisfy the heat demand for an area over 60,000 m^2. Kupiainen[17] compared two different cooling options for a data centre in the Futura building in Jyväskylä, central Finland. The combination of free cooling and HP (heat pumps) saved EUR 280 000 over a 20-year lifespan compared to free cooling and refrigeration. Stenberg[18] simulated a data centre with an electrical capacity of 3 MW in Helsinki, Finland. The optimal temperature setting for the use of waste heat in a data centre cooled by a *CRAH* (*computer room air handler*) was investigated. The results of the study showed that the use of waste heat could save millions of euros over its lifetime of 20 years. The most economical system would be heat pumps (HP), which raises the exhaust heat temperature to 75 °C and sells heat to either the supply or return side of the district heating system depending on the outside temperature. The investment costs for HPs raising temperatures up to 75 °C (Heat Factor (RSHF = 3.5) are EUR 420 000 higher than in the comparison case if the server room is cooled by free cooling and no waste heat is used. As the HPs were used to cool the server room, this increases the annual electricity consumption by more than 4 GWh compared to the reference case, which increases the financial costs. However, the annual sales of waste heat to the district heating network would be almost EUR 600 000 in this case. In conclusion, the study suggests that the payback period for investments in refrigeration equipment would be less than 2 years, as the revenue from the sale of heat is higher than the total additional electricity costs, investment costs and operating and maintenance costs.

4.5.2 Possibilities of using waste heat from data centres in Estonia

A very large data centre in terms of Estonia (server park, see photo below) will be built near the small town of Harku in Saue ParishFigure 4.9). The initial electrical capacity is planned to be 6 MW_{el} (~50 GWh of waste heat per year if operating evenly at full capacity all year round), which will later be increased to 20 MW_{el} if necessary, with the possibility of further additions (up to 32 MW_{el}). In comparison, Telia has a 24 MW_{el} data centre in Finland with 200 GWh of waste heat per year and it is used in the district heating network. Slightly more than 10 Gwh goes to conduct electrical processes. In data centres, about 95 % of the electricity supplied is unnecessarily lost as heat when waste heat is not used. Thus, compared with Telia, a data centre with a capacity of 20 MW should receive at least 150 GWh per year as waste heat (does not operate continuously at nominal load). With this amount of heat, the entire Õismäe district could be heated. As this data centre, being built by MCF Group Estonia, is to the left of Paldiski highway (if you drive from Õismäe towards Keila), then the district heating network of Harku settlement should be from a few hundred metres away from the centre (according to a member of Harku Rural Municipality Council) to 1.4 km (according to Nomine Consult OÜ)[19] and Õismäe Astangu district heating network about 4—5 km from a bird's eye view. From Harku settlement to Tallinn, a canal has been built in limestone soil for water and sewerage pipelines, to which district heating pipelines could be added if necessary. The district heating network of Harkujärve Village is also about 4 km away in the same direction.

[17] Kupiainen M. Lämpöpumppu konesalin jäähdytyksessä ja lämmöntalteenotossa (In Finnish, Data center cooling and heat recovery with a heat pump).

[18] Stenberg S-Å. Tietokonesalien hukkalämmön hyödyntämismahdollisuuksien teknistaloudellinen optimointi (In Finnish, Technical and economical optimization of data centre waste heat utilization) Master's thesis Espoo, Finland: Aalto University; 2015.

[19] Nomine Consult OÜ, 2019, Tallinn. Preliminary study of the possibilities of using the residual heat of Harku data centre

For all existing and future larger data centres (over 0.5 MW), it would definitely be worth considering and analysing the deployment and cost-effectiveness of waste heat, as 4 GWh of waste heat could be obtained in the best case scenario. If it is possible to sell it to a district heating network company at a variable cost price of ~20 EUR/MWh, then EUR 80 000 a year could be obtained from the sale. By analogy with the Finnish example, the return on investment would also take less than 2 years, but in Estonia it still depends on the length of the connecting pipeline and the conditions for commissioning the route and may not be as cost-effective. This does not mean that the waste heat of even smaller data centres cannot find a useful application.

Recommended

When planning data centres, one could also consider whether there is a working district heating network with sufficient heat load to which the waste heat could be directed. Secondly, it is necessary to find the nearest and most suitable power plant. The locations of the substations are selected according to the needs of the electricity network and the district heating network may not be in their vicinity. However, there may be suitable places in larger cities. If it is known in advance that the heat can be sold, it can also offset the higher cost of buying or renting a data centre.

Figure 4.9. MCF Group Estonia Harku data centre next to Harku substation Photo Ü. Kask

4.6 Methods for the detection of industrial waste heat

Surplus detection methods are usually classified as either top-down or bottom-up. In addition, the potential identified may be theoretical, technical or economic (see next section).

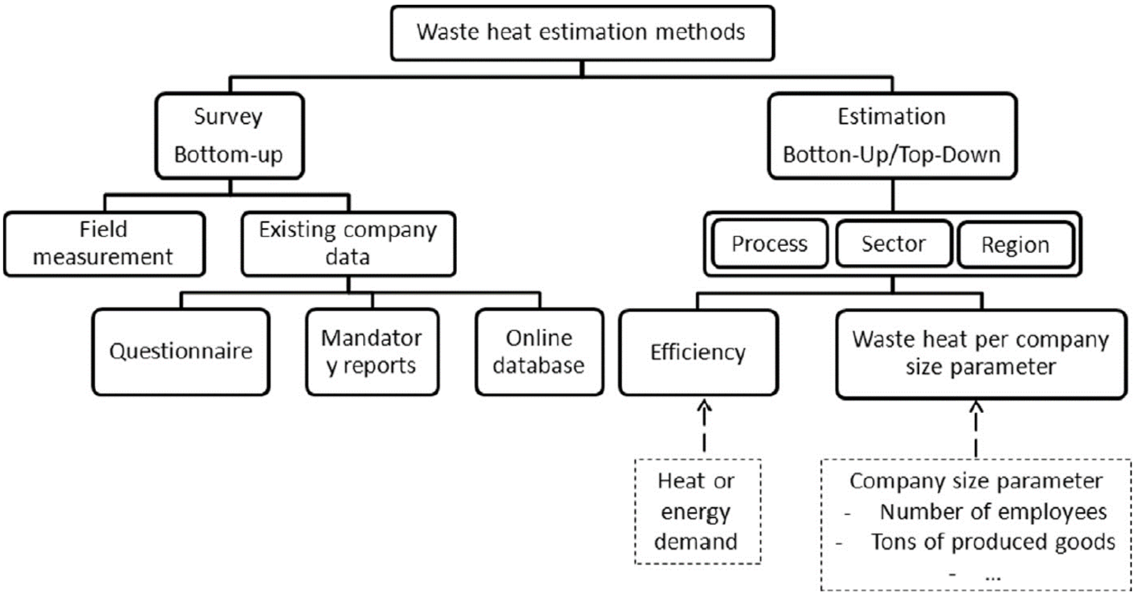


Figure 4.10. Classification and method of determination of waste heat[20]

Top-down approach: Based on the use of primary energy, the assumptions about energy efficiency and energy distribution allow one to assess the potential of waste heat in different sectors. Using this method, it is difficult to decide on the temperature and availability of waste heat.

Bottom-up approach: specific data on representative companies and places in the field are collected through questionnaires or even measurements. Depending on the level of detail of the questionnaire, this method allows conclusions to be drawn about the technical potential of a particular company or sector. Measurements are by far the most complex method. Several companies/sites need to be reviewed and re-measured and there may be a conflict with the confidentiality of process data.

A top-down and bottom-up approach could also be combined.

Method for determining the exhaust heat temperature level

The temperature level of the actual industrial waste heat depends on the temperature of the refrigeration and cooling equipment used, i.e. the temperature of the cooling water, air, etc. This waste heat can be collected, for example, from the hot side of refrigerators/coolers. However, the possible temperature level is even higher, as the network of heat exchangers improves and develops, which can sometimes raise the temperature level by a certain amount. In addition, upgrading the network of heat exchangers for the use of waste heat would reduce the amount of waste heat that could be used and would also affect its temperature level. All these aspects are important in waste heat recovery projects. To quantify these parameters, so-called complex process integration curves and bottleneck analysis have been developed.

Bottleneck analysis is a method of thermal integration based on thermodynamics.

In terms of energy or heat use, the process consists of streams that go through either a heating or cooling process. The flows are characterised by initial temperature, target

[20] S. Brueckner *et al.* Methods to estimate the industrial waste heat potential of regions – A categorization and literature review. Renewable and Sustainable Energy Reviews 38 (2014)164–171.

temperature and heat load. Flows that need cooling are called hot (regardless of absolute temperature) and streams that need heating are called cold.

When all hot streams are combined into one hypothetical stream (in terms of temperature and load), a so-called hot composite stream or mixture is obtained. Similarly, a cold composite stream (mixture) is obtained by combining all the cold streams. The combined flows show the accumulated cooling and heating needs. When composite flows are plotted on a graph of temperature and heat load, *composite curves are obtained*) (Figure 4.11).

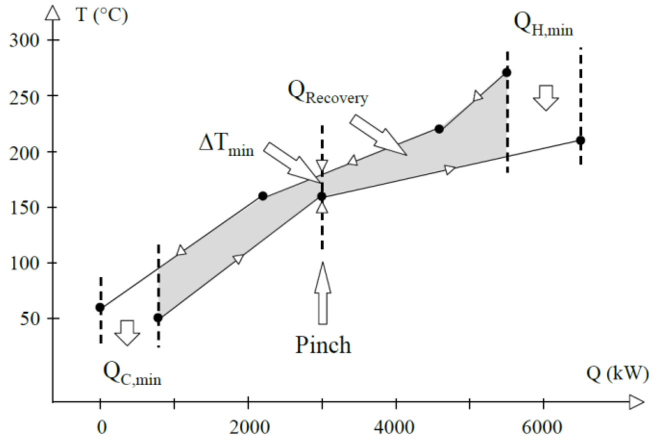


Figure 4.11. Relationship between waste heat source capacity and waste heat carrier temperature, i.e. composite curves [21]

Pinch point – breaking point or deadlock, constriction, bottleneck; $Q_{recovery}$ – heat to be used (convertible heat).

The maximum thermodynamically possible amount of heat recovery can be determined from the composite flow curves. The curves are separated by a minimum temperature difference (based on the temperature difference), which is the minimum starting temperature for heat exchange. This location is called a breakpoint or bottleneck. The low temperature difference increases the possibility of heat recovery, although it reduces the demand for use, but also increases the required heat exchanger surface.

The breaking point temperature divides the system into two parts. Above this point we have a heat deficit area, below, however, is the surplus area. Therefore, the breaking point rules must not be violated in order to obtain a system with minimum waste heat consumption, for example, it is not wise to place the condenser above the breakpoint. Cooling of the hot streams above the breaking point takes place during the heat exchange between the processes. Similarly, it is not practical to place the heater below the breaking point. Heating of the cold streams below the breaking point takes place by heat exchange between the processes. In addition, we do not transfer heat downwards through the breaking point.

A large composite flow, or composite curve – also called a heat surplus diagram – shows the net heating or cooling demand on a temperature scale.

[21] ANNEX XV: Industrial Excess Heat Recovery –Technologies and Applications. Supported by Denmark, Germany, Norway, Portugal, US and Sweden Final report Phase 1, 5 May 2015. Prepared by Thore Berntsson CIT Industriell Energi AB, Sweden, Anders Åsblad CIT Industriell Energi AB, Sweden. IETS

Besseling & Pershad[22] present the temperature ranges of the available waste heat as shown in Figure 4.12. Most of the waste heat is available at lower temperatures, below 150 °C.

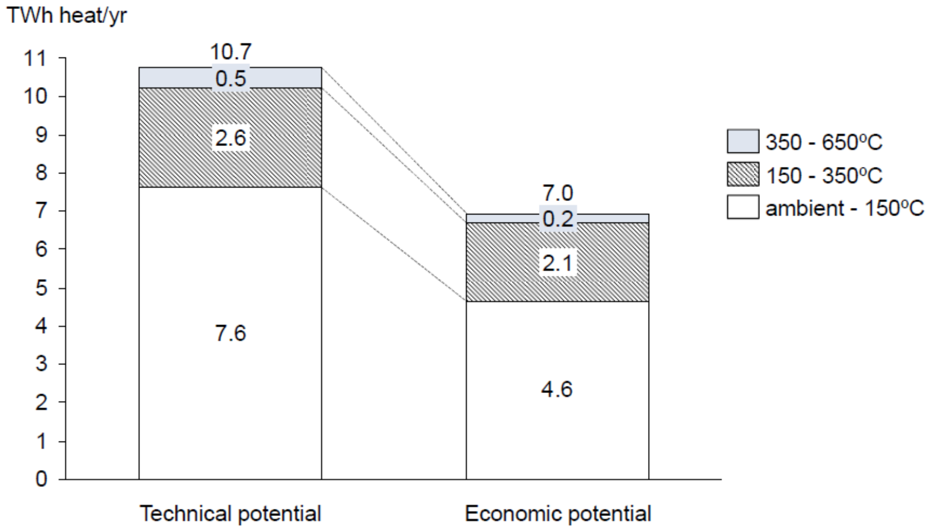


Figure 4.12. Exhaust heat temperature levels considering technical and economic potential

4.7 Definition of waste heat potential

In order to estimate the waste heat by different methods, it is first necessary to differentiate the heat potentials. In general, three different types of potential can be distinguished: theoretical or physical potential[23], technical potential and economically feasible potential (Figure 4.13)[24]. The theoretical potential only takes into account physical constraints: heat above ambient temperature related to the environment, etc. Thus, scattered heat, such as radiation, is not assessed. It also does not take into account whether and how heat can be separated from the carrier medium or how it could be used. These limitations will be taken into account in determining the technical potential. This potential therefore depends on the technologies used. Technical limitations are, for example, the minimum temperature for the operation of the system, temperature losses due to heat transfer, etc. The economic aspect of waste heat application (usage) is considered when assessing the economic potential. This is often referred to as economically feasible potential. Financial parameters such as energy prices, interest rates and payback period are taken into account.

[22] J. Besseling and H. Pershad, 'The potential for recovering and using surplus heat from industry,' Element Energy Limited, London, 2014.

[23] Metz B, Davidson O R, Bosch P R, Dave R, Meyer L A (eds). IPCC Fourth Assessment Q4 Report: Climate Change. Working Group III: Mitigation of Climate Change. Cambridge, United Kingdom; New York, NY, USA: Cambridge University Press; 2007

[24] S. Brueckner *et al.* Methods to estimate the industrial waste heat potential of regions – A categorization and literature review. Renewable and Sustainable Energy Reviews 38 (2014)164–17.

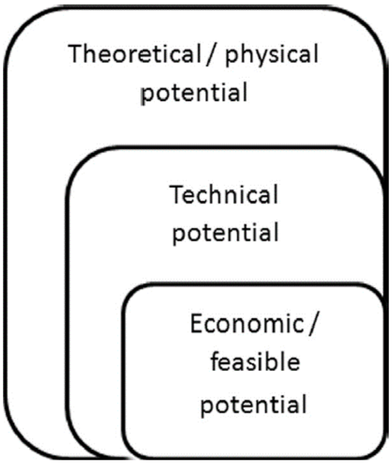


Figure 4.13. Types of waste heat potential (theoretical or physical potential, technical potential and economically feasible potential)[25]

4.8 Exhaust heat utilisation threshold (rated capacity of the heating system, heat carrier temperature)

The terms waste heat and residual heat have been used in both foreign and Estonian literature. In the context of this work, it would not be sensible to start defining either of them separately, but only the content of the term 'waste heat' used in the Energy Efficiency Directive is covered by the definition in 'The Handbook of Sustainable Development'. The production process needs to be seen in a broader context, covering direct production, the service sector, energy, agriculture and the housing sector. All energy conversion processes, wherever they occur, which emit heat and can be used cost-effectively (continue to convert), should be considered. Under Article 14(6) of the Energy Efficiency Directive, Member States may set thresholds, expressed in terms of available useful waste heat.

Pursuant to paragraph 5(c) and (d) of the above Article, heat sources and their waste heat potential with a rated output of more than 20 MW should be considered in each Member State, including a cost-benefit analysis if:

> (c) an industrial plant producing waste heat with a total rated thermal input exceeding 20 MW and a useful temperature is planned or substantially repaired in order to assess the costs and benefits of using waste heat, including cogeneration, to meet economically justifiable demand and connecting that installation to the district heating and cooling network;
>
> (d) a new district heating and cooling network or a new power plant with a total rated thermal input exceeding 20 MW in the existing district heating and cooling network is

[25] S. Brueckner *et al.* Methods to estimate the industrial waste heat potential of regions – A categorization and literature review. Renewable and Sustainable Energy Reviews 38 (2014)164–171.

planned or a major refurbishment of such an existing plant to assess the costs and benefits of using waste heat from nearby industrial installations.

The authors of the report base their threshold for Estonia on the capacity of the waste heat source from 5 MW, based on which the quantities of waste heat may be of interest to district heating networks or other companies that can potentially use low-temperature waste heat (covered fish gardens, dryers, fish and algae farming, etc.). Of course, companies in particular can and should try to make the most of the waste heat they generate (for preheating ventilation air, heating washing water, heating office buildings and in technological processes). In fact, quite a number of companies have already done so or plan to make corresponding investments in the near future (Saint-Gobain Eesti AS in Elva).

According to the literature[26], waste heat losses, i.e. waste heat, could be divided into three categories:

1. **High temperature waste heat** – temperatures above 400 °C (exhaust gases from internal combustion engines, exhaust from industrial furnaces, exhaust air from high temperature processes, etc.). In Estonia, the lower limit for high-temperature heat could be 300 °C, because it can be converted into electricity using economically reasonable costs using ORC technology (assuming, for example, support for the resource efficiency measure);

2. **Medium temperature waste heat –** this category covers temperatures between 100 and 400 °C (flue gases from combustion plants, exhaust air from some industrial processes, etc.). In Estonia, it would be in the range 100—300 °C;

3. **Low temperature waste heat** – temperature below 100 °C (heating, refrigeration, cooling and ventilation systems, exhaust air from many industrial processes, etc., estimated to be predominant in Estonia).

4.9 Obstacles to the use of waste heat

Financial and regulatory constraints are very common barriers to new technologies, as well as to waste heat technologies. In addition, earning income from waste heat is not the main business line of production companies. But, as the International Energy Agency[27] (IEA) points out, there are significant technical challenges in waste heat recovery. These technical challenges are sometimes the main barriers to the implementation of industrial waste heat recovery projects. Table 4.2 gives a list of expert-weighted barriers, according to their relevance, in the form of high-temperature exhaust gases or process gases, is added. In various processes, these gases can contain corrosive substances/components and particulate matter, making them difficult to trap and recycle. With the introduction of waste heat recovery technologies, frequent shutdowns of equipment and production lines, physical constraints on the environment and space, proximity and use of heat recovery are also issues to consider and, where possible, address.

[26] Bruckner, S. Liu, M. Laia, M. Radspieler, L. F. Cabeza and L. Eberhard, 'Industrial waste heat recovery technologies: An economic analysis of heat transformation technologies" Applied Energy, vol. 151, No. 1, pp. 157—167, 2015.

[27] International Energy Agency, Industrial Energy-related Technologies and Systems. Industrial excess heat recovery technologies & applications; 2010.

Table 4.2. Barriers to the use of waste heat weighed by experts[28]

Barriers	Possible solutions	Relevance[a]
Technological barriers		
No nearby heat sink		High
For in-house use		High
For heat transfer to third parties	Building heating pipes, heat transport	High
No information about heat sinks nearby	Waste heat exchange (information portal)Look for neighboring businesses such as in industrial areas	High
Time discrepancy Generation of heat/demand	Using heat in a different way such as power generation or feeding the power grid, storage	Medium
Temperature levels		
Too low	Using heat pumps	Medium
Too high	Mixing in steam or similar, cascading the use	Low
Production process		
Disturbance of the operation		High
Production reliability		High
During the conversion phase		Medium
Ongoing		
Boiler reliability	Redundant boilers	Medium
Financial and administrative barriers		
Availability of investment funds	Subsidies, loans	Medium
Priority of the core business	Use of service providers, waste heat contracting	Medium
Too high rate of return expectations	Information about life cycle costs	High
Uncertainty of the economic future		
For the investing company		High
For potential heating customers		Medium
Administrative effort for approval, execution and accounting		Low
Information		
Lack of business knowledge and personnel	Information campaigns and technology specific training courses for selected target groups	Medium
Research costs too high	Development investment calculation tools for consulting engineers and facility operators in the workplace	Low

[a] Emphasis determined by 30 experts during a workshop in April 2010.

Relevance – relevance/importance

Table 4.2 there are a total of 8 high/critical barriers to the use of waste heat in industry. The first four concern technological barriers: there is no place nearby to direct waste heat both inside and outside the company, there is no knowledge of where to direct heat in the neighbourhood. Two crucial barriers concern production processes: disruption of operation and production reliability. The latter two factors concern financial and managerial barriers: the expectation of too high a return and uncertainty about the economic future (investors do not tend to finance). Other circumstances are mostly in the middle (8) and low (3) risk classes.

4.10 Transition to a low-temperature district heating network as a prerequisite for realising the potential of waste heat

The main structural barrier to the deployment of waste heat sources is the temperature difference between the waste heat carrier and the district heating network carrier. In the course of this work, the potential of low-temperature networks in reducing primary energy

[28] S. Brueckner *et al.* Methods to estimate the industrial waste heat potential of regions – A categorization and literature review. Renewable and Sustainable Energy Reviews 38 (2014)164—171.

consumption was also mapped. It is not necessarily necessary to build low-temperature networks on a large scale immediately (i.e. to convert existing ones to low-temperature), instead practical strategic steps could be taken to build so-called low-temperature district heating islands in existing district heating areas (larger cities). These can be, for example, the new development area of Paekalda in Tallinn, the new development area of Kopli lines, etc. Another option is to connect buildings in existing district heating areas to the return pipeline of the existing network. In this way, individual buildings could be merged in any area of the network where technical conditions allow.

The decrease in primary energy consumption is the result of a combination of different activities.

Key findings from the literature review:

— The construction of a low-temperature district heating network is also competitive in terms of lifetime costs (higher pumping costs) compared to a high-temperature network due to lower investment costs (lower costs due to the need to use compensators). Heat losses in pipelines are reduced.

— The connection of buildings and groups of buildings to the return pipeline is possible and has a very positive economic effect across the system, as the efficiency of high temperature heat production increases as a result of increasing the difference between supply and return temperature in a district heating boiler, which is especially important when using flue gas condensing equipment (scrubber).

Initial recommendations need a more detailed effect assessment:

1) When allocating state reconstruction subsidies, in the case of complete (complex) reconstruction projects, to encourage the design of buildings with low-temperature heat carriers.

Recital The lifespan of building heating systems is very long, thus the further the implementation of the low-temperature heat carrier is delayed, the further the introduction and deepening of waste heat is *technological lock-in* is delayed. The readiness of the low-temperature heat carrier is not likely to significantly increase the cost of reconstruction and construction.

2) When processing general and detailed plans, consider and envisage the possibility of connecting a low-temperature district heating network to the return line of the district heating network in the case of new developments, encouraging it with financial measures if necessary. The so-called low-temperature district heating islands (LTDH islands) should be created.

3) To find opportunities for financing pilot areas of the low-temperature district heating network (LTDH islands), where the pipelines have not yet been reconstructed or the aim is to establish new district heating areas.

4) Offer apartment associations that have not yet joined district heating or wish to do so after reconstruction to join the district heating network return (for switching to low-temperature heating or its construction), in any part of the district heating network. These would be low temperature heating buildings.

District heating systems require dynamic modelling (simulation calculations) when district heating networks will be partially or completely switched to low temperature mode (e.g. 60-40 °C or other). It is necessary to find so-called bottlenecks through which the required amount of heat carrier (hot water) cannot be passed, to investigate whether and to what extent pipes, heat exchangers, mains pump, etc. should be replaced.

Secondly, it should be clarified to what extent and under what conditions the existing district heating network is ready to accept or what can be done to receive low-temperature heat from industry, housing, the service sector, etc. Also, whether there is technical and economic potential for the construction of a seasonal heat storage (or a shorter-term heat storage) in the district heating network. Particular attention must be paid to district heating systems with CHP stations.

To illustrate the potential for primary energy savings in low-temperature networks, statistics on the area of licensed premises were used and an attempt was made to assess the effects on the system.

4.11 Summary of waste heat potential assessment

There are many different methods for estimating the potential for waste heat. They mostly depend on existing and available data. Due to the lack of country-specific data in many countries, basic data from other countries have been applied in several studies. Within the European Union, a common definition of industrial sectors is used. However, outside the European Union, special attention must be paid to the definition and boundaries of sectors. Due to differences in national databases, a direct comparison of different methods has not been possible so far. This lack of data is a major obstacle to the quantification (determination of the quantity) and use of industrial waste heat. Meta-analyses of different survey results in the same area would also be needed.

Another local problem in Estonia is the lack of data on the amount of waste heat (heat carriers), especially in the industrial and service sectors. The situation is better in the energy and housing industries, especially in the energy industry, where there are several data sources, on the basis of which the theoretical and partially used waste heat can be estimated (Statistics Estonia, the Environmental Agency, the Estonian Power Plants and District Heating Association).

5 Waste heat sources in more detail

5.1 Waste heat from district heating systems

In district heating companies, waste heat is generated in the following places (consider the existing cases in Estonia):

A. Waste heat from combined heat and power production (CPH). If there is a cogeneration unit(s), the heat not used or left over from the electricity production qualifies as waste heat. Where the heat is released exactly, in turn depends on the technology and equipment used.

1. In the case of a back-pressure turbine CPH, the steam operated in the turbine is directed to a heat exchanger, where it transfers its heat to the district heating water. The most common variant in Estonia

2. In the case of an intermediate turbine (Balti Elektrijaam Narva), it is possible to use both intermediate steam (pressure level depends on the technical parameters of the district heating system) in district heating heat exchangers and cooling water heat from the condenser. The latter generates a large amount of heat, but it is of low temperature and cannot be used directly in a district heating system. The heat pump must be used or the heat must be used directly in fish farming or elsewhere. Uncommon in Estonia

For both types of turbines, steam is produced from a steam boiler. If they work with wet wood chips or natural gas, the waste heat can still be obtained from the flue gas cooling or condensation (usually to 40-50 °C) and the flue gas cooled in the flue gas condenser (scrubber, scrubber) can be cooled down to 30 °C, and use the resulting heat to preheat the outside combustion air (this should be done if the respective boiler has not already been used, where the combustion air from the boiler room passes between the boiler walls where it heats up). It would also be possible to use the heat of the condensate (water) generated during the condensation of flue gases, which could be transferred to the district heating network (utilised at Utilitas Tallinn AS Mustamäe SEK station) or elsewhere (water-to-air heat exchanger, e.g. to dryers).

The steam heat from the steam boiler purge (continuous and intermittent purge) can also be used via a heat exchanger, e.g. to preheat the feed water or combustion air or in certain drying processes. In general, in steam boiler houses, the use of exhaust steam heat is already planned in the design, where in the same boiler house it is not economically feasible (e.g. in the preparation of feed water, in deaerators).

The use of waste heat in steam boiler houses in industrial enterprises may not be applied as efficiently as in steam boiler houses in heat enterprises and power plants. Today, steam boilers are practically no longer used in conventional district heating boiler houses, some reserve boilers may still be present.

3. In the case of an Otto or diesel CPH plant, the largest amount of waste heat is obtained through a heat exchanger, where the heat of the engine exhaust gases is transferred to the district heating water. The second part of the heat is obtained from the coolant circulating in the engine cooling jacket by means of a heat exchanger and the third part by means of a heat exchanger cooling the engine lubrication system. These heat streams are all routed to the district heating network or for own use, e.g. when the engine is running in a biogas plant, some of the heat is used to heat the fermentable mass and in some cases also for the hygienisation (pasteurisation) of the digestate. Used in biogas plants in Estonia.

4. In the case of wood gas generators, heat is obtained from ash cooling (not for all manufacturers' equipment) and from the flue gases, water jacket and oil cooling of the gas engine (usually the Otto engine) (similar to the previous one). It is probably not used in Estonia yet, but a lot in Latvia and Lithuania.

<u>B. Waste heat from district heating boiler housings</u> The above must be repeated here. If the boilers work with wet wood chips or natural gas, the waste heat is obtained from the cooling or condensation of the flue gases (usually to a temperature of 40–50 °C). With such devices (flue gas condenser, washer, scrubber) it would be possible to obtain an additional 10–20 % of heat, which, when not in use, is transferred to the atmosphere as waste heat of wet flue gases. The flue gas cooled in the flue gas condenser could in turn be cooled down to 30 °C and the resulting heat used to preheat the outside combustion air (this should be done if the respective boiler, where the combustion air taken from the boiler housing passes between the boiler masonry walls where it heats up). It would also be possible to use the heat of the condensate (water) generated during the condensation of flue gases, which could be transferred to the district heating network (utilised at Utilitas Tallinn AS Mustamäe SEK) or elsewhere (water-to-air heat exchanger, e.g. to dryers).

In fact, in almost all boiler housings, the flue gases from the boiler hearth are used to heat the boiler feed water in an economiser. In a sense, it is the utilisation of heat generated during combustion in the hearth and utilisation of heat unused in the convective heating surfaces of the boiler. It probably doesn't make sense for us to consider this as waste heat, because the application of the economiser in practically all modern boiler housings is already designed and provided by the boiler manufacturer (it was already here during the Soviet era).

<u>C. Other possibilities for obtaining and using waste heat in a district heating system:</u>

1. Heat obtained from district heating consumers. If the consumer is an industrial plant, the use of their waste heat in a district heating plant can be attractive. AS Kroonpress in Tartu is a good and so far the only example in Estonia. The company's building has been connected to the district heating network for a long time and receives heat from it if necessary. At the same time, they generate waste heat from the cooling of the printing machine, and in certain periods this heat is directed to the district heating network of the city of Tartu. If they themselves need heat, they get it from the district heating network. The district heating company (Fortum Tartu AS) generally wants to obtain heat at a temperature that can be fed into the district heating network supply pipe. This is especially important if a CHP station is operating in the district heating network and/or if a flue gas condenser is used. If more heat is directed to the return pipe, it raises the return water temperature and the CHP device and flue gas condenser are no longer very efficient. A small amount (compared to the amount of heat circulating in the district heating network) could also be absorbed by the return water line. For example, from some small company, small server station, Apartment Association housing, etc.). This optimal amount needs to be determined (calculated) for each district heating network separately, however, it is possible in large district heating networks (Tallinn, Tartu, Pärnu, Narva, etc.).

2. It would be possible to establish low temperature district heating islands/sub-regions in some newly developed areas of the district heating area. They would receive water from the return line of the main water network (average temperature 50 °C) and use it, for

example, for underfloor heating in the buildings (Paekalda area and Kopli Lines area in Tallinn and two pilot areas in Tartu). Calculations have also been made for the areas of Tallinn, but they have not yet started at low temperatures. In this case, the temperature in the return line of the transmission network would decrease further, which would further increase the efficiency of CHP equipment and the flue gas condenser. The disadvantage is that the required temperature of 55 °C for domestic hot water cannot be ensured without auxiliary equipment (electric heater) or electric boilers (or electric heaters in capacity boilers) should be used instead to heat domestic hot water. Alternatively, solar collectors could be used to heat domestic hot water at least during the summer, and electricity could be used at other times.

3. Construction of large heat accumulators It is economically justified to build them in district heating networks where cogeneration of electricity and heat takes place. In order to ensure maximum electricity production around the clock or all year round, either short-term storage devices (tanks or storages) (a day or two) or seasonal tanks (for storing heat produced in summer for winter) should be built. A short-term tank (heat storage) is in use at the Kuressaare SEK station and seasonal use was planned in Utilitas at Tallinn Power Plant in Väos, Tallinn, but calculations showed that it is not economically justified today. Situations and circumstances may change in the future, since many seasonal heat accumulators are operating in Denmark. Seasonal heat accumulators would also allow the intake of waste heat from small producers (e.g. apartment associations and companies) without the heat company having to reduce the production of its CHP plant. Housing associations should in any case use HP (heat pumps) to raise the waste heat temperature to suit the district heating network.

5.2 Waste heat from industry and the service sector

1. During the summer, it would be possible to produce cooling with absorption chillers on the basis of waste heat (heat carrier minimum temperature 90 °C) (it could be used in both district heating systems and industry).

2. Medium and large industrial enterprises are more likely to receive sufficient amounts of higher and medium temperature heat (above 100 °C) which is economically justified to be directed to the district heating supply line via a heat exchanger. It is possible to raise the temperature of the heat carrier (air, water, etc.) to the water temperature of the district heating network supply line by means of a heat pump (some district heating networks use max 90 °C water, but also lower during part of the heating period).

3. Unfortunately, there are relatively few of such industrial enterprises in Estonian cities that would be located near district heating networks and would have a sufficient and uniform amount (the so-called attractive amount) of waste heat of suitable temperature to be transmitted to the district heating network all year round. In most cases, there is more heat left over during the warm period when the district heating company can efficiently produce heat itself (usually also with cheap wood fuel or, in the case of Kohtla-Järve and Ahtme, with generator gas, which is a residual product in their case). If a biofuel heat plant has to start using fossil fuels (e.g. natural gas or fuel oil) as the weather cools (often between +5 and -5 °C, depending on the district heating system), waste heat from the plants (fed into the supply pipe) would be very welcome.

The following companies in Tartu could be addressed regarding waste heat: A. I.e. Coq AS, Estiko Plastar AS (about heat from thermal oxidiser), Salvest AS, Tarmeko AS, Tartu Veevärk AS, International Aluminium Casting Tartu AS, in the future Epler & Lorenz AS – new waste incineration plant, when it becomes operational, and some others. Utilitas Tallinn

AS and Adven Eesti AS have not been offered industrial waste heat so far, but there would be potential at the AS Tallinna Vesi wastewater treatment plant in Paljassaare (heat from wastewater).

In fact, in all of the above, some of the waste heat from the equipment has already been applied internally, but larger investments to sell off waste heat to meet the buyer's terms and conditions have not yet been considered profitable by companies.

4. Heat from refrigeration equipment (including refrigerators) (usually waste heat from air coolers and compressors) They could be treated separately, as they can be located in CHP stations, district cooling stations (Tartu, Tallinn, Pärnu), boiler housings, industrial enterprises (incl. Beverage and food industry, fishing and agricultural enterprises), commercial enterprises and elsewhere. The waste heat temperatures there are generally low to direct the supply line directly to the district heating network and should be used to raise the temperature of the heat pump.

5. Heat from ventilation systems (industry, trade, services, housings, etc.). When ventilating hot or hot rooms (workplaces), very large amounts of air move, but their temperature is generally not high, below 40 °C. It could be routed to the district heating network via a heat pump. See also chapter 4.5. Data centre waste heat. Exhaust heat from certain industrial processes (cooling of the formed metal, annealing, etc.) may also be transmitted to the district heating network supply line by means of heat exchangers, which would be attractive to the district heating company.

5.3 Summary and some important conclusions

Heitsoojus (*waste heat, excess heat, Abwärme (f), бросовое тепло)* – heat released during the production process and not being used. The generation of waste heat is thermodynamically inevitable in any energy conversion. Redirecting waste heat back to production, using it for heating or water heating saves natural resources (mainly fuels) and reduces overall pollution

The authors of the report base their threshold for Estonia on the capacity of the waste heat source from 5 MW, based on which the quantities of waste heat may be of interest to district heating networks or other companies that can potentially use low-temperature waste heat (covered fish gardens, dryers, fish and algae farming, etc.).

Conclusions

1. High and medium temperature waste heat was already used by power plants, SEC plants and district heating companies during the Soviet era. District heating as a method of heating has historically originated from the utilisation of waste heat (for the first time in 1877 in the United States, Lockport, New York).[29]

2. In individual cases, the use of waste heat from companies has already been implemented or can be implemented, where there is a source of waste heat and the parameters of this waste are suitable for the transmission line, where uniform and year-round availability is

[29] District heating. Convenient, efficient and affordable. Prepared by Ü. Kask. EJKÜ, 2013.

guaranteed and where it is located close to the district heating network (AS Kroonpress in Tartu).

3. Wider use of waste heat in district heating systems requires the presence of a low-temperature district heating network or a seasonal heat accumulator. Reconstruction of existing district heating systems is a very lengthy but potentially positive process for society, which would require a more detailed analysis of how to lower the network temperature on existing infrastructure, connect consumers to the return pipeline and build a low-temperature network.

4. The aforementioned sources that meet all the conditions, are few.

Their use would also pose a risk to the district heating company, as the profile of companies transmitting waste heat today may change in the future, and companies themselves may go bankrupt under unfavourable economic conditions. In this case, the district heating company itself must be able to compensate for the missing amount of heat (it must maintain reserve capacities, the cost of which will be calculated according to the price of heat).

5. Nowadays, most of the district heating companies and CHP plants already use, to a greater or lesser extent, the high and medium temperature waste heat generated in their plants. There is bigger potential, but it is not always economically justified without subsidies.

6. Low-temperature (below 100°C) waste heat has mostly been unused or used to a lesser extent in industry, service companies and housing. The predominant ones are heat recovery for heating the ventilation air being sucked into the building, waste water heat recovery and domestic water heating.

7. Due to the resource efficiency measure (EIC), which partially (up to 50 %) finances companies' resource efficiency projects, waste heat has also been used mainly in-house (e.g. A. le Coq AS in Tartu, installed a flue gas condenser on a gas boiler and uses waste heat to heat buildings, buys less natural gas than before the investment to obtain the same amount of heat).

8. Larger investments to sell waste heat out of the companies (incl. KÜ) to meet the buyer's conditions have not yet been considered profitable (without appreciable support measures) by the companies (except for Kroonpress AS in Tartu).

9. After the last EU financial period (2014–2020), information days and seminars should be organised to present waste heat and energy efficiency projects funded from the resource efficiency measures[30]. The awareness of company managers about the possibilities of using waste heat as well as the awareness of support measures for the implementation of the respective projects is not yet sufficient. The resource efficiency measure for companies could certainly continue in the next EU financial period 2021–2027.

[30] Regulation No. 17 of the Minister of the Environment of 28 June 2016 ‘Conditions for Granting Support for the Measure ‘Energy and Resource Efficiency of Enterprises’’.

5.4 Institutional and legal issues related to the use of waste heat

The Industrial Emissions Act[31] (hereinafter IEA) aims to achieve a high level of protection of the environment as a whole by minimising the emission of pollutants into the air, water and soil and to reduce the generation of waste in order to avoid adverse effects on the environment. Direct or indirect release of heat due to human activities into the ambient air, water or soil, which may lead to an impact that needs to be reduced on the environment, human health, well-being, property and cultural heritage is pollution within the meaning of § 5(1) of the IEA. Heat emitted directly or indirectly into the ambient air, water or soil is an emission within the meaning of the Industrial Emissions Act, pursuant to § 5(3) of the IEA. The Industrial Emissions Act regulates, for example, the obligation to provide data on heat emissions in the context of an application for a waste incineration plant or waste co-incineration plant, the obligation to take into account the criterion of the proximity of the heat consumer or heat pipeline requiring the supply of heat from the incineration of waste when choosing the location of the plant, or remove as much of the heat from co-incineration as possible (a good example is Iru Power Plant).

Exhaust heat is not addressed separately in the District Heating Act[32] or the Electricity Market Act[33]. In § 2(27) of the Energy Management Organisation Act[34] (hereinafter EnKS) waste heat is referred to in the concept of efficient district heating and cooling, according to which district heating or cooling is an efficient district heating or cooling system that uses at least 50 % renewable energy, 50 % waste heat, 75 % cogeneration or 50 % combination of renewable energy and waste heat or cogeneration.

Pursuant to § 10(1)(3) and (6) of the EnkS and within the meaning of the Industrial Emissions Act, an undertaker shall prepare a cost-benefit analysis of the conversion of an installation into an efficient cogeneration plant if the undertaker plans:

- major reconstruction or construction of an industrial plant producing waste heat with a total rated thermal input exceeding 20 MW and a useful temperature;
- major reconstruction of an existing thermal power plant in such a way that it would be possible to make efficient use of the waste heat of a nearby industrial installation.

In consultation with the Competition Authority, it was confirmed that, **according to the current regulations, the addition of a waste heat source to the existing district heating network is considered as the purchase of heat by the existing heat undertaker.** Therefore, the heat company should first announce a heat purchase tender for the purchase of waste heat (these terms of reference are drawn up in such a way that the technical conditions and the quantity and period to be purchased are specified). Then, when the winner is announced, the heat company has to apply for a new heat price, because if it buys at a lower price than its variable cost of production, the price to the consumer should decrease to some extent. This is acceptable to the heat company on the one hand, as it increases its competitiveness and may motivate new customers to join, but on the other hand

[31] Industrial Emissions Act Entered into force on 1 January 2020, currently valid.

[32] District Heating Act. Entered into force on 1 July 2017, currently valid.

[33] Electricity Market Act. Entered into force on 1 July 2020, currently valid.

[34] Energy Management Organisation Act Entered into force on 1 July 2020, currently valid.

it involves risks. If a company goes bankrupt, re-profiles its production, has long breakdowns, etc., the heat company must in any case provide heat to its customers. This could mean launching reserve capacity and putting pressure on heat prices. If the latter is short term, the heat company will suffer a reduction in its own profits (reasonable profitability).

In practice, there are obstacles to this process that make the outcome unpredictable and prolong time for procedures. The Estonian Competition Authority (ECA) has not yet developed a methodology on how to start taking into account waste heat purchases from district heating companies. Determining technical conditions can be relatively difficult and in favour of one company, which would violate the terms of competition. Simplified conditions could be created for the introduction of industrial waste heat in district heating networks. The district heating company could decide to buy it itself if it proves to be economically viable. The price of purchased heat should not increase the price of heat in the district heating network area, so it can be lower than the price of variable costs of a district heating company (the relevance of the latter has been verified by the Competition Authority when approving the heat price). A district heating company will be interested in buying industrial waste heat if it can keep the price of heat stable or lower it, as this will improve its competitiveness in the market (consumers will not go to district heating).

The above-mentioned obstacles could be eliminated if the issue of waste heat is reflected in the District Heating Act and/or related regulations. After 2012, no amendments or additions to the District Heating Act or related regulations have been adopted. Legislation should be supplemented on the basis of existing guidelines agreed at the European Union level, the most important of which is Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (hereinafter Renewable Energy Directive), Article 24 of which, in particular paragraphs 4 to 6, deals with the connection of third-party suppliers for district heating and cooling systems. In addition, **Article 24(4)(a) of the 'Renewable Energy Directive' obliges Member States with a share of renewable energy and waste heat in district heating and cooling of less than 60 % to implement measures to increase the share of renewable energy/waste heat by at least one percentage point per year. According to Table 7.2 of this work, according to the data of 2019, the share of renewable energy sources is 55.7 %** and data for the year 2020 are not available yet, but for example, within the framework of the procedure of draft No. 20-0213/01[35] **consideration could be given, as a minimum, to designating a competent authority with limited powers to implement additional measures. This competent authority could also develop and publish non-discriminatory and transparent criteria for combining waste heat sources in the** three cases set out in the Directive (Article 24(4)(b)):

i) To meet the demands of new customers

ii) Replace existing heating or cooling energy production capacity

iii) Increase existing heating or cooling energy production capacity

The more opportunities there are for the use of waste heat for district heating networks (the more it would be available in the summer), the more certain the price of dual or multi-tariff heat should be introduced. If, for example, the price of heat is reduced in summer, consumers who have electric water heaters for the production of domestic hot water would be more motivated to take domestic hot water from the district heating network. Of course, this would require the restoration (in some places also the construction) of the domestic hot

[35] https://eelnoud.valitsus.ee/main/mount/docList/6c13f124-0fff-4aee-bfd7-febd96816259

water distribution pipelines. **The rehabilitation and construction of domestic water systems should be further supported. The benefits would increase due to the production of better quality drinking water, in addition, district heating will be used to heat domestic water, the summer heat load will increase, the use of waste heat from CHP plants and the use of waste heat from other sources will also increase.**

There are no support measures for the introduction of waste heat (except for the resource efficiency measure for companies, expiring in 2020). Without subsidies, companies' investments in waste heat may not be cost-effective. In general, there is no need for low temperature heat in companies. If it has been cost-effective, it has already been used in many places, either for heating washing water, for underfloor heating circuits or for preheating room supply air in ventilation systems. Most of the capacity obtained (used) from waste heat is less than 1 MW per company.

5.5 Industrial waste heat sources and their waste heat carriers

1. Large combustion plants (industrial boilers – hot gases, emitter and hot water)
2. Industrial furnaces (in the cement industry, clinker kilns, lime kilns, brick kilns, metal melting kilns – hot gases, glass melting kilns (baths) - hot air)
3. Autoclaves, steam generators (exhaust steam)
4. Dryers (wood dryers – moist air, paint dryers – polluted warm air)
5. Compressors for refrigeration and cooling equipment (hot water or hot air)
6. Pneumatic compressors – hot water, hot air
7. Boilers (exhaust steam, hot water), pasteurisers (exhaust steam, hot water)
8. Cooling and annealing chambers (hot or warm air)
9. Ash cooling (shale oil industry, hot water or air)
10. Cooling baths – hot water, hot air
11. Cooling of electrical equipment, including servers (hot air)
12. Ventilation (warm air)
13. Sewage water (hot water)
14. Wastewater heat from wastewater treatment plants (hot water, 8–10 °C, potential at the wastewater treatment plant of Tallinna Vesi AS, Paljassaare)
15. Cooling of large transformers (hot oil or air)
16. Server park cooling (hot water, hot air)
17. Water pumped out of mines (water with a uniform temperature throughout the year of 8–10 °C is directed to the HP, where the temperature is raised to 70 °C and it is used, for example, in the district heating network of Kiikla Village)
18. In landfills, either heat from the combustion of methane in a candle burner or heat from a biogas cogeneration plant, see above. Unused, e.g. at Jõelähtme landfill.
19. Grain dryers (warm and humid air, short-term operation)
20. Laundries and dry-cleaning companies (condensate, hot water or hot air)

5.6 Possibilities of using waste heat (mainly low temperature) outside companies that own it

Low temperature waste heat (below 100 °C and up to ~10 °C) can be recovered either through heat exchangers or heat pumps (HP). The following are the application options:

1. Dryers of all kinds (for drying foodstuffs, drying raw materials and paint/varnish, drying wood chips for small consumers, etc.)
2. Heat supply to neighbouring buildings (outside district heating networks) Whether in the underfloor heating circuit or for heating the supply air and ventilation of domestic hot water (the latter requires water or another heat carrier with a temperature of at least 60 °C, alternatively additional heating, e.g. electricity (to kill legionella bacteria periodically)
3. Low-temperature district heating (e.g. use of waste water from a wastewater treatment plant for district heating via HPs (in principle, it could also be used in conventional district heating networks, but this would require a two-stage temperature increase)
4. Heating of greenhouses and other indoor fish
5. Fish farms (for heating water up to 27–28 °C)
6. Algae cultivation (incl. for the production of liquid biofuels)
7. Heating of narrow streets, pedestrian streets, major intersections and squares in densely populated city centres with water from the district heating return line. Tests have been successful in a number of cities in the Nordic countries, where it has proven more cost-effective than snow removal by trucks. When a district heating network runs on renewable sources, it also has a major positive impact on the environment compared to fossil fuel using machines and trucks that remove snow. Undertaking would also be important for road safety, as it would reduce the number of accidents caused by slipperiness.
8. Energy industry companies (power plants, CHPs and boiler housings), if possible, all direct the waste heat generated as a by-product of electricity production or the waste heat from the condensation of water vapour from flue gases to district heating networks. Despite this, reserves still remain available in the field of the energy industry.

5.7 Calculations for the approximate volume of waste heat

The amount of energy transferred as heat is calculated with the formula

$Q = c_p\, m\, (t_1\text{-}t_2)$, J (or 1 J = 0.278 Wh), where

c_p is the thermal capacity of the heat exchange medium; it is expressed in J/(kg K) or J/(m^3 K), depending on whether the heat exchange medium is water or air;

m is the weight in kg (this can also be determined on the basis of the heat exchange medium input, depending on whether the heat exchange medium is water or air and the unit kg/s or m^3/s, thereafter the value has to be multiplied with the density of the heat exchange medium, ρ, kg/m^3, thereafter we have determined the quantity of heat in a unit of time, or J/s or W);

t_1 is the initial temperature of the heat exchange medium, °C, or T_1, K;

t_2 is the final temperature of the heat exchange medium, °C, or T_2, K.

We could take the calculation of the potential of the heat of the waste water from a sewage treatment plant as an example.

In the 65 sewage treatment plants operated by the water company that is active in waste water treatment, around 345 016 m^3 of wastewater is treated every day (125.93 million m^3/a year), in Tallinn around 135 708 m^3 a day and in 2019 49 669 352 m^3 (the share of Tallinn in the wastewater volume of the whole country corresponds to 39.4 %)[36].

The yearly mean minimum temperature difference (in winter) is 10-4=6°C (K). This means the difference between the temperature of the waste water that enters the SP and the temperature of the waste water that is led out of the SP into the environment. The thermal capacity of water is ~4.19 kJ/kg K and the density of water is ~1 000 kg/m^3.

The amount of energy that could theoretically be gained in the case of this difference with the winter temperature would be as follows:

125 930 000 m^3/a x 1 000 kg/m^3 x 4.19 kJ/kg K x 6 K = 3.166 10^{12} kJ/a = 3 166 TJ/per year, or 879 GWh/per year.

If the summer and winter period were combined, that is to say the annual weighed average would be 10 K, Estonian waste water treatment plants could altogether provide 5 276 TJ of waste heat per year, or 1 466 GWh or waste heat per year.

5.8 Some possibilities for using a waste heat and technological solution in Estonia

District heating companies as well as businesses, which use wet wood fuel or natural gas (or bio-gas), are capable of lowering the temperature to the degree that water vapour in the flue gas will condensate. During condensation, heat is released, which can be utilised somewhere with the help of a heat exchanger (flue gas condenser, washer, scrubber). In district heating enterprises, said district heating network is used for providing the consumers with heat. This means the heat, which one could say is additional to the heat they produce by boilers or the co-generation unit.

The cost of these units depends on the precise technological solutions, the type of units and their producers, and ultimately on the market situation.

[36]Conducting stocktaking on sewage sludge treatment in Estonia. PIC eesti AS. The work has been performed on the order of the Ministry of the Environment. Contract No. 2-15-16/691. Tallinn 2001

The temperature of the flue gases that the boiler and the supply water pre-heater (or economiser) that follow the boiler emit, may be on average around 150 °C (sometimes higher, sometimes lower) and it is cooled down to 60 to 70 °C. The temperature of the water returning from the district heating network should be lower than the temperature mentioned above and the lower the temperature of the returning water is, the more heat or gains one can acquire. The water is allowed to warm up to 90 °C, i.e. up to the temperature of the inflowing water (this temperature can also be higher if the temperature of the incoming water is higher).

Numerous district heating enterprises have installed such units. The last one to procure was Põrguvälja Soojus OÜ; ELVESO AS is about to procure. In order to find out the costs of a flue gas condenser (washer), only the costs of this device and its installation have to be found out, because oftentimes something else, such as water filters, are procured. Kuressaare Soojus AS, Utilitas Tallinn AS, Fortum Eesti AS-il, Adven Eesti AS, Danpower Eesti AS etc. also have condensers. Rapla Metall OÜ (as well as Tamult Bioenergy OÜ) are active in procuring and installing such devices.

Some businesses (such as A. le Coq AS in Tartu) have become beneficiaries for installing a flue gas condenser under the resource efficiency measure of the Environmental Investment Centre. Some businesses in the wood processing industry were not granted sufficient aid e.g. for utilising the waste heat from the dryers with the aim of pre-warming the air that is blown in. We could create a common sub-measure for the waste heat and heat re-use projects (in ventilation devices), to be financed on conditions that are more lenient or separate from the use of other resources.

Additionally, waste heat could be used in the food and drink industry as well as in the building material industry, where boiling devices and autoclaves are used. Steam, the temperature of which is up to 150 °C, is also often used there and it could be utilised (as is relatively often done) within the enterprise for warming up washing waters that have various purposes or for warming up the heating water of their own buildings. We can name the beer industry as an example (A. le Coq AS, Saku Õlletehas AS). Autoclaves (and the exhaust steam from them) are in AS Salvest and Põltsamaa Felix AS. Valio Võru Juustutööstus has used steam emission in a fine manner in-house. Autoclaves have been used by AS Silikaat in brick production and by Bauroc AS in fly ash brick production.

Many district heating companies that are equipped with co-generation units and other companies use steam back pressure turbines, where steam is allowed to expand to the pressure from 6 bars (~160 °C) downwards. The industrial extraction is usually 6 bars; however, there are few such enterprises left in Estonia (Silpower AS in Sillamäe is one of them). In co-generation installations, steam in the turbine is allowed to expand till approximately 1.5 to 2 bars (110 to 120 °C), after which it is directed into the heat exchanger of the district heating, where circulating water is being warmed.

Biogas plants (BGP) use internal combustion engines for operating the electricity generators. The heat deriving from the engine exhaust emissions, the water circulating in the engine water jacket and the water that is used for cooling the motor oil are used for warming up the water circulating in the district heating systems at Aravete, at Vinni (Vinni Biogaas OÜ), at Ilmatsalu and at Oisu (said BGS's are intending to switch to the production of biomethane or have already done so). There is surplus waste heat available at the electricity heat and power co-generation installation in the Jõelähtme landfill (other landfills and wastewater treatment plants have such installations, cf. Estonian Biogas Association[37]). This also counts

[37] Estonian Biogas Association. Production and usage. On the web: /http://eestibiogaas.ee/tootmine-ja-kasutamine/

as use of waste heat. In places where gas turbines are used for the co-generation of heat and electricity, emissions can likewise be used for warming up water circulating in district heating or local heating systems (high temperature waste heat approximately ~600 °C). Gas turbines are used in Estonia in very few isolated cases and as far as is known, there are actually none in district heating systems.

Biogas plants in Estonia[38]

Biogas plant enterprises that operate based on agricultural input (5):
Aravete Biogaas OÜ – heat passed on to district heating
Oisu Biogaas OÜ – heat passed on to district heating
Biometaan OÜ – produces biomethane, Koksvere, Põhja-Sakala rural municipality, no district heating
Vinni Biogaas OÜ – produces biomethane – heat passed over to district heating, 2018
Tartu Biogaas OÜ – produces biomethane – heat passed over to district heating, 2018
Saare Ekonomiks OÜ - Valjala, heat for captive use, does not possess district heating.

Waste water treatment (4) and industrial waste water treatment station (3) enterprises, that produce biogas:
Tallinna Vesi AS - biogas heat for own consumption
Kuressaare Veevärk AS - Kullimäe, heat for captive use
Narva Vesi AS
Tartu Vesi AS
Eastman Specialties OÜ
Salutaguse Pärmitehas
Estonian Cell AS – produces biomethane, near Kunda

The production of landfill gas takes place in the following enterprises/landfills (5):
Paikre OÜ, that is to say Rääma landfill, Paikuse rural municipality
Tallinna Prügilagaas OÜ (in Jõelähtme landfill), Rebala Village, Jõelähtme rural municipality
Uikala Prügila AS (Uikala landfill) Kukruse Village, Toila rural municipality
Aardlapalu landfill – Uhti Village, Kambja rural municipality)
Väätsa landfill – Roovere, Järva County

Many apartment associations that have had a heat recovery ventilation system heat pump installed in their residence during renovation works use heat they acquire for captive use, e.g. use the heat for warming up raw water or also for warming up heating water (in which case less energy is drawn from the district heating network). It is likewise possible to warm up the fresh air that is blown in with the ventilation system exhaust air by using a heat exchanger.

Plenty of shops (all newer supermarkets, Paide Maksimarket having been one of the first of these), food industries and fish industries use the waste heat of the refrigerating and cooling system compressors for warming up washing waters or (floor) heating water (if cold stores become empty, then their floors are heated, so as to have moisture purged faster. As a rule, this takes place for captive use. The prices of these systems are unknown.

[38] Estonian Biogas Association. Production and usage. On the web: /http://eestibiogaas.ee/tootmine-ja-kasutamine/

Estonia has several plastic industries, where it would also be possible to gain waste heat for using in greenhouses, dry kilns or even district heating systems. Unfortunately, as a rule these enterprises are located far from district heating networks (with the exception of Estiko Plastar AS in Tartu) and there aren't any greenhouses or dry kilns nearby.

Sawn timber industry and others, who use timber dry kilns, have started to use the heat from waste air arising from them with the purpose of additional pre-warming of the air that is blown in.

Owners of spas and leisure pools that use large ventilation systems with heat recovery additionally acquire extra heat from the condensation of the moist in the air, if they use fitting heat recovery systems (Energent, Zehnder etc.). What is being heated is the fresh air that is drawn from outside.

Some swimming pools and spas use heat exchangers for transferring heat from waste water to cooler water, that thereafter will be directed to the heat exchanger of the domestic hot water (e.g. Tabasalu swimming pool, Harku rural municipality). A two-step warming up process of domestic hot water takes place.

Some problems concerning waste heat use in Estonia

The problems presented below have been mapped in the course of conversations and interviews with managerial employees of Estonia's district heating companies.

The seasonability of the waste heat and the continuity of availability. Especially during the summer period, there is surplus heat, in case the district heating network (DHN) itself has sufficient heat. It would be especially inappropriate to purchase heat in summer, if there is a co-generation installation (CI) operating in the network. This would reduce the heat load and the co-generation device could also produce less electricity, thus lowering efficiency. However, in the case that there were no CI device and the generation of heat were to occur on the basis of fossil fuels, any waste heat input to DHN would be welcome and this could even be useful in the case of biofuels, if the boiler has no condenser (scrubber) attached to it. The most profitable way would be, if the amount of waste heat purchased completely covered the summer heat load. In such case the boiler plant devices could be stopped for that period. The authors of the paper as well as the interviewees are not aware of such sites existing in Estonia, as many sites lack any summer heat load. On the one hand the assertion is correct, that electric boilers in the case of DHN consumers do not favour district heating and are often CO_2 intensive. One such place is the town of Kiviõli, where Kiviõli Keemiatööstus OÜ supplies the town with heat produced on the basis of generator gas, which is a production residue, and there is sufficient waste heat, that could be used to cater for customer needs all year round. If the oil shale production ceases for some reason however, the town could only be heated by using natural gas (Kiviõli Soojus AS does have this possibility).

Cost of the waste heat. A district heating enterprise can purchase waste heat (this is economically sensible) at a price that is lower than the variable cost component of the production, e.g. in the case of the boiler plants operating on the basis of wood fuel, the price today could be an estimated 20 to 25 EUR/MWh.

In the case that the price of the waste heat is lower than the variable cost component of the heat produced from some fuel, it would be sensible for the enterprise that supplies heat to purchase waste heat. If fuel prices rise, then the profitability would improve and it would be possible to buy waste heat at a higher price. Companies that produce heat from fuel oils or any fossil fuels should give special consideration to purchasing waste heat in their district heating network. Additionally, buying waste heat would serve as a reputation enhancement measure. The competition Authority would continue regulating how waste heat is bought and transmitted as it currently does: the price of the heat needs to be changed in the case that the fuel price gets cheaper or it can be changed if it gets more expensive.

Connecting the waste heat source with the district heating network. Even before Kroonpress AS started transmitting heat into Tartu district heating network, it was connected with the DHN. Under current circumstances, it sometimes sells and sometimes buys, that is to say, the heat moves between the company and the district heating network in line with the possibilities and needs. If any company wishes to connect with the DHN only, it would need to make investments in the territory of the company (a heat exchanger or heat pump, automatics, device for measuring the heat sold, pipework and pumps etc.), and the company would need to construct the pipework outside the registered immovable. It all depends on the cost of the investments, the profit gained and the profitability, just like in the case of any other investments. As a rule, companies do not wish to make investments, the pay-back period of which exceeds 3 years or occasionally 5 years. If the company can only transmit heat to a DHN company on a seasonal basis and in a varying amount, then it might not ever be profitable for it and no-one would undertake to do this merely for providing a service to someone.

Dependence on one large waste heat source (e.g. Kiviõli depending on Keemiatööstus OÜ, Kunda potentially on KNC or Estonian Cell and others (since spring 2020 KNC no longer burns clinker and no waste heat can be acquired from this process) is extremely risky.

As we see, there are lots of problems and the list apparently goes on. One important aspect is also the fact that DHN should be of the low-temperature variety, so that starting to receive waste heat in large amounts would be possible in the first place. Waste heat should be directed to inflow, but not to backflow, as the latter would worsen the efficiency of the DHN entrepreneur's operation. Several other aspects that need to be solved could be listed: who is going to invest in adjusting the waste heat parameters (temperature and pressure) to necessary ones and connecting the waste heat source with the district heating network; how it would be ensured that transmission would take place to DHN on a constant basis or with a pre-determined schedule (for an hour or two), what to switch off and the reception of what waste heat to be limited, if DHN does not need waste heat. Lots of problems could be solved by having a seasonal construction; however, the source would in any case need to ensure the availability of heat that has the parameters set by the heat company.

5.9 Suggestions and solutions with regard to problems concerning the use of waste heat.

1. Seasonal heat accumulators would be best suited for preventing the seasonality of the heat waste and ensuring the continuity of availability. Thus far, the construction of these has been economically unprofitable, but in the case that certain support measures are designed, the profitability could be improved. Large seasonal heat accumulators would nevertheless be possible in relatively big district heating networks and in those that also have heat and electricity co-generation blocks or devices. Industrial waste heat could be directed to these accumulators either directly or via heat pumps.
2. Connecting the companies with the district heating network with the aim of transmitting and selling the waste heat could also be stimulated with the help of support measures.

The waste heat price could not be so high that all the costs of joining the district heating network would only remain for the company that intends to sell waste heat to cover.

3. The cost of the waste heat that is being transmitted to the district heating network does not attract heating companies and purchasing it is not economically reasonable, if it exceeds the variable cost components of the price of the available heat. According to this price, the support measures should be designed.
4. The term ‘Waste heat’ as well as the basics of using it in the district heating networks should be introduced in the envisioned amendment of the District Heating Act. In line with this, the Competition Authority could also start considering the volumes of waste heat purchases and the resulting heat price for customers in the concrete area of the district heating network, when it is checking how justified the price proposal for heat is.
5. Transforming the district heating networks into a more low-temperature variety or first forming ‘low-temperature islands’ (development areas) could contribute to the more widespread acceptance of waste heat into the district heating networks. This topic is also related to support measures mentioned in points 1 and 3, as well as the District Heating Act amendments mentioned in paragraph 4.
6. Boilers working on wet wood fuel and gas (natural gas, biogas and such) should be equipped with flue gas condensers, starting with the capacity of 1 MW (in the case of boilers using wood fuel) and beginning with 15 kW (in the case of boilers using natural gas). The last mentioned ones nowadays already possess a built-in flue gas condensation solution. In the case of renovation works of local boiler plants and district heating boiler plants there could be/should be a requirement in the initial terms and conditions that such natural gas boilers are installed that have a possibility of flue gas condensation. When designing new boiling plants that are working on wood fuel and renovating old boiling plants, one should already consider the additional heat that we get from the condensation of flue gases – this would prevent the problem during later installation where the additional heat could not be sold to anyone.
7. Companies that produce heat from fuel oils or any fossil fuels (either totally or partially) in particular should give special consideration to purchasing waste heat in their district heating network. Purchasing waste heat would additionally serve as a reputation enhancement measure and help it become more environmentally friendly. This will help turn the district heating into an efficient district heating network and this in turn will enable customers to use a weighing factor with a lower value (0.65 instead of 0.9), that expresses itself in the building’s higher energy class (e.g. energy class C instead of D).
8. In all the plans of the settlements that possess a district heating system (cities, towns, small towns, villages) as well as other development documents dealing the thermo-modernisation should feature an analysis of the construction of low-temperature district heating or a transition to it and the economic viability of this. The topic of industrial waste heat has to be dealt with similarly, especially in the context of the industrial parks. Low-temperature district heating networks and also buildings that are heated with low temperature district heating could have a lower weighing factor than the usual district heating network (e.g. 0.4 instead of 0.65). The respective part of the Building Energy Performance Regulation has to be complemented. This would help achieve energy classes A and B (new buildings) and C (buildings undergoing renovation) that are necessary for new buildings and buildings undergoing renovation more easily.

6 A summary of the results of the survey and the interviews

6.1 On the methodology of the survey and the way of conducting it.

In order to include all possible companies that have waste heat potential in the analysis at hand, the authors took data published by the Estonian Tax and Customs Board on the taxes and employees[39] per the III quarter of 2019 (133 796 organisations) and IV quarter of 2019 (138 383 organisations) as the basis. In order to limit the selection to organisations that have the best prospects for waste heat generation, the authors restricted the aforementioned selection to organisations that paid state taxes in the III or IV quarter of at least EUR 500 000 in total or taxes on labour and payments of at least EUR 250 000 in total or whose turnover was at least EUR 2 000 000, or that employed at least 100 employees.

Out of the organisations covered by the following areas in the Classification of Economic Activities, only the 10 biggest organisations in terms of the number of employees were chosen.

- Agriculture, forestry and fishing;
- Accommodation and food service activities;
- Administrative and support service activities;
- Health and social work;
- Education.

The number of organisations that were chosen from the following areas of activities are 20 and 5 respectively, and the selection was similarly based on the biggest number of employees:

- Wholesale and retail trade; repair of motor vehicles and motorcycles;
- Education;

[39] Tax and Customs Board. Taxes paid, turnover and number of employees. On the internet: https://www.emta.ee/et/kontaktid-ja-ametist/avaandmed-maksulaekumine-statistika/tasutud-maksud-kaive-ja-tootajate-arv

- Organisations that belong to the following areas of activities:
- Public administration and national defence, compulsory social security;
- The activities of the extraterritorial organisations and units;
- The activities of households as employers, undifferentiated goods intended for captive use.

Non-resident organisations were completely excluded from the selection. As a result of said filtration, 1 213 organisations were selected. After that the authors complemented the selection with organisations, in the case of which one could expect the presence of waste heat or cooling on the basis of expert knowledge. For this reason, organisations were added to the selection, which had environmental licences for transmitting waste heat from the stationary source of waste into ambient air. Said data were extracted from the environmental licence registry Kotkas[40], which includes 1 302 of such entries. In order to make the extraction of the data that pools environmental licences faster, automated queries (web robots) were applied from a public registry to the data of the organisations that had been granted a licence. Data[41] of the organisations, to which emission trading EUA units (on 20 April 2020) had been allocated free of charge, were also selected; this means 29 organisations. Finally, individual organisations were added, which based on the knowledge of the experts of the area could have waste heat, but which need not be present in the above mentioned selection, e.g. new data centres.

A query concerning the organisations selected was sent via e-mail, using the e-mail address published in the commercial register as a general rule. General contact information was picked from publicly accessible data at creditinfo.ee by using automated queries (a web robot). In isolated cases, the general contact information of the organisation was substituted or complemented with the contact information of an employee, who according to the knowledge of the experts of the area was engaging in issues of waste heat or who was the employee most aware of this issue. Finally, the following professional associations were added to the selection: Estonian Society of Heating and Ventilation Engineers, Estonian Association of Thermal Engineers, Estonian Power Plant and District Heating Association, Estonian Electric Energy Society. Altogether, the survey was sent to 1 856 contacts from 1 824 organisations.

6.2 Categorising the companies interviewed.

Finding interviewed companies from amongst the respondents of the survey should cover companies with different profiles, for example there are companies whose waste heat could be used for a different purpose. Similarly, companies could be classified based on the waste heat capacity, waste heat amount or some other characteristic.

Companies that answered the survey were first divided into the groups below:

1. those who consider themselves as having no waste heat;
2. those who are already using or are about to start using waste heat generated;

[40] https://kotkas.envir.ee/

[41] https://www.keskkonnaamet.ee/sites/default/files/Kliima/jaotustabel_art_10a_seisuga_20.04.2020.pdf

3. those who have a limited amount of waste heat, but are not intending to sell it or use it themselves (on techno-economic grounds);
4. those who have a considerable amount of waste heat, but who have no user for it in the vicinity;
5. those who have a considerable amount of waste heat, a user in the vicinity and an interest in selling it;
6. those who are already selling or are about to start selling to a user in the near future.

Then Groups 4, 5 and 6 were dealt with and classified into the groups below. In the case that Group 2 has large companies which are using a large amount of waste heat, it would be reasonable to talk to them.

One possibility would be to form three larger company groups (types), depending on which purpose the waste heat could be used for and for which it would be reasonable to use. These companies would be divided according to the way how the waste heat generated could be used:

1) For producing electricity (this presupposes an even flow of the heat exchange medium and a temperature of at least 300 °C. Internal combustion engine emissions, industrial furnace emissions and waste air are suitable for this. ORC technology and corresponding equipment or Stirling engines and thermoelectric converters or in other words thermoelectric generators, TEG can be used to generate electricity The latter two have a relatively low capacity; as a rule it is below 100 kW). A high temperature heat exchange medium could also generate steam and this could be used in industrial processes or for producing electricity with the help of steam power engines);

2) For warming up water (a minimum of 60 °C waste heat suffices for warming up domestic water to a temperature of a minimum of 55 °C. Various washing waters (e.g. in canteens, restaurants etc.) might need a heat exchange medium of up to 80 °C. District heating systems need a 100 °C heat exchange medium for keeping to an annual temperature schedule (in some places, a lower temperature would do), unless a temperature schedule of 110/70 °C is used (occurs in some big cities);

3) for warming up the air (the temperature of the heat exchange medium can start from 30 °C and where this could be used will depend on the air to be warmed. The areas of use would be as follows: dryers, greenhouses, painting lines etc. With air that has an even lower temperature, under 30 °C (air at a temperature of over 30 °C is not excluded either), one could warm the air that is led into living and office rooms or in winter the combustion air; the same goes for the drying air that is sucked into the horizontal belt dryers, which is in turn warmed up with e.g. hot water, as well as drying woodchips in half-open repositories etc.).

Based on what was said above, waste heat (heat exchange medium, e.g. water, air, steam, oil) can in turn be divided into three categories:

1. a heat exchange medium of over 300 °C – a high temperature heat exchange medium,
2. a heat exchange medium of 100 to 300 °C – an average temperature heat exchange medium,
3. a heat exchange medium of under 100 °C – a low temperature heat exchange medium.

The second possibility is to divide companies into groups based on the capacity of their waste heat, whereby the current paper does not cover industrial enterprises with waste heat sources with a capacity of under 5 MW:

1) In housing and service industries it would be up to 1 MW (heat pumps and heat exchangers).

2) In an industry with a waste heat capacity of 1 to 5 MW,

3) In industry with a waste heat capacity of 5 to 20 MW,

4) In an industry with a waste heat capacity of over 20 MW.

From each group (type, category and companies that possess heat power engines with a capacity of over 5 MW), companies were picked out, with whom additional interviews were conducted in order to get answers to every point of the survey and which would be able to speak for the whole group within the framework of the interview. Up to 10 companies are going to be interviewed.

6.3 On the results of the survey and the interviews in more general terms

The company input in terms of the survey and interviews is another important source for the study at hand in addition to statistical data and scientific and applied research. As a result of the survey and the interviews that followed it, the authors gained additional source data for economic analysis and for modelling future scenarios of waste heat use.

The study at hand would benefit from detailed, company-focused mapping, which would reflect the most important indicators for all the companies producing heat and cooling. The indicators would include the amount of the potential waste heat, the amount of unutilised waste heat, the technological solution(s) of using the waste heat and the economic potential. Companies mapped in this way could be grouped according to industry branches, the source of waste heat (e.g. boiler, engine etc.), capacity, waste heat solution (heat exchanger, heat pumps, flue gas condenser, efficient co-generation etc.), as well as the possible channels of sale for the waste heat.

Even though 1 824 companies and societies with 1 856 contacts were included in the survey altogether, feedback was only received from 84 of them, out of whom 18 described varying levels of detail on which technology they used for selling waste heat. Only 6 companies had described cost components necessary for the economic analysis of the waste heat solution and other types of input to some extent. Based on the results of the question, other companies were still interviewed, but a number of them did not have an overview that would have had the necessary level of detail.

Out of the statistical data that were used in the study, the Environment Agency’s company-focused data set is the most detailed one in terms of its design by a wide margin. Based on said data set, the authors could fine-tune the economic analysis of the study at hand to some extent to become sector-specific (e.g.: industry etc.). However, the abovementioned data set does not contain indicators, which would enable one to aggregate the heat sources that are in use in a reasonable manner. The data set contains SNAP Codes that characterise sources of emission. Unfortunately these indicators do not describe the heat industry.

Below we shall treat the company that appears as the first one in the data of the Environment Agency’s 2018 data set as an example. According to public data, the main activity of this

company is processing paper materials. The company's sector of the economy under the Classification of Economic Activities is 'Manufacturing', and the principal activity is 'Paper and paperboard production'. All the sources of emission of this company have been assigned the SNAP Code, that belongs to the group 010103, and it is "*Public power and co-generation combustion plants*". But according to the data set, the same sub-group also includes the sources of waste of companies such as public limited company Anne Soojus and Enefit Green AS. The area of activity of the two latter companies is under the Classification of Economic Activities 'Electricity, gas, steam and air conditioning supply', the principal activity is 'Steam and air conditioning supply'. Even though the companies are very different, both have been assigned the same SNAP Code. The situation described above, i.e. that the SNAP codes of the emission source do not match the heat sources known to the authors (boilers, boilers, motors, etc.) or the purpose of the heat sources (manufacturing, electricity or oil shale energy, district heating and heat, etc.) is pervasive.
Altogether, 1 088 companies have been registered in the data set; these companies either produce heat or their economic activities cause the generation of heat, although they are not energy industry companies. In the case of several companies there is no waste source capacity (MW). Due to this fact it is not possible to precisely determine in cumulative terms how many industrial enterprises have the heat capacity of 5 MW and more, which was the object that the study at hand examined.

Estimating waste heat volumes based on the data set mentioned above is hindered by both the scarcity of data as well as by the diversity of the economic activities of the companies represented in the data set and the multitude of the technologies in use. For example, an industrial enterprise was interviewed within the framework of this study. The industrial enterprise was selected as one of the interviewees due to its large volume of waste heat. The sources of the company's waste heat were as follows:

- general ventilation of the alkyd plant,
- containers for liquid raw material,
- general ventilation,
- general and local ventilation of the alkyd plant,
- synthesis and dilution of the alkyds,
- general ventilation of the industrial paints,
- general ventilation of the wood protection agents,
- general ventilation of the bottling department,
- local ventilation of the dissolvers,
- local ventilation of the laboratory.

Even though the sources of heat listed produce a considerable volume of waste heat and selling it is completely feasible in the case of the particular company, it is not easy to classify said company. The company does not have a nationally registered waste source capacity.
Due to this and other practical hindrances described, aggregation cannot be performed, even on the basis of the most detailed data sets. There is no realistic option for undertaking an automated data gathering venture, as we hoped to do with the help of the web survey. Given the number of companies, it is not realistic to expect the gathering of missing data on manufacturing, servicing industries, agriculture, energy industries etc. with the help of interviews.

Due to the reasons described above, it proved impossible to map the waste heat in this study in a detailed company-based manner with respect to companies that do not fall under close national regulation.

6.4 A summary of the results of the technical part of the survey and the interviews

The questions of the technological field were the following ones:

1. In your case does waste heat arise via a heat exchange medium (steam, hot water, warm air etc.)?
2. What temperature in °C does your heat exchange medium have?
3. What is the maximum capacity in MW of your waste heat source?
4. What is the amount of your waste heat in MWh/year?
5. How big a share of waste heat do you use as captive use, in MWh/year?
6. How big an amount of the waste heat do you use for selling in MWh/year?
7. How big would your potential waste heat amount be in MWh/year? Do you foresee that you will be having more waste heat in the future?
8. Do you transmit waste heat into a district heating network and if yes, then into which one?
9. Into which district heating network could you potentially transmit waste heat?
10. How far from your enterprise is the nearest possible district heating network connecting point?
11. Is it possible to use waste heat in the industrial process both in the ancillary production as well as innovations?
12. Would it be possible to use waste heat outside the enterprise, e.g. in areas under shelter, in dryers etc.?

The survey took place online in the Netigate environment. 84 organisations responded to the survey (4.6 % of those who received the notification of the survey) and the respondents included various energetics, district heating or industrial enterprises. 7 enterprises (inter alia AS Tallinna Vesi, with whom an interview was later conducted and for whom the technical amount of the waste heat that is gained from the waste water was calculated) left the questions of the technical part just unanswered. 17 companies answered 'Yes' or 'No' to the first question but at the same time left other questions unanswered. Many respondents answered the questions of the technical part and 21 companies gave a more or less exhaustive answer. Leaving questions in the technical part of the survey unanswered or giving an incomplete answer was justified by the lack of knowledge of or experience in using the waste heat/corresponding solutions. It is possible that the questionnaire did not always reach the most competent people of the field or they were too occupied with other activities.

Separate interviews were arranged for companies (22 such companies) whose waste heat potential the experts estimated as usable and the ones who had heat-using devices, the capacity of which started with 1 MW or who could name some value of the waste heat amount (MWh). Answers were sought from them (and were indeed obtained) to those questions that they had left unanswered in the web questionnaire as well.

Three main perspectives could be isolated:

- we do not have waste heat in such an amount that would already render its use significant and if this came into being, then starting to use it would be expensive and would not be of primary importance from the perspective of the company (the overwhelming majority);
- we are already using waste heat in-house and there is nothing left for selling or the customers would be too far away;
- we acquire waste heat from our processes and are already selling it (the ones, who owned heat and power co-generation devices and/or flue gas condensers). These were district heating companies and heat and electricity co-generation plants.

None of the industrial enterprises questioned would have been interested in selling waste heat outside the company, as the investments would have been too big and the revenue rather small (very long pay-back period). Most of the industrial enterprises questioned were also located in places that were so far from the district heating networks that it would make selling the heat unprofitable (high capital costs). Several companies are intending to start using waste heat in-house if the areas of activity and production are expanded. Some of the companies had new development projects due, in which the waste heat aspect was also said to be covered. Almost all district heating companies, which use wet wood fuel or natural gas, have considered starting to use waste heat from the condensation of flue gases with the aim of selling it to customers. Much depends on the parameters of the heat exchange medium that the heat district heating network uses and on the necessity of the additional heat and the capacity of the boilers (people are generally unwilling to install waste heat capture devices on moist wood fuel boilers with a capacity of less than 5 MW.) For economic reasons, people are not willing to construct major seasonal heat accumulators yet.

If the EU new financial period sets corresponding support measures, then no doubt people will start more seriously considering introducing waste heat use both in their enterprise itself as well as for selling outside to industrial enterprises in the vicinity or to district heating companies.

6.5 A summary of the results of the economic part of the survey and the interviews

84 organisations responded to the survey (4.6 %) and the respondents included various energetics, district heating or industrial enterprises. Regardless of this, numerous companies left the part of the questionnaire intended for generating input for the analysis of the economic potential unanswered. Weak participation in the economic query was justified by the lack of experience in solutions that use waste heat.

The results of the query demonstrate that if waste heat is utilised at all, then this is being used in-house, which often leaves much of the waste heat unused. Despite this, 31 companies that participated in the query answered that they did not consume waste heat in-house. The rest of the companies presented various evaluations as to the degree to which the in-house residual heat was being utilised. A considerably smaller share of companies (3) were selling waste heat. This included co-generation plant owners for example. Towns, i.e. district heating company’s customers, were some of the customers, i.e. they belonged to those who were being sold waste heat.

According to the results of the survey and the interviews that supplemented the survey, the companies saw the transmission of waste heat as the biggest opportunity to sell it to the district heating network, but for some companies it was difficult (and expensive) due to the distance to the district heating network connection point. As already highlighted above, use of waste heat within the company was the way of utilising waste heat that was indicated most often; this could manifest itself in warming up either water or air and it enabled them to spare fuels, that were either non-fossil (e.g. wood) or also fossil fuels (e.g. natural gas, fuel oil). In the absence of waste heat they would have had to be used for warming.

Among the companies that produce heat for district heating, there turned out to be one that indicated that the regulated pricing of heat does not allow the producer to earn additional revenue from the reduction in the abovementioned costs. One company that complemented their answers during the interview indicated that not a single one of the known waste heat gathering solutions is economically profitable for them and that the company could rather reduce waste heat by modernising the devices that are producing heat or it could do something for improving the efficiency of the waste heat use, should a favourable national support measure arise.

Although 18 respondents described with varying levels of detail, which technology they use for utilising waste heat, only 6 companies have described its cost or at least some cost components. In order to get a wider picture of the economic situation of the adoption of the waste heat, the authors of the study conducted interviews with industrial enterprises of various degrees of maturity in terms of using waste heat (Table 6.1).

Table 6.1. Data on the companies that described the initial investments necessary for the utilisation of the waste heat; based on the combined data of the questionnaire and the interviews[42]

Organisation	Type	The options for using it	Lifetime	Amount, MWh/year	Investment volume, in thousands of €	The ratio of the initial investment per the waste heat amount of the first year per unit in EUR/MWh (in brackets an annual average)
Company	Industry	W.A.C.D.	10	1000	300	300 (30)
Company	Energetic/district heating	W, C	15	4500	750	166.6 (11.1)
Company	Agriculture	W, D	10	660	80	121.2 (12.1)
Company	Industry	W.A.C.D.	15	1000	200	200 (13.1)
Company	Energetic/district heating	O	15	33900	2500	73.7 (4.9)
Company	Industry	W, A, C	25	450	54	120 (4.8)
Company	District heating	W, D	15	10500	700	66.6 (4.4)
Company	District heating	W, D	15	11000	740	67.2 (4.5)
Company	Industry	W, A, C, D	NA	NA	NA	NA

[42] Data on two respondents, who presented forecast data, that according to an expert opinion are adjusted data.

Company	Industry	A, C	NA	NA	NA	NA
Company	Water supply	W, A, C	NA	NA	NA	NA

Abbreviations: W – heating water, A – heating air, C – for captive use, D – for district heating

The survey and interview that supplemented the surveys revealed that district heating companies are probably in the best position to utilise waste heat and are self-supporting, which again would be due to lower costs. Said companies made investments in the magnitude of 60 to 80 euros for utilising 1 MWh of waste heat, whereas for industrial enterprises this figure was 120 to 300 euros. District heating companies also had a good chance of benefitting from the utilisation of waste heat. Back pressure turbines or ORC device heat and electricity co-generation plants use heat exchangers for transferring heat to district heating networks and heat exchangers for warming up the district heating water. Due to this it is possible to increase the return of sales (in the case that customers are available for the extra heat) or to reduce the amount of heat generated by reducing the waste heat captured. Even though the latter is not the return of sales per se, it manifests itself in the lowering of fuel costs, for which district heating companies sometimes natural gas as auxiliary heat or alternatively the use of the main fuel, such as wood-based fuels (e.g. woodchips) can be reduced.

Depending on the technology and the sector, industrial enterprises could utilise the waste heat captured from flue gases either in-house or alternatively find opportunities for utilisation by others. Reducing the capacity of the heat source by the amount of heat waste captured was not as easy for them as it was for the district heating companies described above. Due to this, added to the fact that the investments per unit of the industrial enterprises were 3 to 5 times higher, it was difficult for them to find a solution for making a profit or reducing the costs of fuel/energy.

7 Demand for heating and cooling

In accordance with Annex I point 4 of Delegated Regulation (EU) 2019/826 of 4 March 2019 'Amendment to Annex VIII' the trends in the demand for heating and cooling in the perspective of the next 30 years were described in GWh, in particular taking into account projections for the next 10 years, the possible changes in demand in buildings and different sectors of the industry, and the impact of policies and strategies related to demand management, such as long-term building renovation strategies under Directive (EU) 2018/844 (REKS cited in the study at hand);

For assessing and forecasting the demand for fuel and cooling, we can take the Statistics Estonia's (ESA) Energetics Database data as well as some future forecasts on heat use that had been drawn up earlier as the basis.

A relatively thorough analysis has been prepared in the study 'The Energy Savings of the District Heating' by the Estonian Development Fund performed in 2013. The reduction of the energy consumption achieved via the introduction of different measures has been presented in table 7.1.

Table 7.1 Energy savings potential of the district heating, GWh [43]

The activity for the energy savings	Savings potential, GWh
Complex renovation of buildings	1 380
Modernising the heat production	137
Renovating the district heating pipeworks	542
Total	**2 059**

A forecast concerning the long-term heat consumption is presented in the study mentioned above. Considering the fact that people are stepping forward towards more energy-efficient solutions as well as renovating the buildings and enhancing and modernising the production, we expect to see a reduction in heat consumption in the future.

The prognosis of the consumption in district heating areas until the year 2050 has been presented in table 7.2.

Table 7.2 The prognosis of the consumption of the district heating areas until the year 2020, GWh

Year	Consumption, GWh
2011	6 537 (ESA data, consumption of heat in district heating)

[43] The Energy Savings of the District Heating', an Estonian Development Fund study, 2013.

Year	Consumption, GWh
2012	4 600
2016	6 650 GWh (ESA, heat sold in district heating also includes consumers outside the housing renovation, cf. Table 10.1)
2019	2 269.4 GWh (EJKÜ data, this includes around 90 % of the heat produced)
2019	5 401.7 GWh (ESA, the actual end-consumption of the heat, or heat sold to the customers, i.e. what is being sold directly to the industries, cf. Table 10.2) The consumers of all the district heating networks – 4 593.8 GWh (2557.1 GWh, or 55.7 % from renewable energy sources)
2020	4 186 (60 % from renewable energy sources)
2030	4 025 (75 % from renewable energy sources)
2050	3 703 (100 % from renewable energy sources)

Note: information written in red was not present in the Development Fund's study. The share of the renewables use from 2020 to 2050 is an estimation of the authors of the study at hand.

The heat consumption values in figures that are presented in Table 7.2 in black and red are not easily comparable with each other. The values in black colour represent the consumption in the district heating areas (not all municipalities, where district heating networks could be found, had introduced district heating areas by 2012, however most had done so). It is more important to witness a reduction in heat consumption thanks to various possible production and transferring enhancement and consumption saving measures.

It was noted in the same study, that according to ESA, consumption of the heat in the district heating was 6 357 GWh (i.e. the heat sold to customers) in 2011 and the total consumption 8 168 GWh and the total production 9 134 GWh (the difference 9 134-8 168=966 GWh means losses).

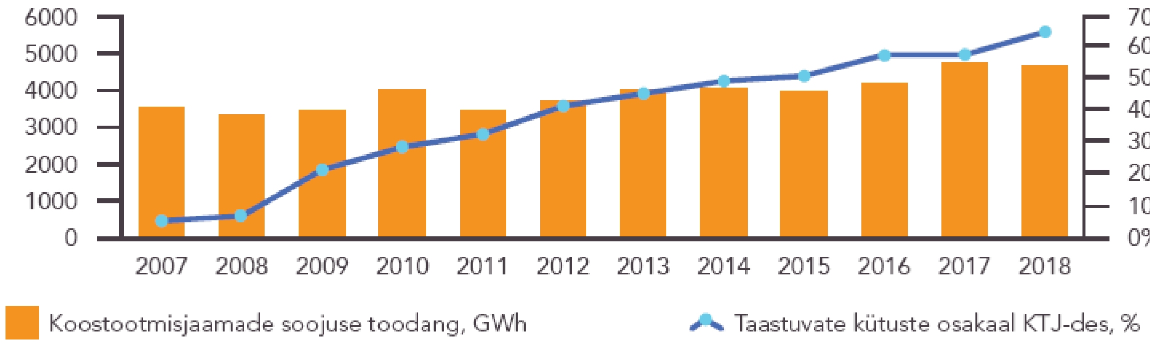
More concerning is the decision taken by Statistics Estonia to henceforth only collect and analyse those energetics data that the EUROSTAT requires. This means that in the heat management area we can only get to know the actual final consumption of heat, which means heat that has been sold to the customer (ESA tables KE0240, energy balance according to the fuel or the type of energy, terajoule, KE0230: the energy balance by fuel or type of energy). All consumers of the district heating networks, regardless of their area of activities (manufacturing, service industry, housing etc.), as well as the companies that are purchasing heat from an enterprise that is purchasing heat from an enterprise operating/producing on the basis of their own heat power engines. Thus, we can take as an example a heating company, which owns or rents a boiler plant or heat and electricity cogeneration plant on the territory of a company and sells heat to it.

Already now are we seeing that many interesting ESA energetics area data series already end in 2016, but some end later (such as KE044: Boilers (boiler plants only); 2018, KE06: Consumption of fuels, cubic metres, GWh; Fuels used for heat production, KE024: energy balance, TJ/GWh); Total fuels used for producing heat, KE024: Energy balance, TJ/GWh); The actual final consumption of heat, including in households, KE023: Energy balance, GWh); Final consumption of heat, KE04: Heat balance, 2016); Consumption of energy and heat, KE05: Final consumption of energy (with the exclusion of fuel consumption for non-energetics purposes, losses in transportation, storage and dividing).

Another source, where the production and use of heat and renewable sources of energy have been treated, is the series of Estonian Renewable Energy Association yearbooks.

According to the year 2019 issue[44], the share of renewable energy in Estonia's energy consumption was, according to the most recent Eurostat statistics, 30 %. In 2019, 1 970 GWh of renewable electricity was produced for the grid, which amounted to 21 % of the final consumption of electricity. Solar power plants stand out for renewable energy added for the second year in a row: last year (2019) a share of 78.72 MW was added to the grid. Among the major production units that started work was the Mustamäe heat and electricity cogeneration plant in Tallinn with the capacities of 10 MWel and 47 MWth, which mostly uses biomass (wet wood-fuels).

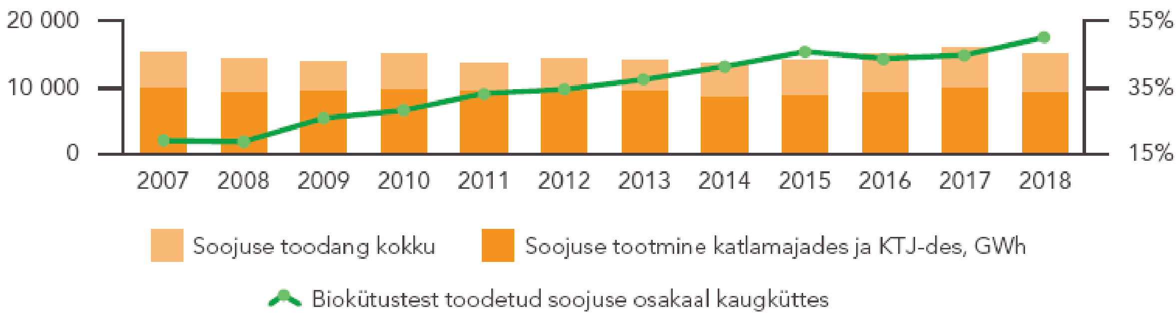
In the year 2019 issue it has been observed that throughout recent years, active investments have been made in Estonia into increasing the share of fuels produced from domestic and renewable sources. Over the last ten years, the use of renewable fuels has strongly grown for producing heat in co-generation installations, having reached 66 % in 2018 (Figure 7.1).



Key: Heat production of co-generation installations (GWh); Share of renewable fuels in co-generation installations (%)

Figure 7.1. The share of heat produced by co-generation installations of renewable fuels, source: ETEK

According to the data that the authors of the issue had, Estonia has yet to reach the European Union co-generation target set for 2020. According to this target, the share of electricity produced in co-generation installations should reach 20 % of the gross consumption. At the end of 2018, it was 14.4 % - over the last eight years it has grown minimally (Figure 7.2). The wider adoption of co-generation would also be an important option for saving primary energy in order to meet the goals of the EU energy efficiency directive.



Key: Total heat production; Heat production in boiler houses and co-generation installations (GWh); Share of heat generated from biofuels in district heating

[44] RENEWABLE ENERGY YEARBOOK, 2019. Estonian Renewable Energy Association (ETEK).

Figure 7.2. The share of the renewable fuels in district heating and the share of the heat produced for district heating in the overall production (Statistics Estonia, ETEK).

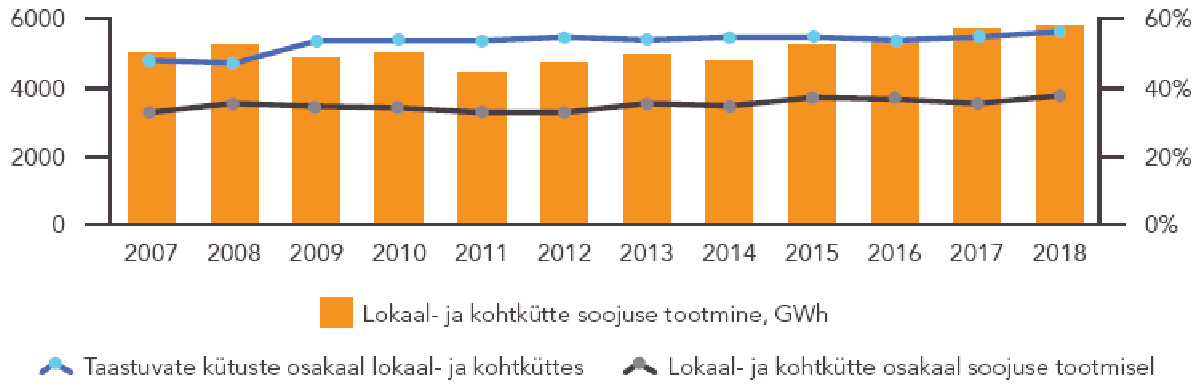
More and more boiler houses and co-generation installations are switching to renewable fuels. According to the ESA's most recent data, in 2018 the share of renewable energy in district heating was 50 %. Over the years, this percentage has increased considerably (see Figure 7.2, the green line). Over 95 % of the fuel produced from renewable raw materials consists of wet woodchips. The more the use of woodchips grows, the bigger the share of the waste heat gained through condensing the flue gases. The increase in the use of gas fuels also increases this. The production of heat in the whole country has not significantly changed over the last 12 to 13 years, a trend of decline by a few percentage points is apparent.

Over the coming years, it is expected that the share of renewable energy in the heat area will continue to grow. Over the last couple of years, several smaller boiler houses have been constructed in Estonia (inter alia at Haabneeme, Saue, Kunda, Kehra), that use woodchips and low-value wood waste. Thanks to the wide adoption of domestic renewable fuels, one can presume that over the next years, particularly small boiler houses which have thus far been using heating oil or natural gas, will switch to renewable fuels. In most of the larger settlements that have been equipped with district heating, the transition to domestic fuels has already taken place. Very many bigger boiler plants and co-generation installations (Valga, Jõgeva, Haapsalu, Mustamäe CPH and others) have been equipped with flue gas condensation devices (washers, condensators) and the intention is to start installing them in increasingly smaller boiler plants that are using woodchips (much depends on the grid parameters and fuel prices).

Block heating and in-residence heating play a significant role in the heating supply of Estonian households. These ways of heating are most often used in smaller settlements or regions, where there are no district heating options.

There are no statistics available on Estonia's block heating, but according to the estimations of ETEK, ESA and the experts of the field, approximately 5 900 GWh of heat was produced in 2018 in block heating.

The share of the renewable fuels in block heating is nowadays estimated to represent 60% (Figure 7.3). This mostly depends on the amount of wood fuels used and the seasonal coefficient of performance of operating the heat pumps. In 2018, the share of wood fuels and heat pumps used in block heating and in-residence heating amounted to 78 % (wood 44 % and heat pumps 34 %), natural gas and other sources were also used to a lesser extent.



Key: Heat production in block heating and in-residence heating (GWh); Share of renewable fuels in block heating and in-residence heating; Share of block heating and in-residence heating in heat production

Figure 7.3. The share of renewable fuels in block heating and in-residence heating, source: ETEK

The boiler plants that are using wood, use wet woodchips to a small extent; they mainly use wood fuels that have better quality, such as dry logs, pellets etc. Many boilers that are used in smaller and average sized block heating and which use natural gas have already had a flue gas condenser added these days and the extra heat gained is used in the same heating system, that the boiler is supplying with heat.

Changing heat and cooling demand in the case of household customers

Cumulatively, the household customers' demand for heat is influenced by reconstruction of the building stock, which in the coming years is going to reduce the demand for heating energy in a significant manner. In the case of block heating and in-residence heating the declining demand for heat is not problematic from the perspective of the energy system, as new block and in-residence heating systems are dimensioned in accordance with the post-reconstruction need for heat. The declining need for heat in the district heating system requires more attention: there the declining need for heat is having a wider impact on the system, for example in terms of the effect that the declining sales volume has on the district heating price.

For evaluating the effects of the reconstruction works, an indirect method was created with the help of which a potentially declining volume of demand in the district heating sector can be ascertained based on the pace of reconstruction works. Detached houses were not included in the calculations, as there are no statistical data (on rooms) on the accession of detached houses to the district heating network, which would even enable one to perform a forecast that would have a large margin of error.

A model was drawn up on the basis of expert evaluations and the forecasts and premises of the paper 'Hoonete rekonstrueerimise pikaajaline strateegia' ('A long-term strategy for the reconstruction of buildings')[45] (henceforth: *REKS*). In order to find out the magnitude of the reduction of heat consumption, a proportion of reconstruction, that is being conducted in district heating areas, was found out on the basis of today's pace of reconstruction of apartment buildings (280 000 m^2/per year). For this purpose, the share of the apartment buildings located in the area of centres of influence were used, as most of the apartment buildings located in the area of centres of influence are connected with the district heating system. In this way it was found that 81 % of the apartment building reconstruction takes place in the district heating areas, which is to say that in district heating areas ca 226 800 m^2 of the surface of living premises is being reconstructed a year. The pre-reconstruction and post-reconstruction energy need was found out by combining the expert evaluations and the studies. 200 kWh/m^2*year was set as the pre-reconstruction specific use and 90 kWh/m^2*year was set as the post-reconstruction specific use. Additionally a situation was mapped, whereby heat pumps had been installed in the course of the reconstruction, which were using the waste heat that is present in the exhaust air of the ventilation for producing locally thermal energy, for which reason the amount of thermal energy consumed from district heating network is ca 25 kWh/m^2* year.

[45] https://adr.rik.ee/ram/fail/7303187/subfile/0

Table 7.3. KE023: ENERGY BALANCE The fuels used for producing heat, 2018

Scenario	Consumption of thermal energy (kWh/m^{2}* year)
1. Unreconstructed building	200
2. Reconstructed building (consumption of thermal energy from the district heating network)	90
3. Reconstructed building (the adoption of waste heat use with the help of heat pumps)	25

A calculation made on the basis of premises presented above shows that with today's reconstruction pace the reduction in the demand for thermal energy could be 2540 GWh/a year in the case that various reconstruction packages were fully applied, which would cumulate throughout the period 202—-2030 to a reduction of 250—400 GWh a year. We are, however, likely to be rather far from such a pace of reduction, as complete reconstruction projects are currently not being carried out in sufficient capacity, i.e. thermal energy consumption is higher than the expected 90 kWh/m^{2}* year.

As REKS first highlights the need to considerably increase the number of complete reconstructions and secondly the need to accelerate the pace of the reconstruction of buildings, then consequently the potential reduction in demand for thermal energy in the case of accelerated reconstruction pace (the so-called 2050 climate neutrality scenario). In this case the reconstruction pace would be two times bigger, or 486 000 m^{2} a year and a decline in demand for thermal energy of 54—85 GWh/year, which in a cumulated manner would be 540—850 GWh by the end of the period 2020 to 2030. Compared with the consumption today, the total heat consumption of the district heating networks would decline by 15 % by 2030, just because of the reconstruction of apartment buildings.

The decline in the consumption of heat from the district heating network in line with various scenarios is illustrated in Figure 7.4. The scenarios depicted in the figure have been worked out on the basis of the following conditions:

- The reconstruction pace of the BAU (the baseline scenario) is 226 800 m^{2} a year, which approximately corresponds to the reconstruction pace today (although as has been described above, the reconstruction is not as effective as the scenario envisions).
- The REKS (reconstructing in a sped-up manner compared with the reconstruction baseline scenario) scenario has set a reconstruction pace of 486 000 m^{2} a year.
- In the case of the KK scenario the building will be constructed without heat pumps in the ventilation heat recovery system.
- In the case of the KK+SPmin scenario, the building will be constructed with heat pumps in the ventilation heat recovery system, where heat pumps are operated in a fashion that disrupts consumption from the district heating network as little as possible (the temperature of the water that return does not change significantly).
- In the case of the KK+SPmin scenario, the building will be constructed with heat pumps in ventilation heat recovery systems, where heat pumps are operated in a fashion that minimises the heat bought from the district heating network.

The scenarios described above thus correspond to the following scenarios described in the Chapter entitled 'Scenarios relevant for the baseline scenario" that discussed the economic analysis of the study at hand: *Base 4* (KK with the pace of KK), *Alternative 4a* (BAU pace + SPmin) and *Alternative 4b* (BAU pace + SPmax). Scenarios REKS pace KK, REKS pace KK

+ SPmin and REKS pace + SP max have been drawn up on the basis of the previous scenarios with the wager that the reconstruction pace would be faster than expected.

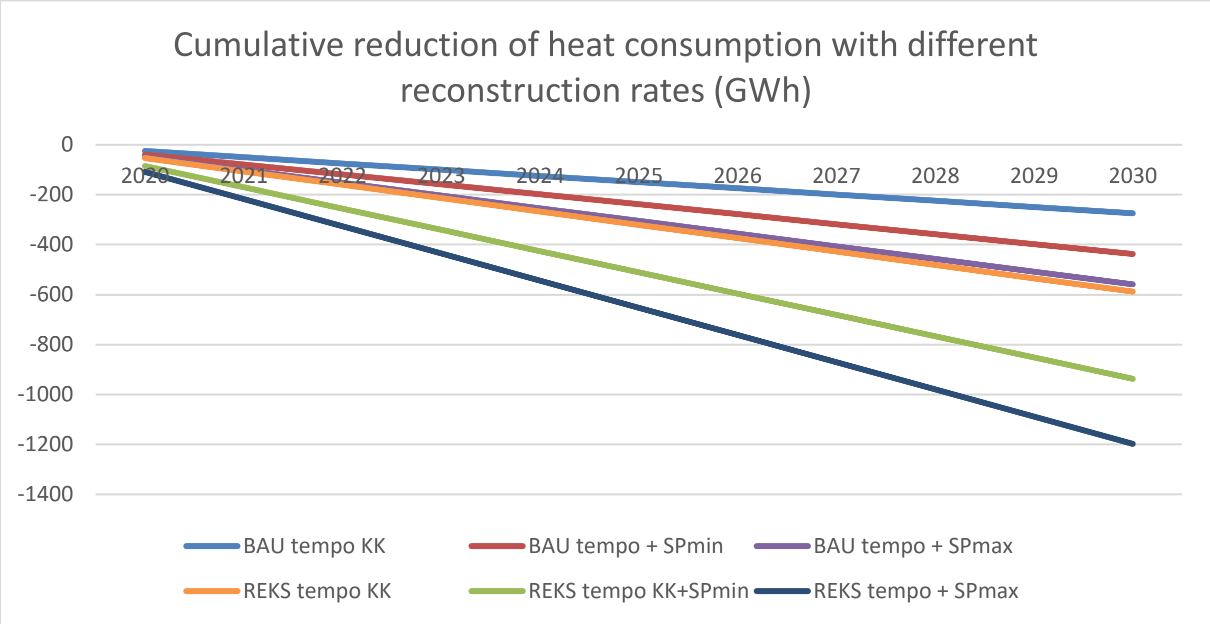


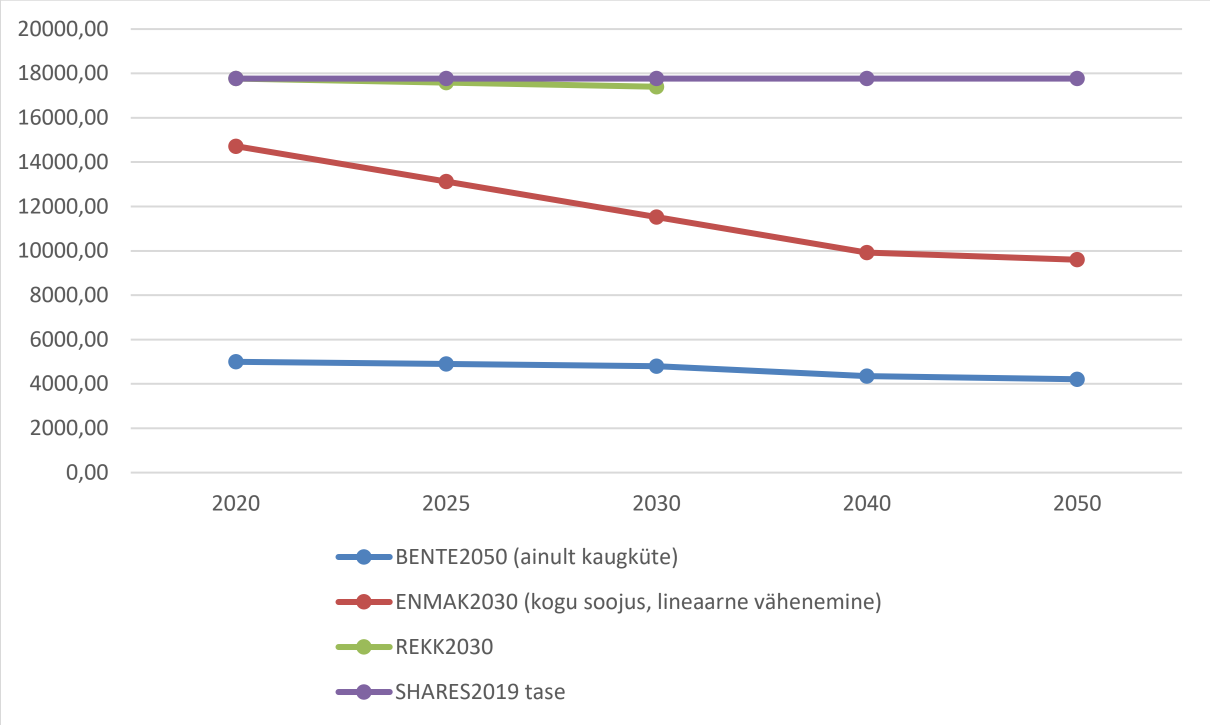
Figure 7.4. The reduction of heat consumption owing to building reconstruction

Estimating the demand for cooling is very theoretical, as installing cooling devices for household consumers in Estonia’s circumstances depends first and foremost on people’s economic options, and not that much on the necessities of ensuring the internal climate. Theoretical cooling demand is estimated by the Hotmaps Project[46], using a statistical methodology[47] that takes into account estimated cooling degree days with the accuracy of an EU Member State and an approximate indoor climate area for 2015. In line with this methodology, the theoretical demand for cooling has been estimated as 313 GWh a year. In order to obtain a corresponding electricity cost, one has to use the cooling device COP (typically in the range of 2 to 4), which means that for meeting such theoretical demand for cooling, the consumption of electricity may increase by 78—156 GWh/year.

Due in part to gaps in the data on the heat management area and in part to differences in data that are gained from various sources, it is very difficult to forecast future demand, especially from a perspective of thirty years. The demand for cooling (admittedly mostly the consumption capacity and savings gained from district cooling as opposed to local cooling), has been addressed in Chapter 10 of this report. It can definitely be asserted, that the demand for district cooling will also rise in energy units, or GWh’s, but not a single one of the companies offering district heating has drawn up relevant forecasts.

[46] https://www.hotmaps.eu/map

[47] https://gitlab.com/hotmaps/heat/cool_tot_curr_density/blob/master/README.md



Key: BENTE2050 (district heating only); ENMAK2030 (total heat, linear decline), REKK2030, SHARES2019 level

Figure 7.5. Different forecasts on the consumption of heating until 2050, in GWh

Figure 7.5. describes different forecasts on the consumption of heat until 2050. BENTE2050 features data, that were extracted from the study 'Baltic Scenarios of Energy Technology 2018', that has forecast the consumption of district heating until 2050[48]. ENMAK2030 collection has been extracted from the National Development Plan of the Energy Sector until 2030, the SHARES2019 level characterises data of the Eurostats SHARES model that have been gathered by analysing the most recent energy consumption data (data of 2019), and the REKK2030 forecast has been found from the corresponding plan for development. When comparing different forecasts, the discrepancy between the values forecast by ENMAK2030 and the real situation are clearly perceptible. Given that REKK2030 is the most recent plan for development drawn up in a manner in which the renewable energy, energy savings as well as the goals concerning greenhouse gases emissions have all been considered, we could expect that significant heat energy consumption is not to be expected from the perspective of the next ten years. A reduction is nevertheless likely in the case of more strict energy efficiency requirements and improved quality of the reconstruction of buildings (see above the analysis of the reduction in the need for heating in the housing industry).

The need for heating experienced by the customers of the district heating networks is expected to decrease by around 20 % by 2050, if the year 2012 is taken as the basis (see Table 7.2). The industry is unlikely to see such a decrease in the use of heating to the extent that district heating is expected to experience. A tendency for an increase (which seems to be on-going) in the demand for heating demonstrated by the customers of block heating and in-residence heating has been observed. Residents continue to move to live in detached houses, terraced houses and smaller apartment buildings in the direct vicinity of big cities, for

[48] https://www.nordicenergy.org/wordpress/wp-content/uploads/2018/04/BENTE-input_data-power_and_heat-updated-21-12v2.xlsm

the sake of which only some isolated district heating networks (Tiskre, Peetri small town etc.) have been constructed. Industrial processes that consume heat are relatively uniform and it is not as easy to reduce the heating need of these as it is to reduce the use of heat in buildings. As companies keep growing and appearing, the use of heating might even grow. The companies will rather start using the waste heat from processes usefully either in-house or by selling it to neighbours or transferring it to the district heating network (by selling it). As the service industries keep developing, their usage of heat can also grow and some more waste heat can come into being, for the utilisation of which solutions will either be found in-house or a purchaser will be found from outside.

8 The suppliers of heating and cooling and the volumes of supplies

8.1 The volume of current supplies of heating and cooling by technology

8.1.1 Efficient district heating and district cooling in Estonia

Statistics Estonia[49] data on heat generated and fuels used

Wood fuels and gas fuels have been observed, the flue gases of which generate heat (waste heat) arising through the condensation of water vapour in the gases, and which could be used for transmitting to customers.

It would also be possible to use heat that flue gases from boilers that are using other fuels contain, but it is not realistically possible (it is not feasible from the techno-economical aspect) to start using the heat from over 20 MW boilers that are using oil heating (there are virtually none of them still in use in Estonia or they are being used as reserve devices) or boilers using solid fuel (oil shale) in district heating networks. The vast majority of the potential heat from the flue gases that the hearths of large boilers emit are utilised for preheating the boiler feed water and burning air. The ESA aggregate tables do not have all the data for 2018 and 2019 yet.

Table 8.1 We see that by condensing the flue gases of the wet wood fuel combustion plants, a minimum of 10 %, or 492 GWh could be gained as an annual average as utilisable waste heat, and from combustion plants that are using natural gas, 319 GWh could be gained. A part of this potential is being used.

[49] https://andmed.stat.ee/et/stat

Table 8.1. KE023: energy balance. The fuels used for producing heat, 2018

Indicator	Type of fuel/energy	
	Chipwood and wood waste, in thousands of cubic metres	Natural gas, mln m^3
For producing the heat consumed	2155	274
Final consumption in the industry sector	298	67
Final consumption in the agricultural and fishery sector	0	0
Final consumption in the transport sector	0	5
Final consumption in the commercial and public service sector	0	29
Total	2,435 thousand cubic metres	341 million m^3
	4,918.7 GWh	3,191.8 GWh
	10 % is 492 GWh	10 % is 319 GWh

The theoretical potential of the waste heat from combustion engines burning wood fuels and natural gas

Based on data collected by the Estonian Power and Heat Association from companies that belong to the Association (most of the district heating companies, providing 95 % of the heat production altogether, are included), in 2019, 2 ,269.4 GWh was transmitted from heat and electricity co-generation installations (heat and electricity co-generation plants) to the district heating networks. This can be classified as waste heat that gets generated in the case of electricity production. 462 GWh of heat was transferred to district heating from other sources of waste heat in 2019 (mostly from flue gas condensers). The data presented above demonstrate, that as EJKÜ's numerical value is approximately the same as the one Table 8.1 presented in (KE023), the share of waste heat gained from flue gas condensers is probably greater than 10 % of the heat produced (in the case of wood fuel the 15 % share of the waste heat would constitute 738 GWh/year).

Table 8.2 heat companies and network areas located in Estonia are listed (district heating systems for which the Estonian Power and Heat Association (EJKÜ) has issued the label 'Efficient district heating'. A total of 24 heating companies and 90 network areas have received this label, the largest number of which is held by SW Energia OÜ, a total of 37 network areas across Estonia. In order to prove the energy efficiency of district cooling systems, EJKÜ has developed the label 'Efficient district cooling', which has so far been applied for by Fortum Tartu and Utilitas Tallinn.

Table 8.2. Efficient district heating companies and network areas in Estonia

Order number	District heating network area	Company
1	Kuusalu	Kuusalu Soojus OÜ
2	Kolga	
3	Kiviõli	Kiviõli Soojus AS
4	Viljandi and Jämejala	Esro AS
5	Lihula	Lihula Soojus OÜ
6	Võru	Danpower Eesti AS
7	Puiga	
8	Pärnu	Fortum Eesti AS

Order number	District heating network area	Company
9	Rakvere	**Rakvere Soojus AS**
10	Narva	**Narva Soojusvõrk AS**
11	Tallinn	**Utilitas Tallinn AS**
12	Haapsalu	**Utilitas Eesti AS**
13	Jõgeva	
14	Keila	
15	Valga	
16	Kärdla	
17	Rapla	
18	Fortum Tartu	**Tartu Keskkatlamaja AS**
19	Kuressaare	**Kuressaare Soojus AS**
20	Orissaare	
21	Alu	**SW Energia OÜ**
22	Käärdi	
23	Kehtna	
24	Kohila	
25	Mustla	
26	Nõo	
27	Õisu	
28	Paldiski	
29	Parksepa	
30	Rakke Niidu	
31	Salme	
32	Sangaste	
33	Sauga	
34	Tõravere	
35	Tõrva	
36	Türi	
37	Uhti	
38	Uulu	
39	Vana-Antsla	
40	Paikuse ja Seljametsa	
41	Ilmatsalu	
42	Haiba	
43	Harku	
44	Kanepi	
45	Kärla	
46	Krootuse	
47	Olgina	
48	Raasiku	
49	Väätsa	
50	Aruküla	
51	Helme	
52	Luunja	

Order number	District heating network area	Company
53	Tõrvandi	
54	Ülenurme	
55	Võnnu	
56	Puhja	
57	Uhtna	
58	Laagri	
59	Loo	
60	Kunda	
61	Väike-Maarja	
62	Adavere	
63	Viiratsi	
64	Narva-Jõesuu	
65	Viimsi and Haabneeme	
66	Põltsamaa	
67	Saue	
68	Püssi	
69	Viru-Nigula	
70	Rae tehnopargi	Põrguvälja Soojus OÜ
71	Saku	Saku Maja AS
72	Kurtna	
73	Kohtla-Järve-Jõhvi-Ahtme	VKG Soojus AS
74	Tarbja	N.R. Energy OÜ
75	Kaerepere	
76	Kiili	
77	Koigi	
78	Märjamaa	
79	Oisu	
80	Turba	
81	Vana-Võidu	
82	Tapa	
83	Kadrina	Kadrina Soojus AS
84	Koeru	Järva Haldus AS
85	Imavere	
86	Elva	Elva Soojus OÜ
87	Jüri	Elveso AS
88	Vaida	
89	Paide	Enefit Green AS
90	Põlva	Põlva Soojus AS

The total volume of heat produced in the network by all these heat companies and their network areas was 1 981.6 GWh and the volume of heat purchased in the network was 2 612.2 GWh (produced by someone other than the network owner/operator). A total of **4 593.8 GWh of heat** was directed to consumers in 2019, of which 2 557.1 GWh or 55.7 % was produced on the basis of renewable energy sources (wood chips, wood waste, pellets and biogas). It is estimated that the companies listed in Table 8.2 produce more than 90 % of the heat directed to Estonian district heating networks.

Conclusion

The total amount of the waste heat that arose during the heat and electricity co-generation process was 2 269.5 GWh and the waste heat gained in other ways (e.g. flue gas condenser) and transferred to the grid was 461.5 GWh in 2019.

By condensing the flue gases of the wet wood fuel combustion plants a minimum of 492 GWh could be gained as an annual average as utilisable waste heat, and from combustion plants that are using natural gas, 319 GWh could be gained. A part of this potential is being used.

8.2 Plants, which produce waste heat or waste cooling energy and their potential heating and cooling supplies

In Estonia, 12 companies (heating companies) produce waste heat while carrying out heat and power co-generation, that is transmitted to district heating networks:

1. ESRO (co-generation installation using natural gas to produce – heating and power co-generation plant, transmission to Viljandi DHN),
2. Kiviõli Soojus AS (receives waste heat from Kiviõli Keemiatööstus AS and transmits it to Kiviõli DHN),
3. Rakvere Soojus AS (receives waste heat from Adven Eesti and transmits it to Rakvere DHN),
4. Tartu Keskkatlamaja AS (receives waste heat from the Tartu heating and power co-generation plant and cooling system and transmits it to Tartu DHN),
5. VKG Soojus AS (receives waste heat from VKG Energia OÜ and transmits it to Kohtla-Järve, Ahtme and Jõhvi DHN),
6. Utilitas Tallinn AS (receives waste heat from OÜ Utilitas Tallinna Elektrijaam, Eesti Energia AS Iru Elektrijaama (Iru heat and electricity co-generation plant) and Utilitas Tallinn AS Mustamäe heat and electricity co-generation plan and transmits it to Tallinn and Maardu DHN),
7. Narva Soojusvõrk AS (receives waste heat from Eesti Energia AS Balti Soojuselektrijaam and transfers it to Narva DHN),
8. Enefit Green AS Paide heat and electricity co-generation plant (the waste heat is transmitted to Paide DHN),
9. Kuressaare Soojus AS Kuressaare heat and electricity co-generation plant (the waste heat is transmitted to Kuressaare DHN),
10. Põlva Soojus (a heat and electricity co-generation plant that uses natural gas, the waste heat is transmitted to Põlva DHN),

11. Fortum Eesti Pärnu heat and electricity co-generation plant (the waste heat is transmitted to Pärnu DHN).

Apart from the ones listed above, who have been granted the efficient district heating label, Silpower AS is also producing heat (waste heat) on a co-generation basis and transmitting it to Sillamäe DHN.

Several heating companies are catching waste heat in the process of flue gas condensation and transmitting this to district heating networks: Fortum Tartu AS, Utilitas Tallinn AS (Mustamäe heat and electricity co-generation plant and some natural gas boilers equipped with scrubbers), Utilitas Eesti AS, OÜ Utilitas Tallinna Elektrijaam, Kuressaare Soojus AS, Adven Eesti AS, Enefit Green AS, Danpower Eesti AS, in the near future ELVESO AS and Põrguvälja Soojus AS.

Waste cooling, that is directed to the Tartu city district heating network with the help of a heat pump, is received from Fortum Tartu AS cooling system.

8.3 The share of the energy produced from renewable energy sources and from waste heat or from waste cooling in the final energy consumption in the district heating and district cooling sector.

According to EJKÜ, altogether **4 593.8 GWh of heating had been transmitted to customers** in 2019, out of which 2 557.1 GWh, or 55.7 % had been produced from renewable energy sources (woodchips, wood waste, pellets and biogas).

The total amount of the waste heat that arose during the heat and electricity co-generation process was 2 269.5 GWh and the waste heat gained in other ways (e.g. flue gas condenser) and transferred to the grid was 461.5 GWh in 2019.

In the following

Table 8.3 drawn up on the basis of ESA data, the capacity of Estonian co-generation plants, electricity produced and heating by heat power engines has been presented.

Table 8.3. KE034: CAPACITY AND PRODUCTION OF CO-GENERATION PLANTS

Indicator	Type of the generator (steam power engine)	Year 2019
Thermal power at the end of the year, MW	Steam condensing extraction turbines	827
	Gas turbines with heat recovery	612
	Internal combustion engines	22
	Total	**1461**

Indicator	Type of the generator (steam power engine)	Year 2019
Electricity produced, GWh	Steam condensing extraction turbines	1077
	Gas turbines with heat recovery	355
	Internal combustion engines	77
	Total	**1509**
Heat produced, GWh	Steam condensing extraction turbines	2914
	Gas turbines with heat recovery	1096
	Internal combustion engines	59
	Total	**4069**

Theoretical potential of the waste heat of the co-generation plants with internal combustion engines (gas fuel)

Table 8.3. (KE034) we observe that the energy production of the internal combustion engines (heat + electricity) was 136 GWh in total and with the yearly average efficiency of 0.8, the amount of primary energy (which the fuel contains) would be 170 GWh. Out of this, up to 15 %, or 25.2 GWh could be used (partially used) in district heating networks or elsewhere as waste heat (sources: exhaust gas, cooling water of the water manifold and oil cooling system). Given that the ratio of water to electricity in modern internal combustion engines has approximately reached the level of 50/50, then based on the data from Table 8.3, we can observe that not all the waste heat produced has not found useful utilisation (being sold). Thus, it can be said, that the estimation given is rather conservative and the actual potential might be somewhat bigger.

Steam condensing extraction turbines are present in all heat and electricity co-generation plants that burn wood fuels, but they can also be found in such plants that burn other fuels. In 2019, their total capacity was 827 MW and heat production 2 914 GWh, a large share of which is already finding utilisation in district heating networks of settlements (Table 8.3 (KE034)). These results are relatively well in line with EJKÜ data: in 2019, 2 269.4 GWh were transmitted from heat and electricity co-generation plants (devices) into district heating networks.

Wood fuels are mainly used in heat and electricity co-generation installations that have been equipped with steam condensing extraction turbines (installations in Estonia's biggest towns and the ones that belong to Graanul Invest AS group) and to a limited extent with power plants that have condensing turbines (Balti Elektrijaam and Eesti Elektrijaam). Natural gas (and biogas as well) are generally being used in installations with internal combustion engines (Table 8.4, KE035).

Table 8.4. KE035: FUEL USED IN CO-GENERATION INSTALLATIONS, 2019

Type of generator (steam power engine)	Type of fuel/energy	Indicator	2019
Steam condensing extraction turbines	Wood fuel (non-upgraded)**, thousands of cubic metres, GWh	Amount of the fuel consumed	1802
		Energy of the fuel consumed, TJ	13898
	Natural gas, million m³	Amount of the fuel consumed	0
		Energy of the fuel consumed, TJ	2

Gas turbines with heat recovery	Wood fuel (non-upgraded)**, thousands of cubic metres, GWh	Amount of the fuel consumed	220
		Energy of the fuel consumed, TJ	1 842
	Natural gas, million m³	Amount of the fuel consumed	0
		Energy of the fuel consumed, TJ	1
Internal combustion engines	Natural gas, million m³	Amount of the fuel consumed	10
		Energy of the fuel consumed, TJ	331

Table 8.5 (KE044) it is not possible to highlight boilers using wood fuel or gas fuel specifically by power ratings. Combined data on boilers using wood fuel and gas fuel have been given.

Table 8.5. KE044: BOILERS (only boiler plants), 2018

Sector of the economy	Type of boiler	Number of boiler at the end of year	The cumulative capacity of the boilers, MW	Heat produced, GWh
Industrial sector	Boilers with a capacity of up to 1 MW	667	282	230
	Boilers with a capacity of 1.1 to 5 MW	154	393	514
	Boilers with a capacity of 5.1 to 20 MW	45	391	650
	Boilers with a capacity of 20.1 to 60 MW	1	25	29
	Boilers with a capacity of over 60 MW	0	0	0
	Boilers using wood (incl. woodchips and wood waste)	279	351	782
	Boilers using gas fuel (natural gas, liquid gas)	383	562	534
Energy sector	Boilers with a capacity of up to 1 MW	304	132	148
	Boilers with a capacity of 1.1 to 5 MW	149	361	472
	Boilers with a capacity of 5.1 to 20 MW	54	475	917
	Boilers with a capacity of 20.1 to 60 MW	6	220	346
	Boilers with a capacity of over 60 MW	7	814	606
	Boilers using wood (incl. woodchips and wood waste)	121	316	617
	Boilers using gas fuel (natural gas, liquid gas)	184	1400	908
Agriculture, forestry and fishing	Boilers with a capacity of up to 1 MW	133	47	23

Sector of the economy	Type of boiler	Number of boiler at the end of year	The cumulative capacity of the boilers, MW	Heat produced, GWh
	Boilers with a capacity of 1.1 to 5 MW	15	36	12
	Boilers with a capacity of 5.1 to 20 MW	2	11	5
	Boilers with a capacity of 20.1 to 60 MW	0	0	0
	Boilers with a capacity of over 60 MW	0	0	0
	Boilers using wood (incl. woodchips and wood waste)	45	19	11
	Boilers using gas fuel (natural gas, liquid gas)	37	36	16
Land transport and transport via pipelines, water transport, air transport	Boilers with a capacity of up to 1 MW	35	14	7
	Boilers with a capacity of 1.1 to 5 MW	6	12	6
	Boilers with a capacity of 5.1 to 20 MW	0	0	0
	Boilers with a capacity of 20.1 to 60 MW	1	26	0
	Boilers with a capacity of over 60 MW	0	0	0
	Boilers using wood (incl. woodchips and wood waste)	12	10	1
	Boilers using gas fuel (natural gas, liquid gas)	13	35	11
Commercial and public service sector	Boilers with a capacity of up to 1 MW	826	254	237
	Boilers with a capacity of 1.1 to 5 MW	79	197	163
	Boilers with a capacity of 5.1 to 20 MW	35	262	139
	Boilers with a capacity of 20.1 to 60 MW	0	0	0
	Boilers with a capacity of over 60 MW	0	0	0
	Boilers using wood (incl. woodchips and wood waste)	136	81	81
	Boilers using gas fuel (natural gas, liquid gas)	485	472	367

Data on boilers with a capacity of over 20 MW in various sectors of the economy have been hidden in blue colour (they are predominantly in the energy sector). Apparently this does not include heat and electricity co-generation boilers, because their number should be much bigger otherwise. (Table 8.5, Table 8.6, Table 8.7).

Table 8.6. KE044: boilers - All economic activities - 2018

Year	Industry branch	Type of boiler	Indicator		
			Number of boiler at the end of year	The cumulative capacity of the boilers, MW	Heat produced, GWh
2018	Total - all fields	Boilers with a capacity of up to 1 MW	1 965	729	645
		Boilers with a capacity of 1.1 to 5 MW	403	999	1 167
		Boilers with a capacity of 5.1 to 20 MW	136	1 139	1 711
		Boilers with a capacity of 20.1 to 60 MW	8	271	375
		Boilers with a capacity of over 60 MW	7	814	606
		Total MW	**2 159**	**3 952**	**4 054**
		Boilers using wood (incl. woodchips and wood waste)	593	777	1 492
		Boilers using gas fuel (natural gas, liquid gas)	1 102	2 505	1 836

Total heat in 2018, that was generating with boilers bigger than 5 MW, was 2 692 GWh, and with wood fuel alone, 1 492 GWh was generated with all boilers bigger than 5 MW (waste fuel accordingly 150 GWh). 1 836 GWh (waste heat 184 GWh) was generated by using natural gas (en estimated share of 10 % of heat generated).

It remains unclear whether bigger boilers and their heat production (Table KE044) have also been counted in the heat and electricity co-generation installation heat generation table (KE035). This is not possible to be distinguished.

Table 8.7. KE044: boilers - All economic activities, aggregate - 2018

Year	Sector of the economy	Type of boiler	Heat produced, GWh/%	
2018	Total - all fields	Boilers with a capacity of up to 1 MW	645	14.32
		Boilers with a capacity of 1.1 to 5 MW	1 167	25.91
		Boilers with a capacity of 5.1 to 20 MW	1 711	37.99
		Boilers with a capacity of 20.1 to 60 MW	375	8.33
		Boilers with a capacity of over 60 MW	606	13.45
		All boilers bigger than 5 MW	**2 692**	**59.77**
		All boilers, total	**4 504**	**1**
		Boilers using wood (incl. woodchips and wood waste)	**1 492**	**0.33**

The most heat is produced with boilers, the capacity of which lies between 5.1 and 20 MW, i.e. 1711 GWh/2018, which amounted to 38 % of the total heat production of all boilers. Most of the wood fuel is probably burnt in boilers with a capacity range of 1.1 to 20 MW, as almost all district heating network woodchip boilers belong to this range. With over 20.1 MW boilers, only 981 MWh of heat was produced, which represented ~22 % of all the heat produced.

In Table 8.8 (KE06) the amount of wood fuel and gas fuel is presented, that has been used in the country for producing heat (including heat and electricity combined), including in small households.

Table 8.8. KE06: CONSUMPTION OF FUELS, cubic metres, GWh

Type of fuel	2016		
Wood fuel (non-upgraded)**, thousands of cubic metres, GWh	4 647	9 387	940
Natural gas, millions m³, GWh	518	4 848	485
Biogas, millions m³, GWh	25	150	15

Note: Table 8.8 In the last column, a theoretical waste heat amount (GWh) has been presented, that could be acquired by condensing the water vapour in the exhaust gases caused by burning wet wood and gas fuel. Conservative estimates have been made, that a minimum of 10 % of the energy that fuel contains could be acquired by condensing the water vapour, taking into account the temperature schedules of the district heating networks. The estimate has the shortcoming that not all of this heat can be used, as some fuels (especially wood fuels) are being burnt in the households, where waste water is actually used in heating devices with storage possibilities or for warming up domestic hot water. Modern natural gas boilers (small and medium-size devices) already have flue gas condensing by default and this heat is being used.

The waste heat potential of AS Tallinna Vesi Paljassaare wastewater treatment plant

The estimate of the waste heat potential of this company relies on a source ('Paljassaare arenduspiirkonna soojusvarustuse põhimõtteline lahendus AS-i Tallinna Vesi reoveepuhastusjaama heitvee soojuse baasil' ('The principal solution of the heating supply of the Paljassaare development area based on the heat of the wastewater of AS Tallinna Vesi wastewater treatment plant') Tallinna tehnikaülikool, soojustehnika instituut, 2008) and on the 2019 data on the wastewater volumes (effluent) sent by the company's development manager.

AS Tallinna Vesi provides an overview of the wastewater volumes of the wastewater treatment plant Table 8.9 and the temperature of the wastewater leaving the plant and on the temperature of the effluent that flows out of the plant Table 8.10.

Table 8.9. Waste water amounts, m³

Month	2007	2006	2005	2004	2003	2019
January	5 262 803	3 263 405	7 557 259	3 576 947	3 847 870	3 534 776
February	3 124 398	2 643 261	3 210 722	3 185 829	3 003 601	4 663 976
March	4 489 362	3 675 629	3 466 697	4 607 790	3 623 794	5 076 417
April	3 570 059	4 834 358	3 679 144	4 012 562	4 282 939	3 565 964
May	3 457 483	3 378 407	3 555 097	3 407 978	4 725 904	3 944 530
June	3 095 741	2 964 354	3 438 254	3 381 269	3 472 909	3 139 008
July	3 215 316	2 850 424	2 952 188	6 235 034	3 518 961	3 248 975
August	3 767 041	3 133 633	4 832 997	5 708 205	3 375 405	3 797 884
September	4 432 996	2 975 919	3 354 452	4 540 669	3 103 638	3 720 580
October	4 356 964	3 731 717	3 449 752	5 178 426	3 731 399	5 854 146
November	3 847 386	3 929 869	4 114 914	4 554 577	3 680 531	4 086 466
December	3 973 571	4 156 424	3 911 313	4 907 979	5 129 752	5 036 630
Year	**46 593 120**	**41 537 400**	**47 522 789**	**53 297 265**	**45 496 703**	**49 669 352**

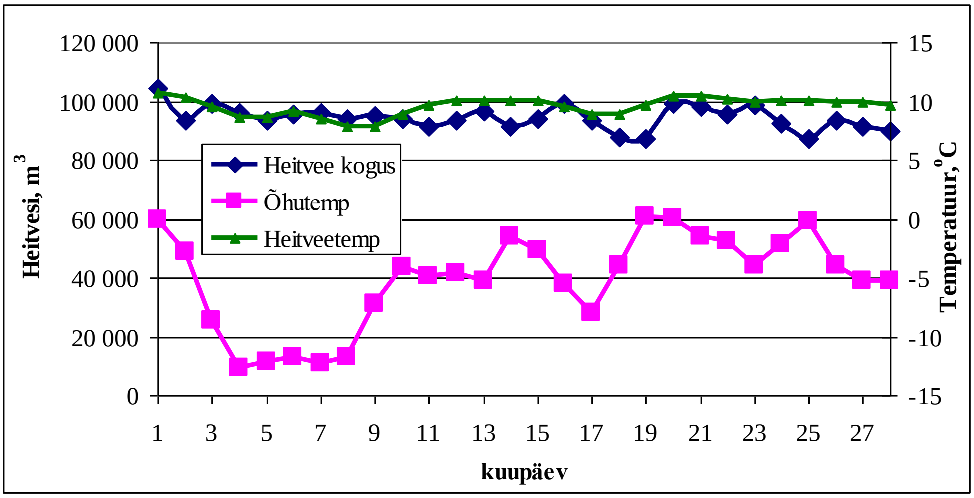
Table 8.10. Waste water temperature at outflow from the plant

2019	Outflowing waste water temp °C
January	9.5
February	8.8
March	9
April	11.9
May	14.1
June	18
July	19.2
August	19.3
September	17.6
October	13.9
November	12.6
December	10.7

A better overview of the effluent amounts, aimed at utilising the heat found in the effluent, can be found when comparing the amounts with the temperatures For this purpose, graphs have been drawn on February and July 2006, see Key: X axis – month; Y axis, left-hand side: effluent (m³); Y axis, right-hand side - temperature (°C); box, top to bottom - total effluent, air temperature, effluent temperature

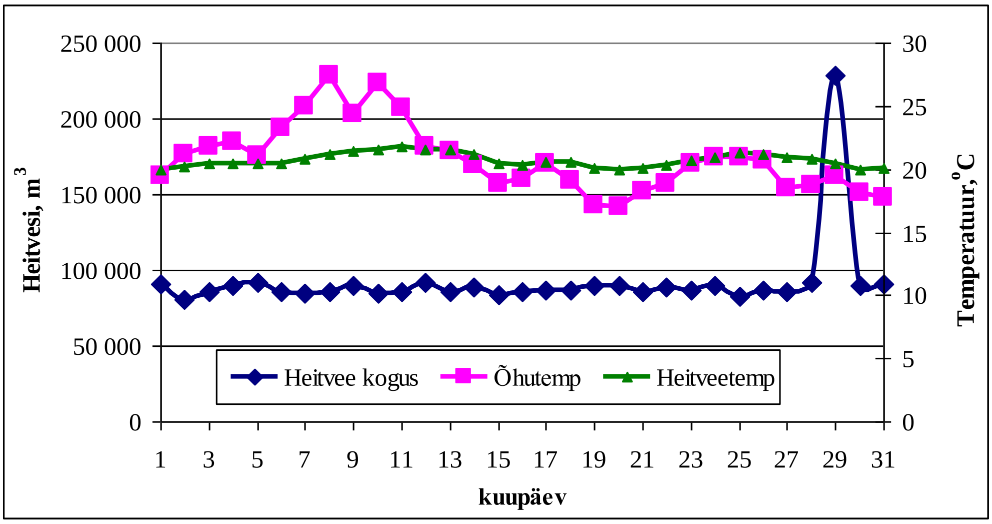
Figure 8.1 and Key: X axis – month; Y axis, left-hand side: effluent (m³); Y axis, right-hand side - temperature (°C); box, left to right - total effluent, air temperature, effluent temperature

Figure 8.2.



Key: X axis – month; Y axis, left-hand side: effluent (m³); Y axis, right-hand side - temperature (°C); box, top to bottom - total effluent, air temperature, effluent temperature

Figure 8.1. Amount and temperature of the effluent and the temperature of the ambient air, February 2006.

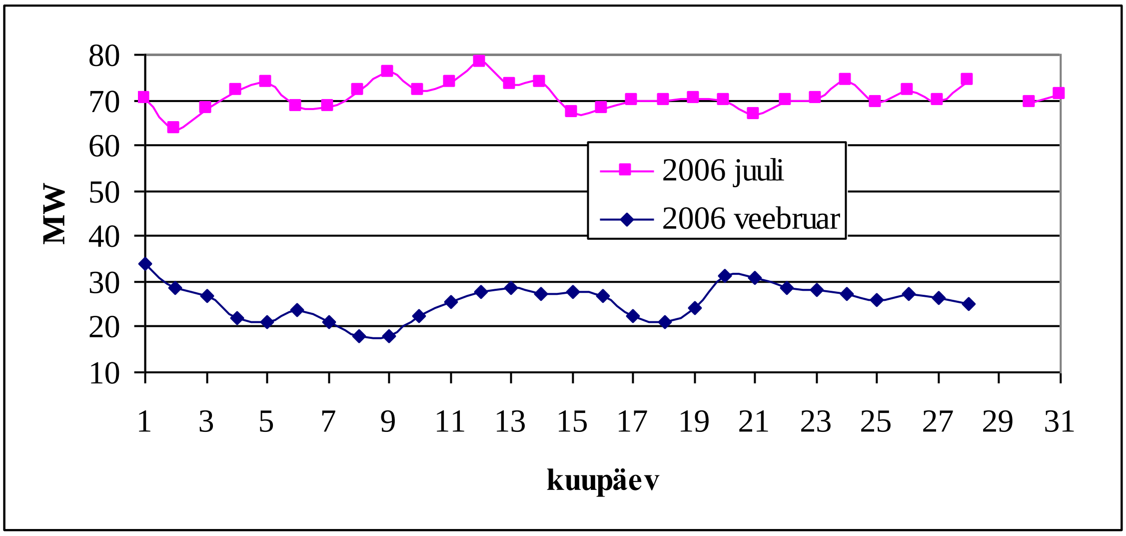


Key: X axis – month; Y axis, left-hand side: effluent (m³); Y axis, right-hand side - temperature (°C); box, left to right - total effluent, air temperature, effluent temperature

Figure 8.2. Amount and temperature of the effluent and the temperature of the ambient air, July 2006.

The amounts of the effluent are not in a one-to-one relationship with the external temperature; rather, they depend on rainfall, melting of snow and people's consumer habits. In two previous figures it can be observed that the fluctuations of the effluent temperature are not very big (less than five degrees), and that it is e.g. +10 in February and +20 Celsius in July. Nevertheless, a fluctuation of the temperature by a couple of degrees affects the capacity of a heat pump to a significant degree. In order to illustrate this better, it would be worthwhile demonstrating the capacity achieved just like with the two previous figures, see Key: X-axis – month; box, top to bottom – July 2006, February 2006

Figure 8.3. .



Key: X-axis – month; box, top to bottom – July 2006, February 2006

Figure 8.3. The thermal capacity gained from the effluent in February 2006 and July 2006, MW

As we see, due to the fluctuations in temperature and waterflows, with weather conditions being equal, the thermal capacity can fluctuate by 20 MW, which could be considered a relatively large fluctuation. This is why it is sensible to take the minimal burdens as the basis, when planning the heating supply of a development area, so as to mitigate risks.

Secondly, such activities should be avoided that would reduce the temperature of the wastewater collected in the settlements before it reaches the wastewater treatment plant, so as to ensure a favourable environment (temperature) for the life of bacteria in the treatment stations of activated sludge. It is economically more feasible to first treat the wastewater and then use the heat of the effluence (cleansed wastewater) for raising it to higher temperature levels with the help of heat pumps and transmitting it to the district heating network.

When the ambient air temperature fell to -10 °C in February 2006, a waste heat burden of ~18 MW was possible (in Tallinn Paljassaare wastewater treatment plant). In such a case, for example, 432 MWh could be used a day as waste heat. The summer burden peaks reached 80 MW in July 2006 , which would enable one to obtain 1,920 MWh of waste heat a day. In accordance with a conservative estimate, a yearly (8,760 h) waste heat amount could be in the magnitude of 430 GWh, but it can also reach up to 580 GWh/year.

Of the residual heat of technological processes in a company, one could consider utilising the residual heat that is captured from burning biogas here. At the current rate of usage, an estimated 1,600 MWh of heat is left when biogas is burnt at a wastewater treatment plant. Considering the need for heat for development projects outside the company or in-house, this is a relatively minuscule part (~3 %). Thus it is not feasible to make extra investments for utilising this relatively small source of heat.

Conclusion

The amount of waste heat acquired from condensing flue gases during heat production by burning wet wood fuel and gaseous fuels might be 492 + 329 = 821 GWh/a in line with Statistics Estonia's data (see Table 8.1). Conservative estimates have presumed, that a minimum of 10 % of the total heat produced could be re-used as waste heat. This part of waste heat has surely already found a use (flue gas condensers in boiler plants) either in district heating networks or industrial enterprises.

Based on data collected by the Estonian Power and Heat Association from companies that belong to the Association, in 2019, 2,269.4 GWh was transmitted from heat and electricity co-generation installations (heat and electricity co-generation plants) to the district heating networks. This can be classified as waste heat that gets generated in the case of electricity production. 462 GWh of heat was transferred in 2019 to district heating from other sources of waste heat (mostly from flue gas condensers).

It is impossible to estimate the waste heat amount that has already been used in industrial enterprises, owing to the absence of data (the queries gave very imprecise answers as to this topic). Respondents likewise could not estimate the potential for waste heat in the enterprises. **One of the few companies with the largest waste heat potential is AS Tallinna Vesi, which has a wastewater treatment plant at Paljassaare, where the low temperature of the wastewater discharged into the sea could be recovered with heat pumps, which could yield up to 450 GWh of waste heat with a suitable temperature for supplying e.g. nearby future residential development areas with heat or for transmitting such to the Tallinn district heating network.** This is about half of the theoretical amount of waste heat obtainable from burning wood and gas fuels. The waste heat utilisation opportunity with the biggest potential would be the use of effluence heat of water companies; however these companies are usually located far from the district heating networks of the settlements and investments for starting to use this heat might turn out to be very large.

District cooling and waste heat from district cooling

District cooling, similarly to district heating in densely populated areas, is a central energy supply service that enables the creation of a higher quality urban space. Cities have less noise and vibration and a building has a nicer look, if it lacks local cooling devices on its walls, balcony or roofs (which is especially important in heritage conservation regions and old towns), and production devices have been installed outside the city centre for district cooling plants created for this purpose. At the same time, users of the buildings have been guaranteed a quality indoor climate and the heat directed out of the buildings during the cooling will be utilised in the district heating network or elsewhere and does not end up directly in the environment.

In the district cooling plant, the water (cooling carrier) is either cooled down with water acquired from the environment (sea, river, lake), air or coolers (such as an absorbing device down to 6 to 10 °C (so-called free cooling) and is sent via pipelines to the cooling unit located in the building. There, this water cools the building's ventilation air and the water circulating in the cooling system. In this case, local coolers or Freon (F-gas) that they contain, are not used in the building. The water that discharged cold in the course of the cooling process will be directed back to the district cooling plant, where it will be cooled down again and the heat gained may be transmitted to the district heating network via heat pump.

In 2019, 797 MWh of district cooling plant waste heat was transmitted to the district heating network of the city of Tartu via heat pumps. That year, other district cooling plants (Tallinn, Pärnu) did not transmit waste heat into district heating networks.

The favourable influence of the district cooling systems manifests itself in the better efficiency of the industrial equipment, primary saving due to the use of free cooling, and the use of cooling agents with a smaller greenhouse gas equivalent. No less important is the fact that bigger systems are also better supervised and a professional operation minimises leaks and breakdowns. It is worth separately underscoring the reduction of greenhouse gases thanks to the adoption of better cooling agents, the influence of which reaches up to 21 500 $tCO_{2\ Equivalent}$, if we were to use the up-to-date data of the Centre for Environmental Studies and FOKA.

9 Visualising data on the maps

In accordance with Annex I point 3 of the Delegated Regulation (EU) 2019/826 of 4 March 2019 'Amendment to Annex VIII', all the maps of Estonia are shown below, on which the following has been covered:

(a) heating and cooling demand areas following from the analysis of point 1, while using consistent criteria for focusing on energy dense areas in municipalities and conurbations;

(b) plants, which produce waste heat or waste cooling energy and their potential heating and cooling supplies GWh/year

(c) planned heating and cooling supply points of the type described under point 2(b) and district heating transmission installations.

The maps show data tables collected and developed within the framework of the Hotmaps project. Data tables are available on the Hotmaps website[50]. Additional explanations are available in the project documentation[51]. Additionally, data tables collected while conducting the study and drawn up by the authors of the study as well as databases owned by the authors have been used.

Maps with a higher resolution have been attached to the study as separate files.

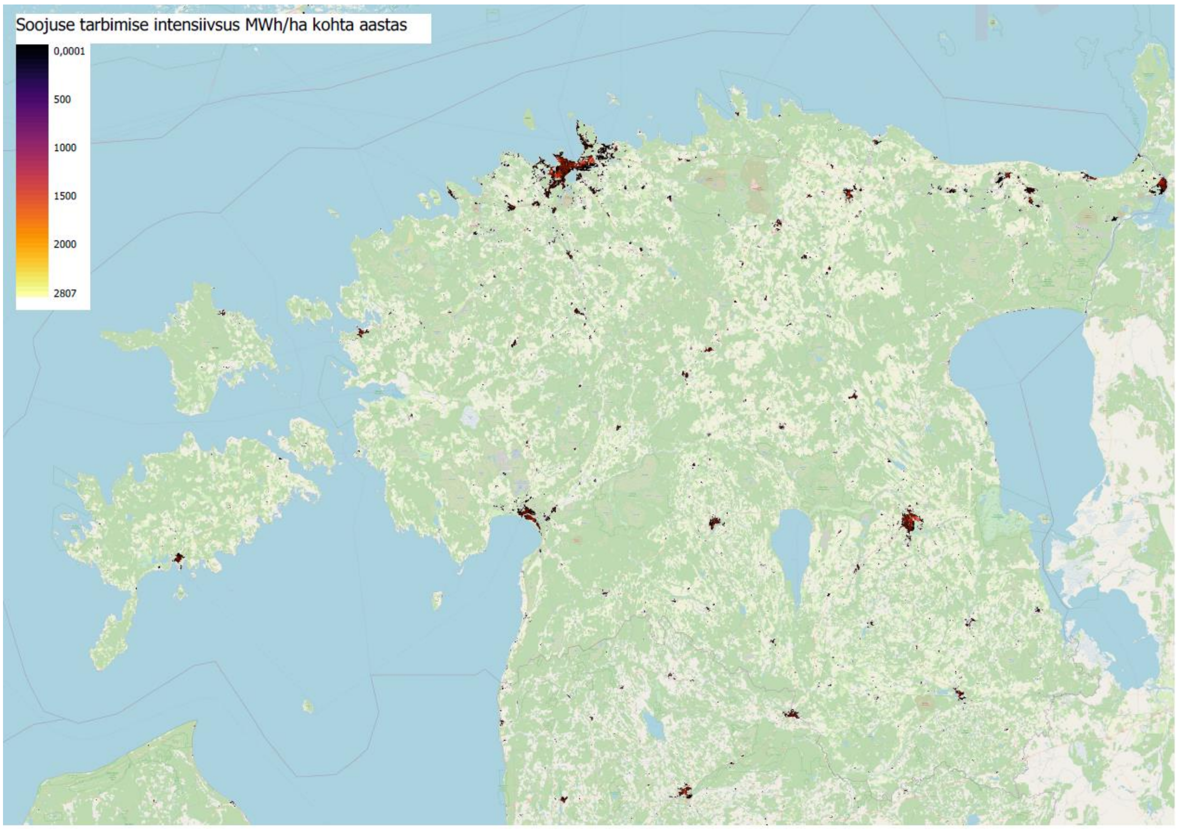
9.1 Heating and cooling demand areas were identified in the course of the study, while using consistent criteria for focusing on energy dense areas in municipalities and conurbations.

When estimating the heating and cooling demand, the maps were created as a hectare-based raster and energy consumption has been expressed as the useful energy consumed. When calculating the intensity of consumption, we were guided by the statistical method, which is based on the approach that the useful energy demand (henceforth: UED) is

[50] https://gitlab.com/hotmaps

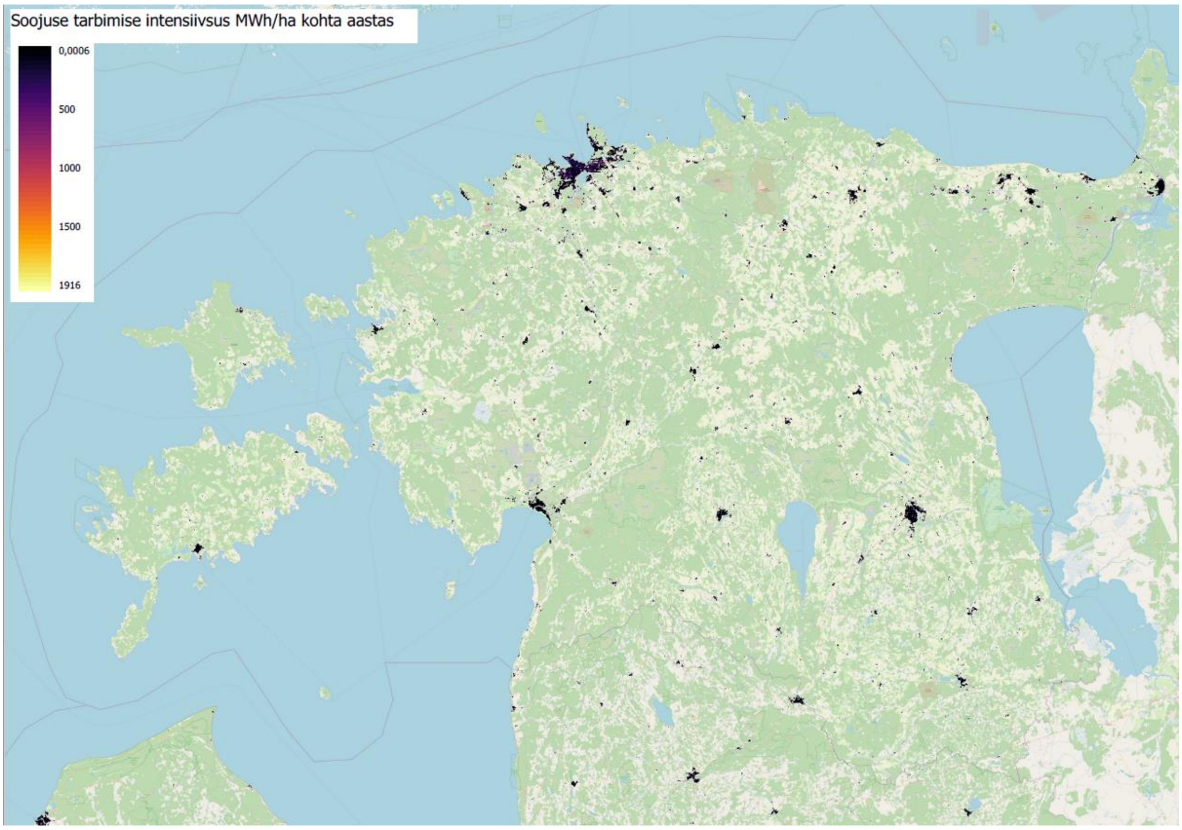
[51] https://www.hotmaps-project.eu/wp-content/uploads/2018/03/D2.3-Hotmaps_for-upload_revised-final_.pdf

connected with the population density, economic activeness and climate conditions, as expressed in degree days of heating/cooling.



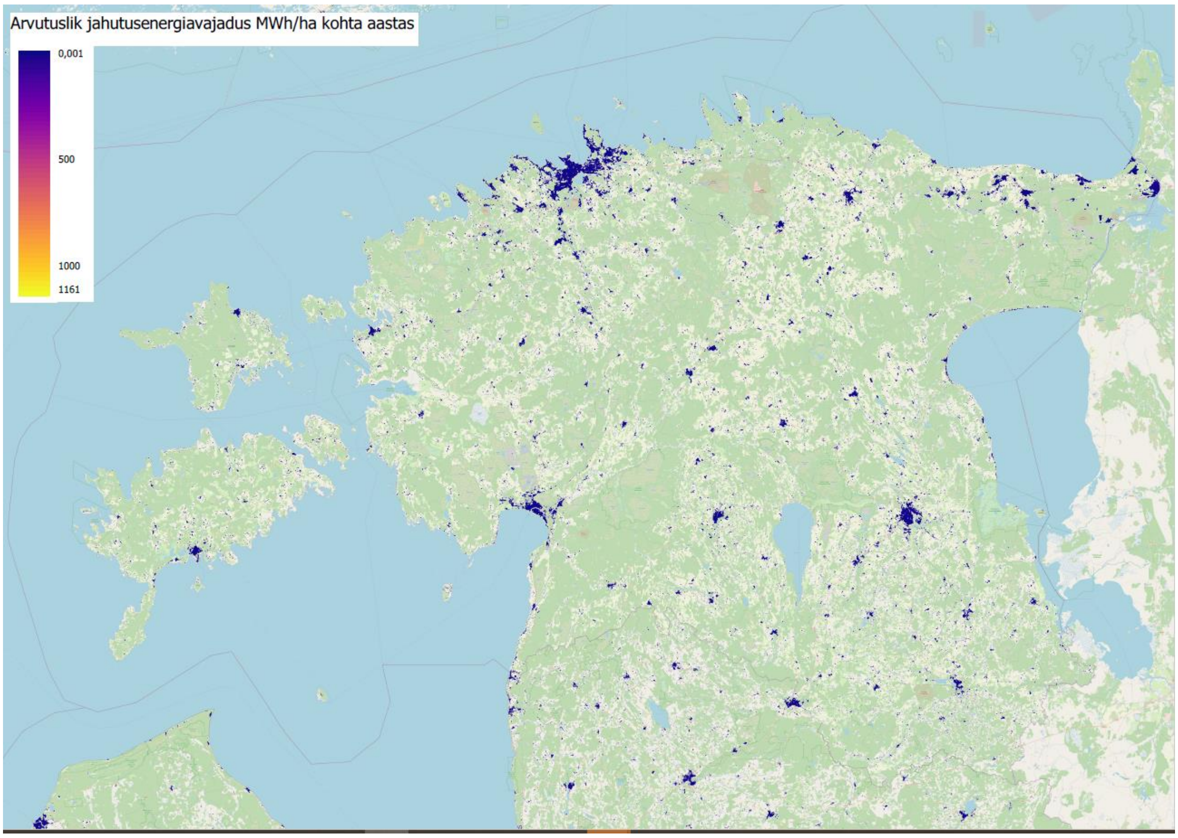
Key: Intensity of heat consumption (MWh/ha per year)

Figure 9.1. Heat consumption intensity in housing industry



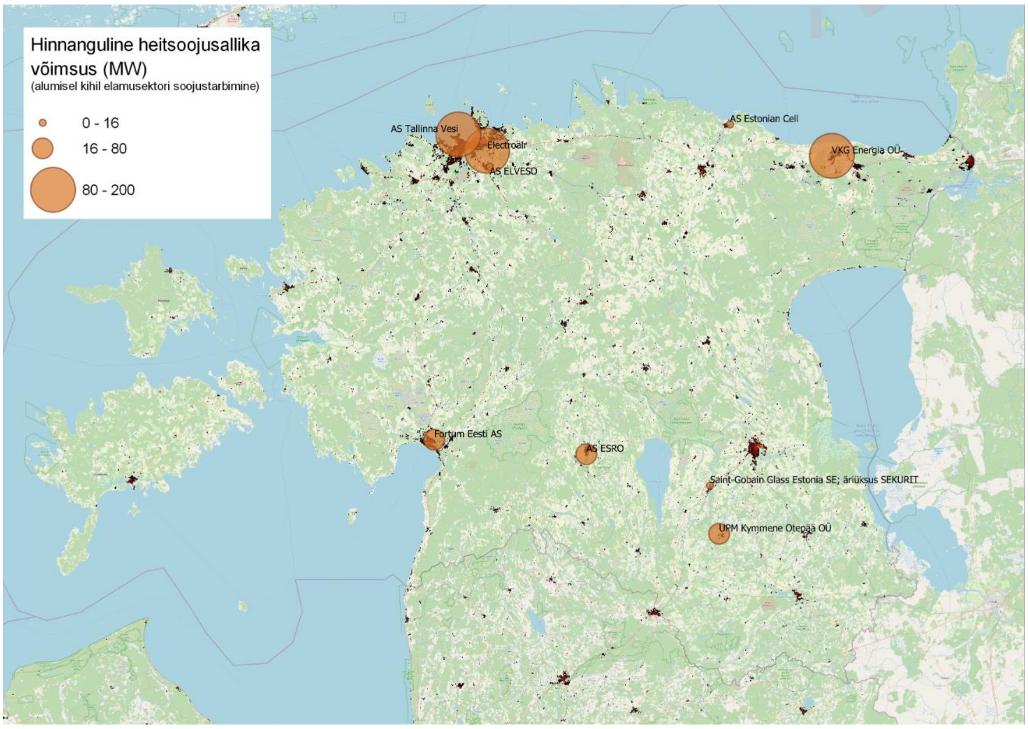
Key: Intensity of heat consumption (MWh/ha per year)

Figure 9.2. Heat consumption intensity in service sector and industries



Key: Predicted cooling need (MWh/ha per year)

Figure 9.3. Predicted cooling need in the housing sector



Key: Box – estimated waste heat source capacity (MW), heat consumed by the housing sector at the lowest stratum

Figure 9.4. Waste heat

10 Forecast trends in heating and cooling demand

Heating demand

The trends in the demand for heating and cooling from the perspective of the next 30 years were described in GWh, taking into account in particular, projections for the next 10 years, possible changes in demand in buildings and different sectors of the industry, and the impact of policies and strategies, such as long-term building renovation strategies under Directive (EU) 2018/844.

First we shall see,how much heat has been produced in Estonia during recent years with all fuels taken together (Table 10.1), For 2019, no data were available.

Table 10.1. Total fuels used for producing heat[52]

Year	Total fuels	
	TJ	GWh
2016	39 032	10 842
2017	40 737	11 316
2018	36 836	10 232

According to an extract received from the Environmental Agency database, in 2018, in all the heat production devices registered by them and using any combined fuel, 11 779 GWh, or 11.78 TWh was produced in-house and for selling.[53] Here one should rather use the ESA table KE024 data (see Table 10.1).

Table 10.2. Final consumption in private households, total fuels[54]

Year	Total fuel		Heat	
	TJ	GWh	TJ	GWh
2016	30 198	8 388	13 057	3 627
2017	30 626	8 507	13 320	3 700
2018	30 599	8 500	13 500	3 750

[52] ESA KE024: energy balance, TJ/GWh

[53] Note: heat has generally been calculated by considering the heating value of the fuel used and the energy conversion efficiency, but in the case of wood fuel, impreciseness when calculating the amount of heat can sometimes be observed, which is why one can have doubts as to the reliability of the total amount

[54] ESA KE024: ENERGY BALANCE, TJ/GWh

Table 10.3. The actual final consumption of heat, incl. in private households[55]

Year	Consumption	Heat, GWh
2016	Actual final consumption	7 993
	..final consumption in private households	3 627
2017	Actual final consumption	8 619
	..final consumption in private households	3 700
2018	Actual final consumption	8 125
	..final consumption in private households	3 750

Table 10.4. Energy and heat consumption in Estonia in 2016[56]

Year	Tarbimine, TJ/TWh		Share in total consumption, %	
2016	Total energy	Heat	Total energy	Heat
	121 688/33 802	28 776/7 993	100	23

In the Energetics database of Statistics Estonia, the data on final consumption of heat has been given as of 2016 (Table 10.5). In the years after that, the Eurostat methodology has been adopted and some of the older data are no longer published on the website (Table 10.6).

Table 10.5. Final consumption of heat in 2016[57]

Indicator	GWh
District heating (the share of the heat sold to customers from the total production)	6 650
Consumption	8 640
..consumption in industry (including mining and energetics)	2 835
..consumption in construction	37
..consumption in agriculture	105
..consumption in private households	3 627
..consumption in other branches	2 036

Note : The total losses in the district heating networks were 901 GWh in 2016.

The heat sold to customers also includes heat, which has been sold either to district heating customers or to entrepreneurs, who do not produce heat themselves, but are rather buying it separately from the producer (in Estonia, Adven Eesti AS frequently sells heat to companies).

[55] ESA KE023: ENERGY BALANCE, GWh

[56] ESA table KE05: FINAL CONSUMPTION OF ENERGY (excluding fuel consumption for non-energetics purposes, losses in transportation, storage and dividing)

[57] ESA KE04: HEAT BALANCE, 2016

Table 10.6. Heat balance in years 2017, 2018 and 2019[58]

Year	Sector, indicator	Heat	
		TJ	GWh
2017	**Actual final consumption**	**19 924**	**5 534.4**
	Final consumption in the industry sector	1 550	430.6
	..final consumption in the iron and steel industry	0	0
	..final consumption in the chemical industry	720	200
	..final consumption in the non-ferrous metal industry	0	0
	..final consumption in the manufacture of other non-metallic mineral products	72	20
	..final consumption in the manufacture of transport vehicles	63	17.5
	..final consumption in mechanical engineering	216	60
	..final consumption in the extractive industry	2	0.6
	..final consumption in the food and tobacco industry	127	35.3
	..final consumption in the paper and printing industry	35	9.7
	..final consumption in the logging industry	62	17.2
	..final consumption in construction	83	23.1
	..final consumption in the textile and leather industry	65	18.1
	..final consumption in industries not classified elsewhere	105	29.2
	Final consumption in the transport sector		0
	Final consumption in other sectors	18 374	5 103.9
	..final consumption in the commercial and public service sector	4 980	1 383.3
	..final consumption in private households	13 320	3 700
	..final consumption in the agricultural and forestry sector	74	20.6
	..final consumption in the fisheries sector	0	0
	..final consumption in sectors not classified elsewhere	0	0
2018	**Actual final consumption**	**20 165**	**5 601.4**
	Final consumption in the industry sector	1 497	415.8
	..final consumption in the iron and steel industry	0	0
	..final consumption in the chemical industry	647	179.7
	..final consumption in the non-ferrous metal industry	0	0
	..final consumption in the manufacture of other non-metallic mineral products	95	26.4
	..final consumption in the manufacture of transport vehicles	81	22.5
	..final consumption in mechanical engineering	219	60.8
	..final consumption in the extractive industry	5	1.4
	..final consumption in the food and tobacco industry	121	33.6
	..final consumption in the paper and printing industry	29	8.1
	..final consumption in the logging industry	68	18.9
	..final consumption in construction	77	21.4

[58] (ESA table KE0240: ENERGY BALANCE, in TJ: GWh, EUROSTAT methodology), i.e. heat sold to customers

Year	Sector, indicator	Heat	
		TJ	GWh
	..final consumption in the textile and leather industry	64	17.8
	..final consumption in industries not classified elsewhere	91	25.3
	Final consumption in the transport sector		0
	Final consumption in other sectors	18 668	5 185.6
	..final consumption in the commercial and public service sector	5 100	1 416.7
	..final consumption in private households	13 500	3 750
	..final consumption in the agricultural and forestry sector	68	18.9
	..final consumption in the fisheries sector	0	0
	..final consumption in sectors not classified elsewhere	0	0
2019	**Actual final consumption**	**19 446**	**5 401.7**
	Final consumption in the industry sector	1 401	389.2
	..final consumption in the iron and steel industry	0	0
	..final consumption in the chemical industry	610	169.4
	..final consumption in the non-ferrous metal industry	0	0
	..final consumption in the manufacture of other non-metallic mineral products	80	22.2
	..final consumption in the manufacture of transport vehicles	70	19.4
	..final consumption in mechanical engineering	190	52.8
	..final consumption in the extractive industry	4	1.1
	..final consumption in the food and tobacco industry	110	30.6
	..final consumption in the paper and printing industry	32	8.9
	..final consumption in the logging industry	65	18.1
	..final consumption in construction	80	22.2
	..final consumption in the textile and leather industry	67	18.6
	..final consumption in industries not classified elsewhere	93	25.8
	Final consumption in the transport sector		0
	Final consumption in other sectors	18 045	5 012.5
	..final consumption in the commercial and public service sector	4 300	1 194.4
	..final consumption in private households	13 680	3 800
	..final consumption in the agricultural and forestry sector	65	18.1
	..final consumption in the fisheries sector	0	0
	..final consumption in sectors not classified elsewhere	0	0

Total heat consumption, according to Table 10.6, is uneven from year to year, but in 2019 it was the lowest (it is not known whether consumption has been corrected to a normal year).

When comparing final consumption data

Year	Total fuel		Heat	
	TJ	GWh	TJ	GWh
2016	30 198	8 388	13 057	3 627
2017	30 626	8 507	13 320	3 700

2018	30 599	8 500	13 500	3 750

Table 10.3 and Table 10.6 (the latest one based on Eurostat methodology), we see the differences in the final heat consumption figures in the same years. The difference is that Eurostat's methodology only takes into account the heat sold and not what is produced for own use. Because of this, the values given in

Year	Total fuel		Heat	
	TJ	GWh	TJ	GWh
2016	30 198	8 388	13 057	3 627
2017	30 626	8 507	13 320	3 700
2018	30 599	8 500	13 500	3 750

Table 10.3 are higher. For example, in

Year	Total fuel		Heat	
	TJ	GWh	TJ	GWh
2016	30 198	8 388	13 057	3 627
2017	30 626	8 507	13 320	3 700
2018	30 599	8 500	13 500	3 750

Table 10.3 the actual total heat consumption for 2018 is 8 125 GWh and in Table 10.6, in the same year, 5 601.4 GWh.

Before forecasting the demand for heating and cooling, we could look at the heat production in Estonia in the last three years. As can be seen in Table 10.7,

Table 10.8 and **Error! Reference source not found.**,

Key: Electricity and heat production (TJ); Corrected by degree days (TWh)

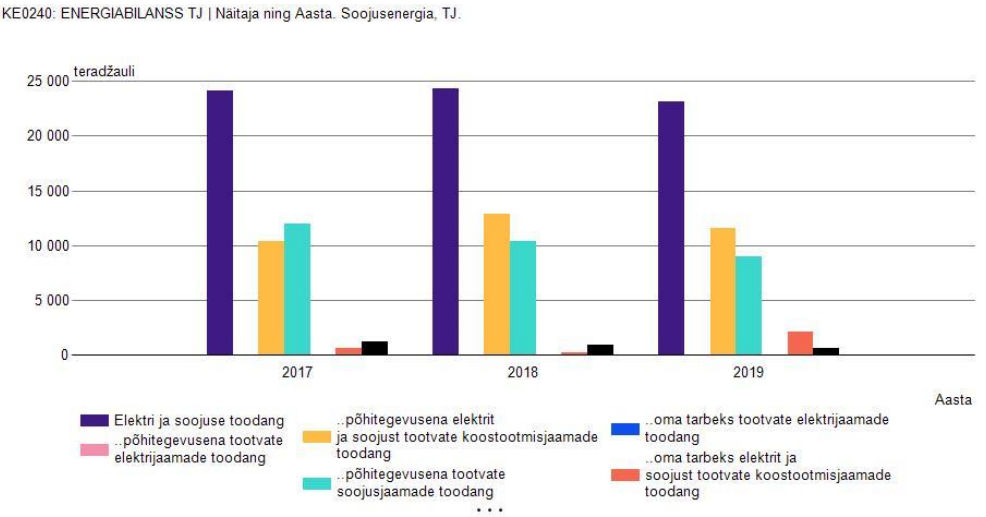
Figure 10.3 heat production corrected by degree days has increased slightly every year. Values uncorrected by degree days remain more or less stable. If the heat is sold to companies, the part that goes into the production processes would not need to be reduced by degree days, but it is not possible to indicate this part separately (the part is also used for space heating).

Table 10.7. Heat production in 2017, 2018 and 2019[59]

Indicator	Unit	Year		
		2017	2018	2019
Heat production	TJ	24 179	24 360	23 172
Corrected by degree days	TJ	26 023	27 260	27 353
Corrected by degree days (at 17 °C, Tallinn's equilibrium temperature)	GWh	7 240	7 572	7 598

[59] ESA table KE0240: ENERGY BALANCE, in TJ. Indicator, type and quantity of energy (EUROSTAT methodology), that is produced for sale

..production of main activity CHP plants	TJ	10 411	12 912	11 565
..production of main activity producer heat plants	TJ	11 935	10 322	8 990
..production of autoproducer CHP plants	TJ	596	219	2 044
..production of autoproducer heat plants	TJ	1 237	907	574



Key: (top row) Production of electricity and heat; Production of main activity CHP plants; Production of autoproducer power plants; (bottom row) Production of main activity power plants; Production of main activity heat plants; Production of autoproducer CHP plants

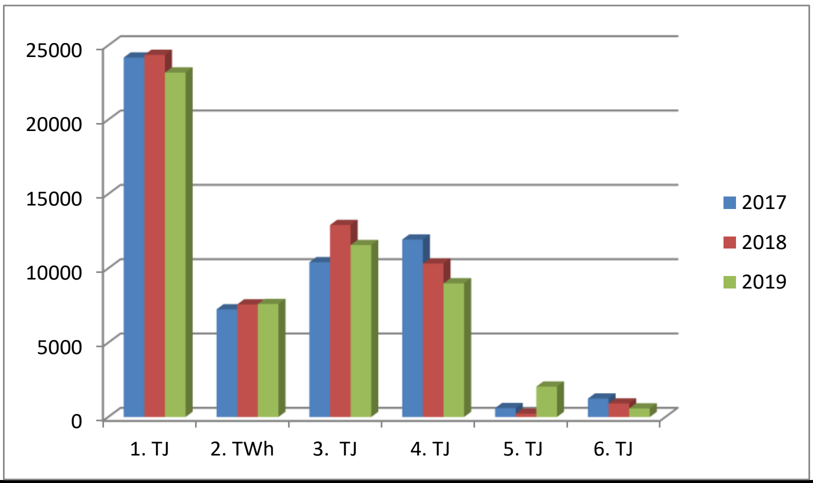
Figure 10.1. Heat production by industry sector in Estonia in the last three years, in TJ

As Key: (top row) Production of electricity and heat; Production of main activity CHP plants; Production of autoproducer power plants; (bottom row) Production of main activity power plants; Production of main activity heat plants; Production of autoproducer CHP plants

Figure 10.1 and

1	Heat production
2	Production of heat corrected by degree days
3	..heat production of main activity CHP plants
4	..production of main activity producer heat plants
5	..heat production of autoproducer CHP plants
6	..production of autoproducer heat plants

Figure 10.2 show, only the autoproducer production of main activity cogeneration plants producing electricity and heat has increased in recent years, which is sustainable in terms of primary energy use. Thus, waste heat from CHP plants (a by-product of electricity generation) has also been increasingly used in wood dryers or in the drying of raw materials in pellet plants (in the latter there may even be a surplus).

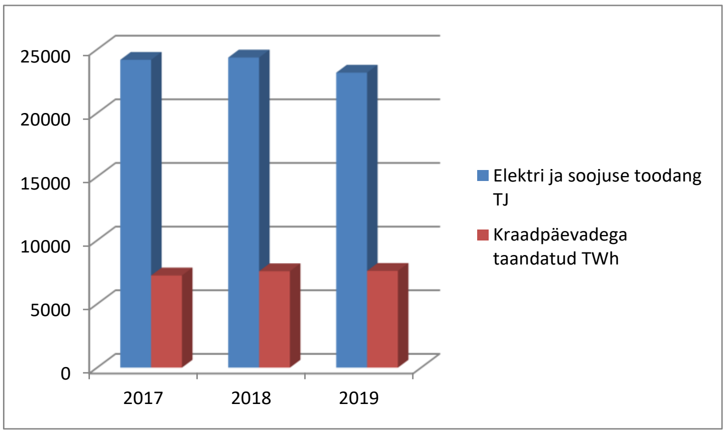


1	Heat production
2	Production of heat corrected by degree days
3	..heat production of main activity CHP plants
4	..production of main activity producer heat plants
5	..heat production of autoproducer CHP plants
6	..production of autoproducer heat plants

Figure 10.2. Heat production by industry in Estonia in the last three years[60]

Table 10.8. Production of heat in Estonia corrected by degree days

Indicator	Unit	2017	2018	2019
Electricity and heat production	TJ	24 179	24 360	23 172
Corrected by degree days	TWh	7.24	7.572	7.598



[60] TWh – has been corrected by degree days

Key: Electricity and heat production (TJ); Corrected by degree days (TWh)

Figure 10.3. Heat production in Estonia in the last three years

To assess heating demand, and the role of renewable energy sources in it, the goals of NECP 2030 have been reviewed[61]:

Final energy consumption 32 TWh/y: In order to maintain final energy consumption in 2021—2030, energy savings must be achieved every year equal to 0.8 % of the average final energy consumption in 2016—2018. The achieved energy savings must be cumulative, i.e. the amount of savings achieved in previous years must be maintained throughout the period.

The required energy savings in the period 2021—2030 are 14 667 GWh or 1 267 GWh/y or 1.47 TWh/y. That is total savings in all forms of energy, incl. heat.

The share of renewable energy in the total final energy consumption must be at least 42 % in 2030: in 2030 16 TWh or 50 % of final energy consumption will be produced from renewable sources, incl. renewable electricity 4.3 TWh (2018 = 1.8 TWh), renewable heat 11 TWh (2018 = 9.5 TWh) and transport 0.7 TWh (2018 = 0.3 TWh).

Renewable energy accounts for 63 % in the heating sector. In the field of heat and cooling, the potential of Estonian wood fuels is being exploited and the share of heat pumps is increasing (Table 10.5).

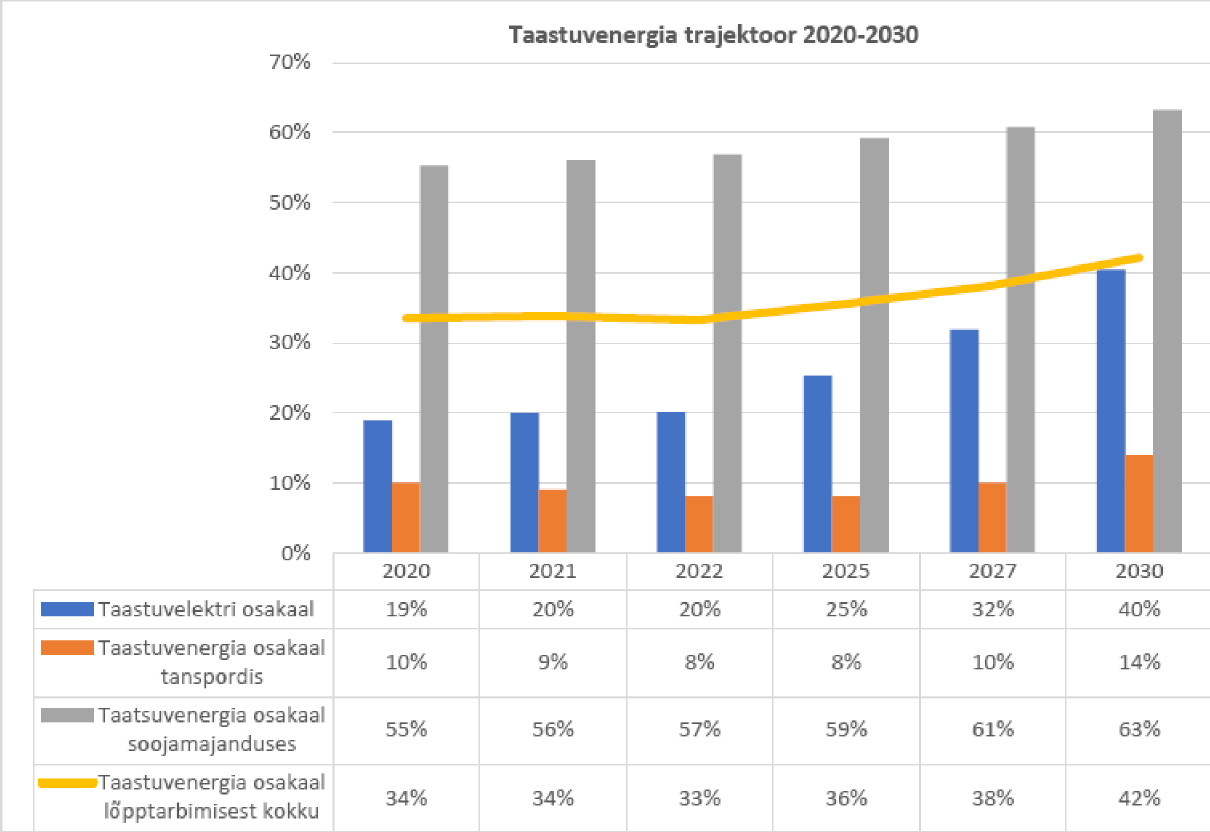
The above is based on the national target set for 2030 in ENMAK 2030 that renewable energy will account for at least 50 %, i.e. 16 TWh, of the final energy consumption of 32 TWh by 2030 (electricity 4.3 + heat 11 + transport fuels 0.7).

According to ENMAK 2030, 11 TWh of the total heat demand in 2030 will be supplied with biomass, incl. that 80 % of district heating in Estonia will be produced from renewable sources. Considering the volume of building stock to be renovated and the forecasts updated by the sector on the development of the use of renewable fuels in the district heating sector, renewable fuels (11 Twh) will account for at least 63 % of total final heat consumption in 2030 (17.4 TWh in 2030). **Thus, the total final heat consumption in all sectors should have reached 17.4 TWh per year by 2030**. **In 2019, it was 7.6 TWh corrected to a normal year.**

Estimated energy consumption trajectory showing the share of renewable energy in final energy consumption in each sector (electricity, heating and cooling and transport) in the period 2021-2030 Key: (title) Renewable energy trajectory 2020-2030; (table, top to bottom) share of renewable electricity, share of renewable energy in transport, share of renewable energy in the heating economy, share of renewable energy in total final consumption

Figure 10.4 (NECP 2030).

[61] NECP 2030, p. 8 and Table 2 Estonia's main energy and climate policy goals, policy directions and measures.



	2020	2021	2022	2025	2027	2030
Taastuvelektri osakaal	19%	20%	20%	25%	32%	40%
Taastuvenergia osakaal tanspordis	10%	9%	8%	8%	10%	14%
Taatsuvenergia osakaal soojamajanduses	55%	56%	57%	59%	61%	63%
Taastuvenergia osakaal lõpptarbimisest kokku	34%	34%	33%	36%	38%	42%

Key: (title) Renewable energy trajectory 2020-2030; (table, top to bottom) share of renewable electricity, share of renewable energy in transport, share of renewable energy in the heating economy, share of renewable energy in total final consumption

Figure 10.4. The share of renewable energy in final energy consumption in Estonia in general and by sectors[62]

The expected trajectory of the renewable energy share in heat consumption is given in Figure 10.4. The highest growth potential, i.e. 47 % in the field of heat and cooling energy, is forecast for heat pumps (Table 10.9).

The production of heating and cooling energy from renewable energy sources was 9,062 GWh (9.1 TWh) in 2017 and the target for 2030 is 11,000 GWh (11 TWh), which makes an increase of 1,938 GWh (1.9 TWh) or ~21 %, i.e. about 1 % a year.

[62] The 2020 figures are based on forecasts. The statistical quantities of renewable energy sold to other Member States in the context of statistical trade must be deducted from the forecasts.

Table 10.9. Renewable energy consumption in the heating sector (NECP 2030)

Taastuvenergiatehnoloogiate panus eesmärkidesse (GWh)	2020	2022	2025	2027	2030
Taastuvenergia tarbimine soojusmajanduses:	**9950**	**10160**	**10475**	**10685**	**11000**
Lokaalküte	5 000	4 960	4 900	4 860	4 800
Muundatud soojus	4 000	4 160	4 400	4 560	4 800
Soojuspumbad	950	1 040	1 175	1 265	1 400

Key:
Contribution of renewable energy technologies towards targets (GWh)
Consumption of renewable energy in the heating economy:
Block heating
Transformed heat
Heat pumps

In 2017, 2.4 TWh of heat energy was produced with wood-fired boilers, and in 2018, power plants using wood fuels produced a record 4.2 TWh of heat energy and 1.1 TWh of electricity (total power plant production 12.3 TWh).[63]

Share of renewable energy in district heating

In the heat sector, there has been a constant shift to renewable sources in recent years, which have now reached a share of 51.64 %. More and more boiler houses and cogeneration plants have switched to renewable fuels, and according to 2017 data, the share of renewable energy in district heating was 52 %, of which 93 % has received an efficient district heating label. The label 'Efficient district heating' is awarded to a district heating system that uses at least 50 % renewable energy or 50 % waste heat or 75 % cogeneration or 50 % of combined such energy and heat for heat production, following the European Union's Energy Efficiency Directive 2012/27/EU. The label certifies the efficiency of the district heating system and the share of renewable or cogeneration energy in the heat transferred through the network. It is important to note here that biomass used in the heating sector must meet the sustainability criteria of the Renewable Energy Directive (EU) 2018/2001 and take into account the waste hierarchy.

The nature of district cooling and the demand for district cooling

In a district cooling station, water is cooled to 6–10 degrees with environmental heat (water or air, i.e. free cooling) or in the corresponding cooling equipment (adsorption equipment, compressor equipment) and directed to the cooling unit in the customer's building via piping. There, this water cools the building's ventilation air and the water circulating in the cooling system. During the cooling process, the used cooling water, which has risen in temperature, is returned to the district cooling station, where it is re-cooled.

The main customers of district cooling are business and commercial buildings. District cooling can be used in all systems in a building that need cooling: for drying incoming ventilation air, for cooling rooms with *fan coils*, cooling beams or some other method, in precision air conditioners, as well as in process cooling. Process cooling can be used to cool, for example, servers, industrial processes, cooling systems in shops – anything that needs to be cooled to 6—-10 °C.

[63] Raudsaar, M. (Keskkonnaagentuur) 2019 Puidubilanss. Ülevaade puidukasutuse mahtudest 2017 (in Estonian, Overview of wood usage volumes 2017). On the web: https://www.keskkonnaagentuur.ee/sites/default/files/elfinder/article_files/puidubilanss_2017_0.pdf

The Utilitas energy group built the first district cooling station in Tallinn in the Ülemiste district heating boiler house in the Juhkentali area of Tallinn, which started offering cooling services to the surrounding buildings in the autumn of 2019. The first customers were two office buildings in the Fahle Park quarter.

Two main factors can be identified to accelerate the development of the refrigeration sector in Estonia:

The first of these is the construction of an investment-intensive transmission pipeline:

- The diameter of the cooling pipe is always about 3 units (DN) larger than the district heating pipe required to transfer the same amount of energy.
- The transmission pipelines are installed in city centres, where there are many large public buildings, other communications and busy daily traffic close by, which makes construction work difficult and expensive.
- It is a large initial investment that needs to be developed from scratch, so to speak, and is therefore risky.

Another factor is connecting existing buildings and the motivation of building owners:

- The technical systems in existing buildings are not suitable for the immediate introduction of district cooling.
- Depending on the type of building and the technical solution, the installation of a cooling unit or the construction of a complete indoor system must be considered.
- State support would accelerate the introduction of district cooling, even in buildings where local solutions have not yet been fully depreciated.

In order to accelerate the development of the sector, it is necessary to design and develop a national programme, that, on the one hand, reduces the risks in constructing transmission pipelines and, on the other hand, increases the motivation of building owners to join such an environmentally friendly service. An analogy exists in the district heating sector, where comprehensive packages with investment subsidies are offered to heating companies and also building owners.

District cooling is also mentioned as a separate measure with the number En13 in SEI's (Stockholm Environmental Institute Tallinn Centre) report on Estonia's climate neutrality, but at the time of writing, analysts did not have sufficient data on the direct impact of the measure.

The Estonian Power and Heat Association (EJKÜ) has involved the best knowledge of Estonian district cooling companies, and with the help of their specialists, prepared a development assessment of the sector for the next seven years, including market volumes and impact on greenhouse gas reduction. This forecast is based on the assumption that the development of district cooling can be supported analogously to the current package for the district heating sector and that the programme will be open for the entire seven-year period.

Table 10.10 below provides an estimate of the district cooling potential over the next 7 years.

Table 10.10. Assessment of district cooling potential

Length of district cooling pipeline to be built, km	Cost of pipeline constructio n, million euros	Area of connected buildings, million m^2	Replaceable capacity of local cooling equipment, MW	Cost of renovation of indoor cooling systems, EUR/kW	Building renovation costs, million euros	Energy savings, MWh	Substitute d refrigerant savings, t CO_2-eq	Total CO_2 savings over 7 years, t CO_2-eq
15.4	14.1	1	55	350	19.3	35 800	21 500	51 200

The CO_2 savings in the amounts invested can be shown in the following table 10.11. As the consumption of cooling (GWh/y) has not been estimated, it is not possible to show the waste heat from district cooling (GWh/y).

Table 10.11. CO2 emissions savings from district cooling

Support	CO_2 savings per year	CO_2 savings over 7 years	CO_2 savings against the euros invested
Up to 50 %	7 314	51 200	3.07

It is based on the assumptions that in more complex areas the construction cost of transmission pipelines is up to EUR 1 200 per linear metre of pipeline, and in more complex cases the cost of renovating indoor systems is up to EUR 350 per kW of building cooling capacity. Using a similar simplified approach, it is also possible to develop and implement the so-called simplified measures of today's structural support framework, which reduce bureaucracy and administrative burdens.

In summary, EJKÜ proposes that MEAC or MoE (or together) design and develop suitable programmes that accelerate the development of district cooling. A similar comprehensive package in the district heating sector has contributed to the result of more than 10 years of renewable energy sources, already accounting for more than 50 % of the sector. The estimated CO_2 emission savings compared to local cooling solutions are 80% and the primary energy savings in production are 80 % when district cooling is used.

The development and combination of similar measures is also supported by EU strategies and initiatives. For example, the Energy and Climate Plans initiative, the National Building Renovation Plan[64] and the *Renovation Wave* strategy under the Green Deal[65]. A comprehensive, inclusive and interconnected package of measures is essential to move towards global climate neutrality.

On district cooling development plans in Tallinn[66]

Initially, it is planned to establish three district cooling areas in Tallinn (Figure 10.5):

64 https://ec.europa.eu/energy/sites/ener/files/documents/ee_ltrs_2020.pdf

65 https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en

66 Excerpt from ‘A greener cooling method for the urban environment’, a presentation by Tanel Kirs, Head of the District Cooling Department of Utilitas Tallinn AS, at a district cooling seminar on 17.8.2020

- **Zelluloos district cooling area** – development period 2019–2029, planned 10 MW from 2019;
- **Ülemiste district cooling area** – development period 2020–2030, estimated cooling capacity 30 MW, network and cooling plant are currently being designed;
- **Kesklinn district cooling area** – development period 2019–2035, estimated capacity 60 MW.

In the distant future, the different networks could be connected:

- The Kesklinn district cooling station would be the main station and the others would become peak load stations;
- Tallinn's district cooling SEER is 18 (*seasonal energy efficiency ratio*);
- Building the distribution network pipeline to the required extent in the centre of Tallinn (almost 12 km of pipeline) is a very costly undertaking.

In the centre of Tallinn, a large part of potential cooling consumers are existing buildings. Transitioning older buildings from local to district cooling can also be very costly for the owner, but district cooling should be considered immediately when designing new buildings. Existing consumers are more likely to think about district cooling when their own cooling system is depreciated and needs to be replaced.

In Tartu and Pärnu, district cooling is already being used and networks developed. In terms of district cooling, the most promising areas in Estonia are the city centres of Tallinn and Tartu. Since 2020, there are two district cooling stations operating in Tartu – the 13 MW district cooling station in Kesklinn and the 5.4 MW district cooling station in Aardla; the total length of the district cooling routes is 2.9 km.

Ülemiste City (the Ülemiste district cooling area) will initially be supplied with district cooling by a district cooling station to be built at Peterburi tee 32a, where approximately 75 % of the cooling energy will be produced by absorption chillers and free cooling. Air cooling is used as a free cooling source and residual heat is the energy generated by the production of heat and electricity in cogeneration plants using renewable biomass as fuel. Both are renewable energy sources and thus district cooling in Ülemiste City is based on 90 % renewable energy. Later, when the Ülemiste City cooling network is connected to the district cooling network, the main free cooling source will be seawater.

Figure 10.5. Planned district cooling areas in Tallinn

11 Waste heat and waste cooling energy actually used in Estonia as of 2019

The Environment Agency's baseline tables of boilers, fuels used, heat and emissions produced have been analysed and expertise on the presence of flue gas scrubbers in the boilers has been used. Boilers with a capacity of 5 MW or more have been examined. On the basis of this, an overview has been compiled and the known estimated use and theoretical potential of waste heat in the energy sector have been highlighted (also featuring some industrial companies that burnt fuel and whose emission source was in the Environment Agency table).

It would be extremely time-consuming to highlight the theoretical potential of individual industries and other sectors, and their waste heat proportions would still be quite small and the quantities vague. The possibilities and quantities of using flue gas heat from industrial enterprises by means of heat exchangers and heat pumps are also not taken into account. This would already require some very thorough targeted research, as the situation may differ from company to company.

1. Waste heat from wood-fired boilers in the power range 5-20 MW

The energy of wood fuels used in wood-fired boilers in 2018 was 804 432 MWh or 804 GWh. An estimated 27 581 MWh of the boiler scrubbers of companies with flue gas condensers (scrubbers) had already been transferred to district heating networks as waste heat (assuming that at least 15 % was waste heat).

If all wood-fired boilers had flue gas scrubbers, the energy of the fuel used in these boilers, 804 GWh, would be ~121 GWh at 15 % efficiency. In 2018, 28 GWh of waste heat was obtained from boilers estimated to have scrubbers and the unused potential would be another 93 GWh. Thus, an average of 93 GWh/y (at 15 % efficiency) could be obtained as waste heat from all boilers with a capacity of 5.1-20 MW that use wood fuels and have a flue gas scrubber.

2. Waste heat from natural gas boilers in the power range 5-20 MW

The energy of natural gas used in natural gas boilers in 2018 was 773 124.3 MWh or 733 GWh. The potential waste heat from this would be 73 GWh (at 10 % waste heat) or 110 GWh (at 15 % waste heat). The possible already existing flue gas scrubbers in these boilers are not publicly known, so the waste heat already used has not been assessed.

<u>Use of waste heat.</u> It is estimated that 28 GWh of waste heat was obtained from wood chip boilers with scrubbers in 2018 (Environmental Agency data table), which makes 23 % (at 15 % efficiency) of the total estimated potential. A maximum of 110 GWh (at 15 % efficiency) could be obtained from natural gas boilers. From boilers using the two fuel types combined, a further 203 GWh of waste heat could be obtained at 15 % efficiency.

3. Over 20.1 MW of waste heat from wood fuel boilers

The energy of wood fuels used in wood-fired or partially wood-fired boilers in 2018 was 2 439 842 MWh or 2 440 GWh. An estimated 225 GWh had already been transferred from scrubbers of companies with flue gas condensers (scrubbers) to district heating networks as waste heat (assuming that at least 15 % was waste heat).

If all wood-fired boilers had flue gas scrubbers, ~366 GWh of energy could be obtained from the 2 440 GWh of energy used in these boilers, at 15 % efficiency. In 2018, 225 GWh of waste heat was obtained from boilers estimated to have scrubbers and the unused potential would be another 141 GWh. Thus, an average of 141 GWh/y (at 15 % efficiency) could be obtained as waste heat from all boilers with a capacity of 20.1 MW that use wood fuels and have a flue gas scrubber.

A correction should be made here for co-fired boilers using oil shale and wood fuel. They are generally not equipped with scrubbers, due to the relatively high ash content of the flue gases and the relatively low moisture content of the oil shale compared to wood fuel. The share of wood fuel in co-firing usually does not exceed 25—30 %. The Auvere Power Plant block can use up to 50 % wood fuel next to oil shale.

4. Waste heat from natural gas boilers over 20.1 MW

The energy of natural gas used in natural gas boilers in 2018 was 3 660 680.3 MWh or 3 661 GWh. The potential waste heat from this would be 366 GWh (at 10 % waste heat) or 549 GWh (at 15 % waste heat). The estimated potential of all potential scrubbers for gas-fired gas boilers would be 549 GWh/y. As some boilers already have scrubbers, their estimated waste heat is 333 GWh at 15 % efficiency. Unused waste heat, i.e. the potential amount of waste heat, would be 216 GWh.

<u>Use of waste heat.</u> It is estimated that 225 GWh of waste heat was obtained from wood chip boilers with scrubbers in 2018 (Environmental Agency data table), which makes 61 % (at 15 % efficiency) of the total estimated potential. There is another 141 GWh of free potential. A maximum of another 216 GWh (at 15 % efficiency) could be obtained from natural gas boilers and ~61 % is already used. From the two types of boilers combined, a further 356 GWh of waste heat could be obtained at 15 % efficiency.

Conclusion

In wood-fired boilers, starting with a capacity of 5.1 MW (all sectors combined), 28+225=253 GWh of waste heat is already being used and the theoretical total potential of free waste heat would be 93+141=234 GWh/y.

In natural gas boilers, starting with a capacity of 5.1 MW (all sectors combined), 333 GWh of waste heat is already being used and the theoretical total potential of free waste heat would be 110+141=251 GWh/y.

The amount of waste heat already obtained from both fuels is 586 GWh and the total theoretical potential still available would be another 485 GWh per year.

The calculations are based on 2018 data and can change quite a lot from year to year. The amount of waste heat obtained from flue gas scrubbers depends a lot on the temperature of the return water from the district heating network and the humidity of the wood fuel.

12 The realistic, untapped potential of waste heat and cooling in the heating or cooling sector and the impact of applying this potential on primary energy savings

Waste heat that has practically not yet been used, with real potential in the district heating sector and where the realisation of this potential would have a direct impact on the reduction of primary energy use, would be easiest to obtain from urban wastewater treatment plants and data centres (server parks). Primary energy here means fuels that are converted into heat by district heating companies and thermal power stations. **Wastewater treatment plants and data centres would be the most convenient and suitable sources of waste heat and partners for district heating companies, as they operate 24/7 with a relatively even load all year round. These waste heat sources would directly save primary energy in both boiler houses and thermal plants, as the heat they generate is waste heat outside the district heating system**. Waste heat from industrial plants (also outside the district heating system) is generally less uniform and not as available year-round (except for glass melting, for example). Heat from wet wood fuel and natural gas boiler houses and thermal plant flue gas condensers (scrubbers) also reduces the need for primary energy (fuel), but it depends a lot on the humidity of the fuel and the return water temperature in the district heating network and is generally not uniform throughout the year. Low-temperature district heating and the heat obtained as a by-product of the thermal plants' own electricity generation do not directly save primary energy, i.e. fuel.

From the aforementioned two sources (wastewater, server park), it is necessary to raise the relatively low temperature heat to a temperature level suitable for the district heating network by means of heat pumps. If these sources are further away from existing district heating networks, it is worth considering transferring the low-temperature heat carrier (using an air-to-water heat exchanger) to the point of connection to the district heating network and raising its temperature to the DHW flow temperature level. In this case, transmission losses would be reduced, especially if the pipeline length is already more than one kilometre.

The waste heat from Harku data centre could save 79 400 pm^3 in the first stage (6 MW_{el}, 50 GWh_{th}) (calculated with an annual average calorific value of 0.7 MWh/pm^3 and a conversion efficiency of 90 % if a flue gas condenser is available). The average primary energy content of this amount of fuel is 55.6 GWh. Heat loss during transmission has not been taken into account, as there is no more detailed information on the temperature of the heat carrier used, the length of the connecting pipeline and the temperature regime of the district heating network receiving heat. Very roughly, the relative heat loss can be 10 %. If the capacity of the data centre has reached the level of 20 MW_{el}, the primary energy savings would be 167 GWh, i.e. 238,100 pm^3 as wet wood chips.

One the few companies with the largest waste heat potential is AS Tallinna Vesi, whose wastewater treatment plant in Paljassaare, where the wastewater heat discharged into the sea could be recovered with heat pumps, which could yield up to 450 GWh/y (714,300 pm^3 damp wood chips) of waste heat for supplying nearby, future residential development areas with heat or for transfer to the Tallinn district heating network. This is about half of the theoretical amount of waste heat obtainable from burning wood and gas fuels. The use of waste water heat from water companies has the greatest waste heat potential if the district heating network receiving this heat is close enough (not kilometres away, but it depends significantly on the amount of heat transferred). Unfortunately, the amounts of wastewater from other cities and settlements are noticeably smaller than in Tallinn and so is the amount of wastewater obtained from them.

The 65 wastewater treatment plants of the water company engaged in wastewater treatment in Estonia treat an average of 345 016 m^3 of wastewater per day (125.93 million m^3/y). For the summer and winter period together, i.e. the difference between the annual weighted average temperatures at 10 K, a total of 5 276 TJ/y or 1 466 GWh/y of waste heat could theoretically be obtained from Estonian wastewater treatment plants (the corresponding saving of wet wood chips would be about 2.3 million pm^3 per year). Apart from some larger cities (Tartu, Pärnu, Narva), the introduction of wastewater heat may not be economically justified, and even in these larger ones, introduction may require financial support. The use of heat pumps significantly increases electricity consumption, which in turn increases carbon emissions (unless electricity generation has become carbon-free).

The untapped potential of waste cooling energy arises when district cooling plants are built near district heating networks (by district heating companies themselves or others), which use heat pumps to increase the temperature level of heat from coolers (refrigeration equipment) to the temperature level of the district heating network supply line. Today, waste heat is used in the Fortum Tartu cooling plant and the waste heat is fed to Tartu's district heating network. Another potential place is being built in Tallinn in Ülemiste and the Kesklinn areas, but their waste heat amounts are not yet known, because the plants haven't started construction. However, the total waste heat of all current and future refrigeration equipment forms a very marginal part of the overall heat use in the district heating networks of both the city of Tartu and Utilitas Tallinn AS. However, in boiler houses and CHP plants, waste heat from cold plants does save primary energy (fuel).

13 Share of efficient district heating and cooling in the total district heating and cooling sector as at 2019

Table 8.2 in Chapter 8 lists heat companies and network areas (district heating systems) located in Estonia for which the Estonian Power and Heat Association (EJKÜ) has issued the label 'Efficient district heating'. A total of 24 heating companies and 90 network areas have received this label, the largest number of which is held by SW Energia OÜ, i.e. a total of 37 network areas across Estonia. In order to prove the energy efficiency of district cooling systems, EJKÜ has developed the label 'Efficient district cooling', which has so far been applied for by Fortum Tartu and Utilitas Tallinn.

The total volume of heat produced in the network by all these heat companies and their network areas was 1 981.6 GWh and the volume of heat purchased in the network was 2 612.2 GWh (produced by someone other than the network owner/operator)**.** A total of **4 593.8 GWh of heat** was directed to consumers in 2019 (according to EJKÜ data), of which 2 557.1 GWh or 55.7 % was produced on the basis of renewable energy sources (wood chips, wood waste, pellets and biogas). It is estimated that the companies listed in Table 8.2 produce more than 90 % of the heat directed to Estonian district heating networks.

In the Competition Authority, the price of heat has been approved for 167 district heating network areas (Coordinated end-user prices, as at 16.12.2020). Thus, ~54 % of them have applied for an efficient district heating certificate. Major district heating networks across Estonia all have an efficient district heating certificate and two district cooling networks will receive an efficient district cooling certificate at the beginning of 2021, which makes up 67 % of the district cooling networks.

14 The untapped potential for efficient district heating and cooling and the impact of realising this potential on primary energy savings

The previous chapter showed that district heating networks in all major cities are efficient and that there is potential for efficient district heating networks in relatively small settlements and their district heating networks. Although it is known that some district heating networks are almost 100 % renewable (Räpina, Muhu Liiva, Ardu, Kääpa, etc.), the operators of these networks have not yet applied for an efficient district heating certificate, whether because they are unaware of the certificate, they are unwilling to deal with bureaucracy, or they are not members of EJKÜ (in fact, non-members can apply for this label). As these are relatively small networks and their combined share in total heat production is around 10 %, the potential in GWh is not very large, but in the case of district heating network areas, 77 network areas have potential. Some would be certified as soon as they apply, but many networks do not meet the requirements for efficient district heating (either due to using only fossil fuels or less than 50 % renewable energy or 50 % waste heat or less than 75 % cogeneration heat or 50 % of such energy and heat combinations).

One other company in Estonia could apply for an efficient district cooling certificate, because three companies in three cities have district cooling networks. It is planned to establish three independent district cooling network areas in Tallinn, two of which may be merged in the distant future.

The statute and certificate for an efficient district heating or cooling area do not in themselves save primary energy. Primary energy is saved if the district heating network area is certified due to the fact that it uses more than 50 % of waste heat and this waste heat is obtained either from sources outside the district heating network or from the installation of a flue gas scrubber. If natural gas is used, it is not possible to obtain more than 50 % of the heat with a scrubber, and if more than 50 % of wood fuels are used, it would be possible to obtain this certificate anyway. In 2020, there are no such potential district heating network areas, and it is unlikely that any areas where more than 50 % of the heat consumed would come from waste heat sources outside the district heating system will emerge in the near future.

15 Analysis of the economic potential of heating and cooling efficiency

Owing to the specifics of Estonia's geography, history, economy and technologies in use, waste heat sources can be classified as business-related, such as manufacturing companies, but also as waste heat from the residential sector, i.e. commercial buildings and households. In the latter, i.e. in the residential sector, heat losses occur when heating the indoor air and water of buildings, primarily through warm air leaving the buildings.

In companies with diversified activities, waste heat is generated primarily in production processes. While the low-temperature waste heat generated in the residential sector can be used to heat air or low-temperature water, the heat generated by production companies is more diverse and can be technologically used to generate electricity or heat water or air.

The economic potential of recovering waste heat of any kind is, in a simplified view, the difference between the price of the type of energy replaced by waste heat (for example: hot water heat) and the cost price of the waste heat itself, i.e. the total cost of waste heat recovery. Therefore, the type of energy that is replaced by waste heat is of great importance.

According to Table 15.1 (mostly based on 2018 data), waste heat has the greatest economic potential if it is possible to replace electricity with waste heat, while heat has the second greatest economic potential, and natural gas comes in third. The least potential, of the types of energy described above, is held by firewood, which would provide up to 7 times less estimated revenue to a unit that could potentially use waste heat, as compared to electricity.

Table 15.1. Prices of relevant energy types[67]

Energy type	Year	Price	Unit
Electricity, households (excl. taxes)	2018	88.9	EUR/MWh
Electricity, households (incl. taxes)	2018	134.8	EUR/MWh
Electricity, other (excl. taxes)	2018	76.69	EUR/MWh
Natural gas, households (excl. taxes)	2018	28.9	EUR/MWh
Natural gas, households (incl. taxes)	2018	40.11	EUR/MWh
Natural gas, other (excl. taxes)	2018	25.78	EUR/MWh
Natural gas, other (incl. taxes)	2018	29.92	EUR/MWh
Heat households (excl. taxes)	2020	63	EUR/MWh
Heat, households (incl. taxes)	2020	75.6	EUR/MWh

[67] Development of calculation methodologies for financial measures suitable for fulfilling the national energy saving obligation and assessment of energy saving potential, 2020. At the request of the Ministry of Economic Affairs and Communications.

Energy type	Year	Price	Unit
Heat, other (excl. VAT)	2018	65.01	EUR/MWh
Heat, other (incl. VAT)	2018	78.012	EUR/MWh
Firewood, other (excl. VAT)	2018	13.73563	EUR/MWh
Firewood, other (incl. VAT)	2018	16.48276	EUR/MWh

Due to the above, knowing the volumes and characteristics of waste heat in the residential, industrial, energy and district heating sectors, temperature especially, makes it possible to estimate the potential for waste heat utilisation and express it in terms of costs and benefits.

The cost indicators of the obtained waste heat depend on the economic sector and the solution of determining and using the waste heat. Waste heat revenue indicators also depend on the source of the waste heat, namely what the sales opportunities and price of the waste heat are, or what kind of energy savings are generated by using the waste heat within the organisation.

The Energy Efficiency Directive focuses on the following technologies and sectors.

— industrial waste heat and cooling;

— waste incineration;

— high-efficiency cogeneration;

— renewable energy sources (e.g. geothermal, solar and biomass) other than those used in high-efficiency cogeneration;

— heat pumps;

— reducing heat and cooling losses in existing district networks.

In the following, we will discuss these groups in more detail (Table 15.2, Table 15.3, Table 15.4, Table 15.5, Table 15.6 and Table 15.7).). The approach below is based primarily on the economic performance of the companies surveyed and interviewed, which is then generalised to the sector as a whole. This only provides a theoretical overview of the sector and does not allow fundamental conclusions to be drawn about the potential of modernising the whole sector.

Table 15.2. Industrial waste heat and cooling (excl. energy sector)

Industrial waste heat and cooling (excl. energy sector)	
Corrected NPV[68] EUR/MWh/y (flue gas condenser)	16.2
Corrected NPV EUR/MWh/y (heat exchanger)	3.7
Non-technological costs of waste heat recovery (e.g. grid connection)	Not estimated
Total heat energy, MWh[69]	~2 936 845
Total waste heat, MWh	>400 000
CO2-eq, t, total	Not estimated

[68] NPV per MWh of energy produced over its lifetime.

[69] Aggregate data of the Environmental Agency in 2018 for 59 companies with a nominal heat source capacity of more than 5 WMh.

Industrial waste heat and cooling (excl. energy sector)	
Proportion of fossil fuels	>90 %

Table 15.3. Industrial waste heat and cooling in the data economy

Industrial waste heat and cooling (data economy)	
Adjusted NPV EUR/MWh/y (heat pump)	6.6
Non-technological costs of waste heat introduction (e.g. grid connection), EUR adjusted per MWh per year	–31—40.6
Total heat energy, MWh	Not known
Total waste heat, MWh	150 000
CO2-eq, t, total	Not estimated
Proportion of fossil fuels	19 %

Table 15.4. Waste incineration

Waste incineration	
Per adjusted NPV EUR/MWh/y	Not estimated[70]
Non-technological costs of waste heat recovery (e.g. grid connection)	Not estimated
Total heat energy, MWh	~815 338
Total waste heat, MWh[71]	~122 300
CO2-eq, t, total	Not known
Proportion of fossil fuels	<5%

Table 15.5. High efficiency cogeneration

High efficiency cogeneration	
Per adjusted NPV EUR/MWh/y (flue gas condenser, heat exchanger, heat pump) [72]	1.1
Non-technological costs of waste heat recovery (e.g. grid connection)	N/A
Total heat energy, MWh[73]	2 269 000
Total waste heat, MWh	227 000
CO2-eq, t, total	Not estimated

[70] There were no representatives of waste management among the respondents

[71] Aggregate data of the Environmental Agency in 2018 for 16 companies with a nominal heat source capacity of more than 5 WMh. Water companies are not initially included in the selection.

[72] On the example of a cogeneration plant.

[73] Statistics Estonia's table KE034.

High efficiency cogeneration	
Proportion of fossil fuels	~50 %

Table 15.6. Renewable energy sources other than those used in high-efficiency cogeneration

Renewable energy sources (e.g. geothermal, solar and biomass) other than those used in high-efficiency cogeneration;	
Adjusted NPV EUR/MWh/y (heat exchanger, heat pump)	-4
Non-technological costs of waste heat recovery (e.g. grid connection)	n/a
Total heat energy, MWh	1 299 161
Total waste heat, MWh	129 916
CO2-eq, t, total	(~0)
Proportion of fossil fuels	0 %

Table 15.7. Residential heat pumps

Residential heat pumps	
Per adjusted NPV MWh/m2 (4 heat pump solution for 5-storey apartment building)[74]	5.8
Non-technological costs of waste heat recovery (e.g. grid connection)	
Total heat energy, MWh	n/a
Total waste heat, MWh[75]	14 800 – 83 900
CO2-eq, t, total	n/a
Proportion of fossil fuels	n/a

[74] The economic indicators are taken from: I. Sarv. Ventilatsiooni väljatõmbeõhust soojuspumpadega soojustagastuse toimivus rekonstrueeritud korterelamus, 2019, TalTech (in Estonian, Exhaust air heat pump heat recovery performance in renovated apartment building)

[75] 226 800 – 486 000 per square metre, which is an estimate of the pace of renovating technologically compatible housing stock

Table 15.8. Reducing heat and cooling losses in existing district networks.

Reducing heat and cooling losses in existing district networks.	
Corrected NPV EUR/MWh/y (flue gas condenser)	2.13
Non-technological costs of waste heat recovery (e.g. grid connection)	n/a
Total heat energy, MWh	3 897 000
Total waste heat, MWh	370 000
CO2-eq, t, total	-

15.1 Considerations

In order to get the best overview of the possibilities for the more efficient use of waste heat and the resources required for it, in addition to the description of technological solutions and statistical data, it is necessary to conduct an economic analysis. The economic analysis should identify the benefits and costs of standard solutions. As part of the economic analysis, a financial analysis must be carried out to assess the viability of the solutions for the investor and to consider some alternative scenarios for waste heat use based on the economic potential of the technologies considered, GHG reduction prospects, primary energy savings and impact on the proportion of renewable energy sources.

15.2 Costs and benefits

The capital costs, as the main fixed costs, are calculated on the basis of the initial cost of the equipment and the estimated service life in years through which the annual depreciation of the equipment is calculated (depreciation provisions). In addition, changes in the value of capital over time, which are characterised by a discount rate, must be taken into account. The annual capital cost can be calculated using the following formula:

$$A = I_0 \cdot \frac{r \cdot (1+r)^n}{(1+r)^n - 1},$$

A – capital cost per year, EUR/y; I_0 – initial investment, EUR; r – discount rate; n – the estimated service life of the device in years.

In this analysis, we assume that the return on investment is the same over the life of the asset and the device depreciates on a straight-line basis over its service life. We estimate the profitability of the waste heat solution using the net present value method (NPV).

$$NPV = \sum_{i=1}^{n} \frac{CF_i}{(1+r)^i} - I_0,$$

NPV – net present value of the investment, EUR; CF_i – cash flow in year i, EUR/y; n – calculated service life of the device, y; r – discount rate; I0 – initial investment.

In the formula, the annual cash flow is the difference between costs and benefits, the values of which have been corrected to the year of the investment. The sum of the annual net present cash flows and the initial investment determines the economic justification of the investment, i.e. a positive NPV value indicates the income earned over the life of the project. If the NPV is negative, the investment is unprofitable.

As we have previously described, the capital cost per unit of waste heat is lower for district heating companies, some of which have taken advantage of this opportunity by setting up appropriate waste heat capture solutions, i.e. flue gas condensers and heat exchangers.

For a more precise breakdown of costs, the authors supplement the investment needs received from companies with known or estimated operating costs, maintenance and repair costs. The calculation of costs has been simplified in this case. All companies participating in the analysis agreed that there were no labour costs and that repair and maintenance costs were also considered low, although costs such as the energy consumption of the equipment, dependent on the waste heat technology, were highlighted.

Although several companies were not very aware of the running costs, one company stated that it estimated various additional costs at 6 % per annum compared to the initial investment and that another company reported historical operating costs at around 4.5 % of the initial investment, the largest being electricity consumption. These operating costs were incurred for equipment such as heat exchangers and flue gas condensers. In the case of heat pumps, operating costs have been identified in several applied studies, ranging from 9 to 10 % of the cost of the equipment. Due to this, it is possible in this analysis to present cost/benefit estimates for the waste heat generating sectors sufficiently represented by the data.

The results of the NPV calculation are shown in Table 15.9.

Table 15.9. Results of NPV calculations

Sector	Technological solution	Initial investment	NPV
Industry	Flue gas condenser	300 000	243 724
Industry	Heat exchanger	54 000	25 171
Industry	Heat pump	658 000	617 001 – 796 529[76]
Waste incineration	n/a	n/a	n/a
Cogeneration	Flue gas condenser, heat exchanger, heat pump	2 500 000	574 699
Production of biogas as an energy source	Heat exchanger, heat pump	80 000	-40 416
Drain-water heat	Heat pump	4 984 846	1 590 378[77]
District heating	Flue gas condenser	740 000	351 820

[76] For industrial plants, NPV calculations are done without the costs of connecting/developing external (district heating) networks

[77] Without connecting to the district heating network

Sector	Technological solution	Initial investment	NPV
Heat pump in housing	Heat pump	60 000	13 997
Heat pump and low temperature heating in housing	Heat pump	2 959 000	2 600 000[78]

Note : Unless otherwise stated, the NPV calculations do not take into account equipment-related investments, such as, in particular, connection to energy networks for the sale of energy produced, which is a major factor in the economic assessment of waste heat recovery potential, especially for industrial plants with high volumes of waste heat.

15.3 Scenarios relevant to the baseline scenario

This chapter discusses the different waste heat use scenarios and the baseline scenario for comparison (Table 15.10).

Table 15.10. Baseline scenario and different alternative scenarios

Scenario	Brief description	NPV, million EUR/y	CO_{2-eq}, thousand t/y	Primary energy savings, GWh/y	Impact on renewable energy sources
Base 0	Existing measures to increase the utilisation of waste heat from district heating plants	N/A	~840-~1 020	1 470	+8 %
Alternative 1	Increased use of flue gas condensers by district heating companies (wood boilers)	10.3	49.2	485	N/A
Alternative 2	Use of heat exchangers in industrial companies outside the energy sector	N/A	N/A	*> 400*	N/A

[78] Volkova et al. Small low-temperature district heating network development prospects. Energy. 178, 2019.

Scenario	Brief description	NPV, million EUR/y	CO_{2-eq}, thousand t/y	Primary energy savings, GWh/y	Impact on renewable energy sources
Alternative 3	Waste heat recovery by water companies	6.4[79]	-3.8	250[80]	-36 % (0 %)[81]
Base 4	Baseline scenario for housing renovation	-21.2	2.5	25	N/A
Alternative 4a	Use of heat pumps in residential district heating conditions	-19.2	-0.2	40	-26 % (0 %)
Alternative 4b	Use of heat pumps in housing with heat recovery	-10.9	0.7	51	-36 % (0 %)
Alternative 4c	Use of heat pumps in residential low-temperature district heating	*104.8*[82]	N/A[83]	N/A[84]	-45 % (0 %)
Alternative 5	Directing waste heat from data economy to district heating	4.9	10.6	75	-36 % (0 %)

Scenario 0: Baseline scenario

The baseline scenario is based on the current situation. The table describes it according to the NECP objectives. Thus, the baseline scenario envisages reducing greenhouse gas emissions from 20.09 million t CO2-eq to 10.7-12.5 million t CO2-eq over 10 years, reducing energy consumption by 14,700 GWh and increasing the share of renewable energy from 34 % to 42 %.

Alternative 1: Increased use of flue gas condensers by district heating companies

For alternative 1 **certain Environmental Investment Centre measures that can support the utilisation of waste heat in district heating are most related to the baseline scenario**.

First, such a measure is '*Efficient heat production and transmission*', which supports the renovation of district heating boilers. This measure supports the installation of flue gas condensers, as well as fuel exchange and the renovation of depreciated and inefficient heat pipelines, preparation of a heating sector development plan and construction of local heating solutions. In order to qualify for the measure, the proposed installation of capacitors by the applicant must be cost-effective and must be calculated by the applicant in the heat development plan or indicating the relevant calculations in its annexes.

[79] This, as well as several other scenarios, do not take into account investments to ensure the realisation of the captured waste heat.

[80] As the scenario concerns the sale of heat for district heating, the economic calculations take into account the maximum sale of half the waste heat (6 months per year).

[81] Following the Renewable Energy Directive, in this case we consider heat produced by a heat pump to come from a renewable source

[82] The authors of this analysis have consulted the head of the underlying study group, who stated, however, that the study underlying the scenario cannot be simply directly used to generalise and define macro-scenarios.

[83] See previous comment

[84] See previous comment

Another relevant measure is support for *'Business Resource Efficiency'.* This measure supports the more efficient use of production resources by companies. The authors of the study assume, depending on the content of the measure, that the measure can also support waste heat use solutions, but the relevant statistics and data are not public. It has not been possible to inspect the projects in the present study, as they are generally confidential and require the permission of companies to use/disclose.

As an alternative scenario, we consider such a theoretical situation where during the period under consideration, i.e. 2020-2030, essentially all the potential that can be tapped with the chosen technical means is used in the district heating sector. As in the case of scenarios in general, the authors of this piece draw up the maximum theoretical potential, and in order to compose a waste heat efficiency improvement plan for each of the identified sectors, the respective sector should be analysed further.

From the previous analysis of the raw data, we learnt that **the use of flue gas condensers at the unit cost of energy on site is cost-effective in district heating plants or CHP plants**. In the analysis in which we want to model the whole sector, the availability of data is important, especially about the number of companies in the sector that have not yet adopted this solution. In Estonia, heat consumption is almost 6 300 MWh/y, of which district heating makes 4 400 MWh/y[85]. District heating producers produce the lion's share of this heat, if just taking into account the members of the Estonian Power and Heat Association at 3 897 MWh/y[86], which coincides well with the data of the Environment Agency for 2018. Of the aforementioned district heating companies, only larger heat companies are centrally relevant in this scenario, i.e. in the case of wider use of flue gas condensers. **Based on EJKÜ data, the unused waste heat potential is 485 GWh/y**. The use of waste heat does not necessarily increase the amount of heat supplied to the district heating network, but rather it is reflected in the reduction of fuel use at the same heat energy consumption volumes. In the case of larger producers, this is primarily natural gas and/or wood-based fuels. Considering the rather large share of renewable sources (wood-based fuels) in heat production, we can calculate the avoidable amount of CO2-eq to be 49.2 thousand t of CO2-eq. The use of a flue gas condenser makes it possible to partially reduce the share of natural gas for heat producers, where energy is partly produced from natural gas and through this the share of renewable energy may increase. The possible change in the share of renewable energy as a result of the scenario is not obvious.

The calculated cost of implementing alternative scenario 1 was based on the district heating company's heating solutions in the research materials. According to both the authors and the companies that provided inputs to the analysis, such an investment can and will be profitable in practice.

Alternative 2: Use of heat exchangers in industrial companies outside the energy sector

While in the first alternative scenario we considered companies connected to the district heating network, this alternative brings together various industrial companies that have different amounts of waste heat, especially medium and high temperature waste. Given that these companies do not belong to the energy sector and are composed of very different production companies, it is not easy for the authors to provide an exhaustive list of currently

[85] https://mkm.ee/et/tegevused-eesmargid/energeetika/soojusmajandus

[86] https://epha.ee/

available measures and policies to influence these companies in the direction of the **baseline scenario** of greater energy efficiency and renewable energy use.

Regarding the respondents, it was clear that the reasonable solution for waste heat recovery for some of these companies is to capture the heat released during production with a heat exchanger. However, compared to the above, the described **alternative** is characterised by a higher relative cost of the initial investment and several difficulties in the reasonable selling of the captured waste heat. While the unit price of a one-time investment in waste heat recovery for district heating companies was EUR 60—80 per MWh of waste heat in the first year, it was higher for several companies outside the energy sector. The biggest obstacle identified by the companies in this group was shortcomings in the economically justified sale of waste heat. **Companies that have more of this waste heat than they can use on their own had difficulty connecting to some district heating networks and there were no other alternatives to sell enough of the waste heat**. All in all, many do not know what to do with their waste heat. Moreover, companies were often uncertain about their actual waste heat potential.

The quantification of alternative scenario 2 is limited by the great diversity of technological solutions in industrial companies, which means that the individual examples collected in this study cannot be extended to sectors in general. The diversity of companies, on the one hand, and their low participation in the survey, on the other, do not allow the creation of subgroups in this large group to ensure a better overview of the sector. The enterprises in this group should be analysed on a product-by-product basis, which would require extremely high additional data collection. For much the same reasons, the waste heat potential of the sectors is very difficult to assess by the energy experts involved in this study. The amount of waste heat potential presented in the above scenario (more than 400 GWh/y) is based on the analysis of the raw data of the Environmental Board, as a result of which a group of energy-intensive industrial enterprises has been compiled, but the estimate of their waste heat can be generalised.

The extensive data collection carried out in this study was not sufficient to provide a nationwide assessment of the potential of untapped waste heat by sector and should be addressed in further analysis.

Alternative 3: Waste heat recovery from wastewater by water companies

The use of waste heat from water companies' wastewater is considered to be at zero, as water companies have not yet implemented ready-made solutions for the use of waste heat from wastewater. In this context, the companies mentioned in the **baseline scenario** do not participate in or contribute to the achievement of energy and climate policy objectives. There are also no specific sectoral or financial measures involving water companies. The Estonian National Energy and Climate Plan until 2030 does not envisage a strategy specifically for the utilisation of waste heat from wastewater.

The alternative does instead rely on the utilisation of wastewater by large water companies, i.e. AS Tallinna Vesi and also, for example, AS Tartu Veevärk. **The quantities of waste heat from wastewater observed in the scenario are large**, reaching 450 000 to 500 000 MWh/y in the case of AS Tallinna Vee, and possibilities for using these quantities have been considered. The introduction of this low-temperature heat source is possible on the basis of heat pump-based technologies, and the heat generated from it can be transferred to a district heating network if a connection is possible. The calculations may be more realistic based on a nearly 2-fold lower amount of waste heat, assuming that waste heat is transmitted to the district heating network in this way for at least 6 months a year, but preferably 12 months a year. Leaving aside the investments and costs associated with directing waste heat to the district heating network, the heat transferred would reduce fuel consumption in district heating companies and have a positive impact on the environment.

The NPV of this scenario largely depends on the sale of heat on the revenue side, which in turn depends on the solutions related to heat transmission (district heating network). Considering the fact that the sale of waste heat is possible at a price of 22 EUR/MWh, while continuing to ignore questions of connecting to or creating a district heating network, the **NPV of this investment is positive, but it does not leave much room for investing in a district heating network**. As heat pumps technologically require electricity and as electricity has a higher calculated CO2-eq, the high energy savings described above will not lead to CO2-eq savings or an increase in the share of renewable energy.

For both this and the following alternatives, which are also based on heat pump technologies, it is important that, according to the preamble to the EU Renewable Energy Directive (RED II), the energy used to start heat pumps using ambient or geothermal energy must be deducted from the total energy used. Pursuant to Article 7(3), the final consumption of the heating and cooling sector produced by such heat pumps is considered to come from renewable energy sources. As alternatives 3 and 5 focus on the heating in question, and 4 is also partly based on efficient heat pumps, it is therefore reasonable to assume that the heat they produce is renewable energy and at least the share of renewable energy does not deteriorate as a result of the changes described in the alternatives.

Alternatives 4a and 4b: Use of heat pumps in residential district heating conditions and heat return to the district heating network

The TalTech study commissioned by the Ministry of Economic Affairs and Communications *'Long-term strategy for building renovation'*[87] describes a scenario in which a significant part of the housing stock will be renovated in the next 10 years in order to reduce heat consumption. Of this housing stock, 226 800 m^2 per year could be renovated in district heating areas, thus having an impact on the consumption of heat transmitted by district heating. Taking this number and the points in the aforementioned strategy into account, the authors have estimated that in the **baseline scenario,** the renovation of buildings will save about 24.9 GWh of energy in final consumption and 2.5 thousand tonnes of CO_2 equivalent per year. This investment is not self-financing and the estimated 10-year NPV is -21.2 million euros.

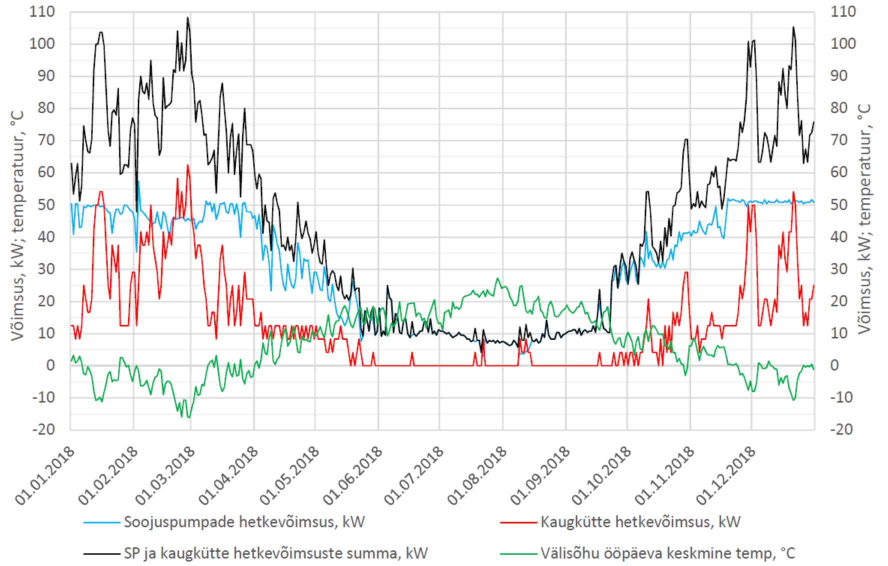
Alternative scenarios 4a and 4b consider supplementing the renovation of the existing housing stock with a modern, sustainable local heating solution. Data on these sustainable solutions is needed to model these scenarios. Although the authors have included some apartment associations in the survey that are known to have implemented a heat pump energy solution in their building, these apartment associations have not provided feedback. The Master's thesis '*Exhaust air heat pump heat recovery performance in renovated apartment building*' from 2019 by Ivari Sarv at TalTech provided important inputs for economic analysis such as cost of equipment sets, personal energy consumption, heat production, etc. In the Master's thesis, a solution based on 4 heat pumps for a 5-storey standard house (the so-called Khrushchyovka) is given a thorough analysis. This solution comes at a very high price, i.e. a set of equipment costing 60,000 euros. **However, according to the calculations made for modelling alternative 4a, it results in a total of 14 thousand euros of positive NPV during the lifetime of the set**, if the retail price of heat can be taken as the unit cost of half of the income, which in this case we take to be the arithmetic average of the marginal heat energy prices in Estonia, at 63 EUR/MWh. Assuming that it would be a heat seller that would supply heat externally, i.e. to the district heating network at an estimated wholesale price of 22 EUR/MWh, this investment would not be

[87] https://ec.europa.eu/energy/sites/ener/files/documents/ee_ltrs_2020.pdf

profitable, with an NPV of -53 thousand euros. As both the above-mentioned types of apartment buildings and 9-storey so-called Brezhnev-type houses are very common in Estonian cities and as they usually do not have smart heat saving solutions, the waste heat potential of the entire housing stock of these types in Estonia can be estimated. Calculations show that if the above-described basic scenario were to be complemented with a heat pump-based heating and water heating solution following **alternative 4a**, it would result in an estimated 10-year NPV of -19.2 million euros, but **would save a total of 39.7 GWh of primary energy per year,** which would be achieved by renovating 226 thousand m^2 of the housing stock. Following similar logic, accelerating the renovation of the housing stock and renovating 486 thousand m^2 **would provide an estimated energy saving of 53.4 GWh per year in the heating areas**.

The inclusion of heat pumps in a complete renovation project as described above is based on the current approach, which is that heat pumps do not return heat to the district heating network, but are primarily designed to minimise heat consumption in the building (i.e. a balance between cost and probable operating hours has been found). In this way, heat pumps could be installed during the renovation and used to cover the heat demand in the building.

The same installed pump set can be operated at 100 % load all year round and as a result it is possible to supply additional heat to the network, which is an assumption for **alternative scenario 4b**. Today, it is not possible to do so because the network configuration does not allow low-temperature heat to be received, but if it were possible, the **need to transmit 50.8 GWh of heat per year to the district heating network would be reduced**. The consumption schedule for one building is shown below. It shows that if there are only residential buildings in the network and there are no non-residential consumers, then it is possible to supply only about 30 % of the potential energy to the network because there is no consumption consistent with production. It is estimated that this could generate heat energy potentially in need of storage of approx. 61.2 MWh/y per such renovated building, i.e. approx. 14.6 kWh/m^2*y.



Key: Y-axis (left-hand side) – Capacity (kW); temperature (°C); Y-axis (right-hand side) - Capacity (kW); temperature (°C); [light blue] instantaneous capacity of heat pumps (kW); [red] instantaneous capacity of district heating (kW); [black] sum of instantaneous capacities of heat pumps and district heating (kW); [green] average ambient night-time temperature (°C)

Figure 15.1. Instantaneous capacities of heat pumps and district heating and outdoor temperature

It is difficult to calculate exactly what the NPV of the investment will be in this case, since, inter alia, the price charged for the heat thus supplied to the network must be estimated. With a number of simplifications, it was calculated that the NPV could amount to -21.8 million euros. Unfortunately, this calculation also completely ignores the need for improvements by the district heating network, as the authors of the work do not have basic data for such calculations. For this reason, the economic share calculations for this alternative remain indicative and further analysis is needed to estimate the total cost of the projects described above.

Contrary to the two previous scenarios, which focus on a thorough reconstruction of the so-called old housing stock, modern heating solutions can be immediately integrated in new development areas, and for some solutions there is no need to coordinate energy production with external district heating. In studies by TalTech energy scientists[88,89] various low-temperature solutions have been modelled specifically for Estonian conditions. The research more than clearly pointed out the incompatibility of existing district heating networks as well as buildings and building heating equipment with low-temperature heating, but at the same time it was found that low-temperature solutions are cost-effective in new apartment buildings, especially in new development areas (e.g. Paekalda, Kopli liinid, etc.).

Investments with a positive 10-year NPV and a 5-year payback period have been modelled for a 4.5 MW low-temperature (60 ^{o}C/35 ^{o}C) solution for a new development area (Tallinn), using a gas boiler and a heat pump using seawater on the primary side. This example is characterised by the low heating demand of already planned buildings (45 KWh/m^{2}y). The low-temperature heating solution used as a basis for the research provided an estimated cost of heat in around 38.86 EUR/MWh, where the usual cost of heat produced with natural gas is 56.65 EUR/MWh. Although in the case of the modelled case the initial investment in the form of a combination of a gas boiler and a heat pump was higher than with traditional heating, this price difference meant that the investment was already profitable in the medium term.

The second study modelled, also for a new residential area in Tallinn, a low-temperature solution that utilises the heat returned to the conventional district heating network (extract from the return line of the district heating network), which is one of the more advanced approaches in housing sector heating. The study concluded that this solution (65 ^{o}C/35 ^{o}C), although it uses heat returned from the district heating network, also requires investment in the network itself. In the case of a new development area with a building area of 180,000 m^2 and a thermal capacity of 15 MW, the investment is profitable from the 3rd year.

For **alternative scenario 4c**, the authors chose a model based on heat pumps and a gas boiler independent of district heating from the two variants described above. The authors have extended this example to the whole sector as a theoretical scenario. To do this, it was first determined what the size of the new building stock compatible with such a heating solution would be. A new building stock of 2 318 thousand m^2 of apartment and office buildings has been put into use in Estonia from 2016 until now[90]. As data on the developer is not stored in the construction register, and therefore it is not possible to extract how many development areas are being developed uniformly, the authors of this work used a clustering algorithm [91] to form potential blocks of new 3-storey apartment and office buildings very close

[88] Anna Volkova et al. Energy cascade connection of a low-temperature district heating network to the return line of a high-temperature district heating network. Energy 198, 2020, 117304

[89] Anna Volkova et al. Small low-temperature district heating network development prospects. Energy 178, 2019, 714-722

[90] On the basis of an extract from the construction register submitted by MEAC.

[91] NetworkX, https://networkx.org/

to each other in a way that is as similar as possible to the study described above, i.e. the alternative would be connecting to an existing district heating network, a classic high-temperature or, as in the study, a low-temperature solution. Thus, within the framework of this work, potential heating areas were formed, which in m^2 units represent 65 % of the total new residential and office building stock.

Table 15.11. Results of block clustering of the relevant building stock licensed since 2016

	Total, t m2	Apartment and office buildings, t m2	Potential heating areas, t m2
In Estonia	3 871	2 318	1 502
In Tallinn	1 706	1 264	845

As a result of clustering, it was found out that 65 % of the square metres of added office and apartment buildings are very close to each other and form a minimum 3-storey building stock, i.e. blocks or development areas, which would be suitable as a miniature heating area.

A GDP and 3-month Euribor[92] based regression analysis[93] predicts an increase in the housing stock of 591 thousand m^2 in 2020[94], then 631 681 and 742 thousand m^2, respectively, until 2023. Predicting the growth of office space and other suitable buildings with the help of macroeconomic data did not prove to be successful in this work, therefore this study was based on the average volumes of square metres in the previous 5 years[95], which showed an increase in the closed net area of non-residential buildings of 315 thousand m^2 per year. In view of these considerations, it can be estimated that from 2021 to 2030, an estimated 6 390 thousand m^2 of closed net area of buildings will be added, which would theoretically be suitable for low-temperature heating areas. The authors admit that the above-mentioned estimate of the net area to be added until 2030 is approximate and does not attempt to predict the growth of the building stock in a scientific way. **However, switching an average of 6 390 thousand m^2 per year to smart heating would have a significantly positive NPV and energy savings**. Based on the same logic, it is possible to assess what energy savings could theoretically be achieved and what impact this would have on CO_2 emissions, if such a switch to low-temperature heating were possible. As Dr.Sc.Ing Anna Volkova, group leader of the aforementioned study, pointed out in consultation with the present authors that the underlying study could not be used simply to generalise and define macro-scenarios, the authors of this study abandoned the potential assessment.

Alternative 5: Directing waste heat from data economy to district heating

The baseline scenario for this alternative scenario is an increase in the number and size of operating data centres, leading to an increase in primary energy consumption. Although the number and size of data centres in operation are expected to increase, there is uncertainty

[92] According to historical data, until 2023, but on the basis of the summer forecast of the Ministry of Finance and the European Central Bank's December 3-month Euribor forecast for December 2020.

[93] Mean Absolute Error (MAE) 75 thousand m^2, coefficient of determination 0.73.

[94] Statistics Estonia's actual number for the three quarters of 2020 is 533.8 thousand m2 of, so at the moment this analysis underestimates the growth rate of the housing stock.

[95] According to Statistics Estonia's table EH046, the following buildings were included in the low-intensity buildings category: Accommodation buildings, Catering buildings, Commercial buildings, Service buildings, Hospitals and other medical buildings, Welfare institution buildings, Educational and research buildings, Entertainment, museum and library buildings, Sports buildings, Office buildings

about the number and size of future centres in the next 10 years. The electricity consumed by data centres has a fossil fuel component. The energy consumption of data centres is high. As electricity has a higher fossil share than alternatives, the above means that the proliferation of data centres will lead to an increase in greenhouse gas emissions and a decrease in the share of renewable energy sources in the future. Therefore, a high-tech data economy can, while undoubtedly beneficial to the national economy, make it more difficult to achieve national energy and climate targets for energy savings.

The theoretical prerequisite of **alternative scenario 5** is the conversion of electricity from data centres, 95 % of which is transformed into waste heat and waste cooling, so that it can be directed to neighbouring district heating areas or other heat consumers. As the authors have detailed forecasts and calculations of the investments required to capture waste heat in one very large data centre, the authors estimate, based on the data, that the **realisation of data centre waste heat has a positive NVP, i.e. it is self-financing**. Unfortunately, the above assessment does not reflect the real situation, as the NPV has been calculated on the basis of this case without taking into account the investment for connecting to a district heating network. **The need to connect to a district heating network caused such large additional investments that the project profitability turned negative**. This conclusion can be seen, among other things, from the financial analysis of the above-mentioned data centre waste heat solution, which took into account the investments necessary for connecting to a district heating network.

Assessing the impact of data centres on greenhouse gas emissions, it can seem to aggravate the situation, as it would reduce the share of traditionally produced heat in district heating (an average of 55 % of which stems from renewable energy sources) in favour of highly fossil electricity (renewable share 19 %, up from 2020). It is also possible to take the exact opposite view and, on the basis of the Renewable Energy Directive referred to above, to consider energy based on heat pumps as coming from renewable energy sources if it is destined for final consumption in the heating sector.

15.4 Borders and an integrated approach

In this analysis, waste heat sources are considered throughout the country and no separate regional analysis has been performed.

15.5 Assumptions

The assumptions of the economic and financial analysis performed in this work are presented in the following table (Table 15.12).

Table 15.12. Assumptions of the economic and financial analysis

Indicator	Value	Justification	Source
Calculated maximum waste heat in the industrial combustion process, %	15	See above	See above

Indicator	Value	Justification	Source
Inflation rate, %	2	Expected long-term inflation rate	The ECB's medium-term objective
Estimated annual ratio of operating and maintenance costs to capital investment, %	5	Estimated annual expenditure to simplify group calculations for operating and maintenance costs as a proportion of the investment made to capture waste heat	Survey, interviews
Estimated annual ratio of operating and maintenance costs to capital investment with heat pump solution, %	10	Estimated annual expenditure to simplify group calculations for operating and maintenance costs as a proportion of the investment made to capture waste heat	I. Sarv, 2019[96]
Service life, y	15	Flue gas condensers, heat exchangers	Survey, interviews
Service life, y	10	Heat pumps	Survey, interviews
Discount rate, %	5.76	District heating producers, by sector	The Competition Authority
C02 emission factor, natural gas	202	t CO2-eq/GWh	MKM
C02 emission factor, wood-based fuels	390	t CO2-eq/GWh	MKM
C02 emission factor, electricity (from oil shale)	358	t CO2-eq/GWh	MKM
C02 emission factor, heat energy	301	t CO2-eq/GWh	MKM
CO2 emission factor, fossil heat	217	t CO2-eq/GWh	MKM
CO2 emission factor, solid biomass	6.99	t CO2-eq/GWh	MKM
Price of natural gas, excl. taxes, in non-households	26	eur/MWh, 2018	MKM
Price of wood-based fuels, excl. taxes	13.7	eur/MWh, 2018	MKM

[96] https://digikogu.taltech.ee/et/Item/a8053c03-b45e-4c99-9bbe-048105d79072

Indicator	Value	Justification	Source
Heat energy, excl. taxes	63	eur/MWh, 2018	MKM
Price of electricity, excl. taxes	77	eur/MWh, 2018	MKM

15.6 Sensitivity analysis

A sensitivity analysis involves going through versions of the scenarios with different energy prices, different discount rates, but also changes in the cost of the initial investment required by the company, which may be due to reduced technology costs, efficiency gains or external financing factors.

The economic viability of the considered alternatives depends on energy prices and the different price scenarios are discussed in the table below.

Table 15.13. Change in the estimated NPV of the scenario (in millions of euros) due to changes in energy prices

	Alternative	Wholesale heat price -25 %	Wholesale heat price +25 %	Retail heat price - 25 %	Retail heat price +25 %	Wood-based fuel and natural gas prices -25 %	Wood-based fuel and natural gas prices +25 %	Prices of relevant energy types - 25 %**
0: Existing measures to increase the utilisation of waste heat from district heating plants	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1: Increased use of flue gas condensers by district heating companies (wood boilers)	10.3	10.3	10.3	10.3	10.3	1.3	19.3	1.3
2: Use of heat exchangers in industrial companies outside the energy sector	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3: Waste heat recovery by water companies* **	6.4	-2.9	15.8	6.4	6.4	6.4	6.4	-2.9
4: Baseline scenario for housing renovation* **	-21.2	-21.2	-21.2	-23.9	-18.5	-21.2	-21.2	-23.9
4a: Use of heat pumps in existing district heating in housing* **	-19.2	-19.2	-19.2	-23.6	-14.9	-19.2	-19.2	-23.6

	Alternative	Wholesale heat price -25 %	Wholesale heat price +25 %	Retail heat price -25 %	Retail heat price +25 %	Wood-based fuel and natural gas prices -25 %	Wood-based fuel and natural gas prices +25 %	Prices of relevant energy types -25 %**
4b: Use of heat pumps in housing with heat recovery***	-10.9	-10.9	-10.9	-18.6	-3.1	-10.9	-10.9	-18.7
4c: Use of heat pumps in residential low-temperature district heating	104.8	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
5: Directing waste heat from data economy to district heating***	4.9	2.1	7.8	4.9	4.9	4.9	4.9	2.1

*Not available, as it is based on the calculations of the authors of the current study
**Wood-based fuels, natural gas, estimated retail price of heat and estimated wholesale price of heat
***This and the following table do not take into account changes in the heat pump's electricity consumption when changing the production volume

In addition to energy type prices, other sector-specific indicators play a role in the economic analysis.

Table 15.14. Change in the estimated NPV of the scenario (in millions of euros) due to changes in various scenario-specific prices

	Alternative	Discount rate -1 %	Discount rate +1 %	Change in demand - 7 %	Change in demand - 15 %	Connection fee EUR 1 million****	Connection fee EUR 1 million, change in demand - 7 %	Connection fee EUR 1 million, change in demand -7 % and foreign support for the project 50 %
0: Existing measures to increase the utilisation of waste heat from district heating plants	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1: Increased use of flue gas condensers by district heating companies (wood boilers)	10.3	13.9	7.3	7.6	4.9	N/A****	7.6	17.9
2: Use of heat exchangers in industrial companies outside the energy sector	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3: Waste heat recovery by water companies	6.4	8.5	4.7	3.8	1.2	2.6	0	9.5
4: Baseline scenario for housing renovation	-21.2	-20.5	-21.8	-21.9	-22.7	N/A****	-21.9	-21.9
4a: Use of heat pumps in residential district heating conditions	-19.2	-18.3	-20.1	-20.5	-21.7	N/A****	-20.5	-19.7
4b: Use of heat pumps in housing with heat recovery	-10.9	-10.9	-10.9	-12.9	-14.9	N/A****	-12.9	-12.1
4c: Use of heat pumps in residential low-temperature district heating	104.8	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*

	Alternative	Discount rate -1 %	Discount rate +1 %	Change in demand - 7 %	Change in demand - 15 %	Connection fee EUR 1 million****	Connection fee EUR 1 million, change in demand - 7 %	Connection fee EUR 1 million, change in demand -7 % and foreign support for the project 50 %
5: Directing waste heat from data economy to district heating	4.9	5.7	4.3	4.1	3.4	-0.9	-1.7	0.2

**** In certain scenarios, the existence of a connection is assumed

The sensitivity analysis carried out regarding the aforementioned **scenarios shows that an increase in the investment necessary for selling moderate amounts of heat,** which may be a 1-1.5 km, 350 mm diameter pipeline necessary for connecting to a district heating network (i.e. 1 million euros), results in a significant **decrease** of NPV indicators in **sectors** dependent on such connections**, and thereafter, a small, i.e. 7 % decrease in consumption volumes causes the projects for selling the waste heat from wastewater plants and data centres highlighted in this study to turn unprofitable.** External financing of 50 % of the initial investment (national or EU support) helps to mitigate the aforementioned risks.

15.7 The economic impact of untapped potential on consumer prices of heating and cooling

The impact on consumer prices of heating and cooling is reflected in particular in the cost-benefit analysis, which shows the cost-effectiveness of possible solutions and scenarios, as well as the price that society should or should not bear in one scenario or the other, but also whether the consumer shall bear the costs through price changes due to market conditions or regulated price changes.

In this analysis, it has been based on the conventional retail price of heat for consumers, which is 63 euros per MWh and corresponds to the arithmetic average of the established price caps. Based on the knowledge of the sector, the purchase price of heat was chosen to be 22 euros per MWh, which is comparable to the variable costs of district heating production and is therefore competitive without increasing the retail price. It is noteworthy that the applied research on which this analysis was based did not use heat tariffs in excess of the marginal prices in the calculations of NPVs and payback periods, nor did it assume that a higher marginal heat price would be allowed to create a new heating solution.

The biggest challenge for the economic analysis continues in some scenarios to be the cost of connecting to district heating and the capacity of district heating networks to absorb more heat. In scenarios where the investment turned out to be unprofitable, the higher retail price of heat reduced the negative net present value, especially for investments designed to modernise the heating systems of the existing housing stock. However, these investments are so commercially unprofitable that even a 25 % price increase wouldn't make them profitable.

The increase in the wholesale price of heat improved the net present value of investments in the resale of heat from data centres and wastewater using the latest technologies. Therefore, this increase in the expected purchase price – which may be accompanied by an increase in the retail price of heat – may be a means of mitigating investors' risks, especially given that both scenarios negate the need to invest in the district heating network itself. These investments have a moderate positive NPV if there is no need to finance the district heating network.

In the case of heat which is not self-generated but which is directed to a regulated market, in particular a district heating network, and provided that the investment in its production is included in the tariff (through depreciation), this may have an appropriate negative effect on consumer prices.

Scenarios (scenario 1) were also discussed above, as a result of which the resulting savings were self-sustaining and there is no difficult-to-assess need for network-side investment. In the latter case, there is no harm to the consumer as a result of the pricing. According to the feedback received from economic operators, there may even be some positive, i.e. price-reducing, effect in the form of a reduction in regulated tariffs as a result of the efficiencies created. In the remaining cases, businesses should not be expected to share the material savings with the consumer.

16 Used materials

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