28.6.2024

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Finland/Comprehensive assessment of heating and cooling efficiency potential under Article 25.1 of the Energy Efficiency Directive (EED) 2023/1791

Provisions and the Commission's recommendations for drawing up a comprehensive assessment:

The work has been carried out in accordance with EED (EU) 2023/1791 Annex X Potential for heating and cooling;
where applicable, used the recommendation of the previous comprehensive evaluation; COM Recommendation C(2019)6625 final.

Part I Overview of heating and cooling

Part I (1)

heating and cooling demand in terms of estimated useful energy and determined final energy consumption in GWh per year by sector

Part I (6)

a forecast of trends in the demand for heating and cooling to maintain a perspective of the next 30 years in GWh and taking into account, in particular, projections for the next 10 years, the change in demand in buildings and different sectors of the industry, and the impact of policies and strategies related to the demand management, such as long-term building renovation strategies under Directive of the European Parliament and of the Council (EU) 2018/844;

		Unit	Year 2022	2025	2030	2035	2040	2045	2050
Heating demand, **final** energy	Residential sector	GWh/a	55823						
	Service sector	GWh/a	19339						
	Industrial sector	GWh/a	NA						
	Other sectors	GWh/a	NA						
Cooling demand, **final** energy	Residential sector	GWh/a	NA						
	Service sector	GWh/a	NA						
	Industrial sector	GWh/a	NA						
	Other sectors	GWh/a	NA						
Heating demand, **useful** energy	Residential sector	GWh/a	49313	48289	44283	42062	39504	37190	35514
	Service sector	GWh/a	18283	15264	13489	11560	9630	8053	7816
	Industrial sector	GWh/a	NA	THEY	THEY	THEY	THEY	THEY	THEY
	Other sectors	GWh/a	NA	THEY	THEY	THEY	THEY	THEY	THEY
Cooling demand, **useful** energy	Residential sector *	GWh/a	NA	IE	IE	IE	IE	IE	IE
	Service sector	GWh/a	NA	3500	4500	5500	6400	7100	7800
	Industrial sector	GWh/a	NA	THEY	THEY	THEY	THEY	THEY	THEY
	Other sectors	GWh/a	NA	THEY	THEY	THEY	THEY	THEY	THEY

*Residential cooling demand included in figures for service sector

Part I (2a)

Identify (where appropriate, assess on-site heating and cooling (GWh) produced in households or in service delivery locations by technology across sectors, distinguishing between energy from fossil and renewable energy sources, where possible. The techniques are broken down as follows: heat boilers, high-efficiency cogeneration, heat pumps, waste heat (when assessing off-site energy), other technologies and on-site/off-site energy from other sources.

Energy provided on-site			Unit	Value
Residential sector	Fossil fuel sources	Heat only boilers	GWh/a	1535
		Other technologies	GWh/a	0
		HECHP	GWh/a	0
	Renewable energy sources	Heat only boilers	GWh/a	IE*
		HECHP	GWh/a	0
		Heat pumps	GWh/a	8009
		Other technologies	GWh/a	7459
Service sector	Fossil fuel sources	Heat only boilers	GWh/a	2540
		Other technologies	GWh/a	0
		HECHP	GWh/a	0
	Renewable energy sources	Heat only boilers	GWh/a	493
		HECHP	GWh/a	0
		Heat pumps	GWh/a	886
		Other technologies	GWh/a	NA
Industrial sector	Fossil fuel sources	Heat only boilers	GWh/a	NA
		Other technologies	GWh/a	NA
		HECHP	GWh/a	NA
	Renewable energy sources	Heat only boilers	GWh/a	NA
		HECHP	GWh/a	NA
		Heat pumps	GWh/a	NA
		Other technologies	GWh/a	NA
Other sectors	Fossil fuel sources	Heat only boilers	GWh/a	NA
		Other technologies	GWh/a	NA
		HECHP	GWh/a	NA
	Renewable energy sources	Heat only boilers	GWh/a	NA
		HECHP	GWh/a	NA
		Heat pumps	GWh/a	NA
		Other technologies	GWh/a	NA

*Residential heat only boilers using renewable energy are reported under Other technologies

Energy provided off-site

Residential sector	Fossil fuel sources	Waste heat	GWh/a	1617
		HECHP	GWh/a	5397
		Other technologies	GWh/a	1815
	Renewable energy sources	Waste heat	GWh/a	IE*
		HECHP	GWh/a	6761
		Other technologies	GWh/a	9952
Service sector	Fossil fuel sources	Waste heat	GWh/a	1060
		HECHP	GWh/a	3067
		Other technologies	GWh/a	1064
	Renewable energy sources	Waste heat	GWh/a	IE*
		HECHP	GWh/a	3521
		Other technologies	GWh/a	4305
Industrial sector	Fossil fuel sources	Waste heat	GWh/a	NA
		HECHP	GWh/a	NA
		Other technologies	GWh/a	NA
	Renewable energy sources	Waste heat	GWh/a	NA
		HECHP	GWh/a	NA
		Other technologies	GWh/a	NA
Other sectors	Fossil fuel sources	Waste heat	GWh/a	NA
		HECHP	GWh/a	NA
		Other technologies	GWh/a	NA
	Renewable energy sources	Waste heat	GWh/a	NA
		HECHP	GWh/a	NA
		Other technologies	GWh/a	NA

* All waste heat is reported under fossil fuel sources

Part I (2b)

Information on the identification of potential supply from installations that generate waste heat or cold (GWh per year):

- (I) thermal power plants capable, immediately or after retrofitting, of waste heat with a total thermal input exceeding 50 MW;
- (II) combined heat and power installations using the techniques referred to in Part II of Annex II with a total thermal input exceeding 20 MW;
- (III) waste incineration plants;
- (IV) renewable energy installations with a total thermal input exceeding 20 MW, other than installations referred to in paragraph 2(b)(i) and (ii), producing heating or cooling using energy from renewable sources;
- (v) industrial installations with a total thermal input exceeding 20 MW that can generate waste heat;

see **Explanation EED Art 25**, pages 4-9.

Part I (2c)

Declared share of energy from renewable sources and waste heat or cold in final energy consumption in the district heating and cooling sector over the last five years in accordance with Directive (EU) 2018/2001

Year	Share of total from renewable or waste heat district heating
2018	43 %
2019	47 %
2020	53 %
2021	56 %
2022	57 %

Part I (3)

Aggregated data for existing cogeneration district heating and cooling networks in five capacity categories

a) primary energy consumption

b) overall efficiency

c) primary energy savings

d) CO2 emission factors

see Annex **EED Art 25**, page 8 (Table 2).

Part I (4)

A description of the existing district heating and cooling networks using energy from cogeneration in five capacity categories covering the following information:

a) total primary energy consumption

b) primary energy consumption of cogeneration units

c) share of cogeneration in the production of district heating or district cooling

d) district heating system losses;

e) district cooling system losses;

f) connection density;

g) proportions of systems by different operating temperature groups

see Annex **EED Art 25**, pages 8-9 (Tables 3 and 4).

Part I (5)

Maps covering the entire national territory identifying

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) existing heating and cooling supply points and district heating transmission installations
c) planned heating and cooling supply points and planned heat installations, as well as identified new areas for district heating and cooling.

see **Explanation EED Art 25**, pages 5.6 and 11-14.

Part II Objectives, strategies and policy measures

Detailed reports in Finland's National Energy and Climate Plan (NECP) (Publications of the Ministry of Economic Affairs and Employment, Energy, 2024:30).

Objectives, strategies and policy measures, reported inter alia in the following chapters:

2.2 Dimension energy efficiency
2.4.4. Energy poverty
3.1.1 . GHG emissions and removals
3.1.2 Renewable energy (energy subsidies, new technology, district heating and cooling)
3.1.3 Other elements of the dimension
4.6. Dimension research, innovation and competitiveness

National building renovation plan
The Energy Performance of Buildings Directive (EPBD) requires EU Member States to have a national building renovation plan. The plan sets out measures to achieve zero emissions of the existing building stock by 2050 and to meet the targets for energy efficiency improvements in the residential building stock. Work to produce the Renovation Plan has started in May 2024, with strong consultation and involvement of stakeholders at both national and regional level. The open online survey will be open until 30 June 2024 to gather stakeholders' views.

https://ym.fi/-/rakennusten-energiatehokkuusdirektiivin-toimeenpano-rakennuskannan-Renovation Plan development

The Renovation Plan replaces the 2020-2050 Long-term Renovation Strategy.

Part III Analysis of the economic potential for efficiency in heating and cooling

The cost-benefit analysis and the data are **set out in Annex EED Art 25** (p. 26-45).

Part IV Potential new strategies and policy measures

An assessment and analysis of new legislative and non-legislative measures to realise any economic potential identified on the basis of a cost-benefit analysis will be carried out in the context of the national energy and climate strategy work and decisions will be taken and implemented once the strategy is finalised. The preparation of the National Energy and Climate Strategy has started and is expected to be completed in spring 2025.

https://tem.fi/energia-ja-ilmastostrategia

EU Renewable Energy Directive (EU) 2018/2001, Article 15(7)

The assessment of potential of energy from renewable sources and of the use of waste heat and cold in the heating and cooling sector is **presented in Annex Overview RED II Article 15(7).**

ATTACHMENTS
Annex Explanation EED Art 25
Annex Overview RED II Article 15(7)

Consignee
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Report

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IN ACCORDANCE WITH ARTICLE 25 EED

COMPREHENSIVE EVALUATION

MINISTRY OF EMPLOYMENT AND THE ECONOMY

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CONTENT

1. INTRODUCTION

The Energy Efficiency Directive (EED) (EU) 2023/1791 requires Member States to carry out a comprehensive assessment under Article 25.1, *including an analysis of the economic potential for efficiency in heating and cooling. The comprehensive assessment shall be carried out in accordance with Annex X to the EED and submitted to the Commission by 30 June 2024 as part of the integrated national energy and climate plan.*

The work is divided into two sub-tasks:

1. Description of supply and demand for heating and cooling
2. Analysis of the economic efficiency potential in heating and cooling

Part task 1 has created a snapshot of the production of heat and cooling in Finland in accordance with Annex X. The sub-task also provides a perspective for the future of the heating and electricity markets. In Finland, heating and cooling networks are mostly implemented and their expansion is currently moderate. Finland's district heating networks are largely expanding with new regional construction sites. As regards district heating in Finland, it is most relevant how it is possible to replace the current production of district heating by, for example, heat pumps and waste heat, allowing for an efficient social system in terms of both costs and primary energy use.

Sub-task 2 has carried out a cost-benefit analysis with a scenario analysis of Finland's heating system until 2030. For sub-task 2, the ry Energy Industry made its member companies: query
district heating production definitely future
viewpoints.
The scenario analysis looks at the large-scale use of waste heat, the impact of electrification and the impact of a change in the number of district heating customers. The work will take into account and consider the socio-economic and environmental impacts of the scenarios.

The work was carried out by Ramboll Finland Oy and a steering group was set up for the work. The Steering Group consisted of representatives from the Ministry of Employment and the Economy, the Energy Authority and the Energy Industry Association.

2. DESCRIPTION OF THE HEATING AND COOLING SUPPLY

This chapter describes the technical data on installations for the production of heating and cooling in Finland and related networks in accordance with Annex X to the Energy Efficiency Directive (EED) (EU) 2023/1791. The Chapter is divided into Annex X, sub-paragraph 2b; 3, 4 and 5c. Technical information
the Energiavirasto's register of power plants and the most recent data from the district heating system in the energy industry have been used as input. The latest available data refer to 2022. (Energy Authority 2024) (Energy Industry 2023a).

2.1 Production of heat and cooling

In accordance with point 2b of Annex X to the EED, installations producing waste heat or cold and their annual heating and cooling energy production have been identified in the report by the following breakdown:

- thermal power plants capable, immediately or after retrofitting, of waste heat with a total thermal input exceeding 50 MW
- combined heat and power (CHP) installations with a total thermal input exceeding 20 MW
- waste incineration plants
- renewable energy installations with a total thermal input exceeding 20 MW other than installations referred to in points (i) and (ii) producing heating or cooling using energy from renewable sources
- industrial installations with a total thermal input exceeding 20 MW that can generate waste heat

Table 1 Methods for the identification of installations

Installation type	Identification working method
Thermal power plants (more than 50) (MW)	• Types of power plants *register stand* -alone production and *nuclear power* plant types • Waste heat output from estimated electrical power ⟶ thermal input (electric power/ 0.4) ⟶ waste heat output (fuel output * (0,9-0,4)) • Also excluded units used for back-up and reserve because: for these, the use of waste heat would be of limited importance.
Heat and electricity cogeneration plants (CHP) (over 20 MW)	• District heating (Taul4) has been selected for the combined capacity of district heating over 20 MW installationswhere has also electricity generation. Waste incineration plants are not included in this category. • Installation-specific quantities of heat production has determined From the network/company value of the district heating system "Net production of district heating in cogeneration" (Taul1), as follows: ○ If only one CHP production plant on the network has been used: direct value. ○ If more than one CHP plant, net split fuel production proportionally. ○ If the undertaking has more than one CHP using the same fuel— plant assumed primary production and net split production
Waste incineration plants	• Identified for spent fuel. • Co-incineration plants were excluded. • Amount of heat produced from CHP plants as specified above for other CHP production.
Renewable energy installations (over 20 MW) not included in categories (i) and (ii)	• Heat pump installations with a thermal input exceeding 20 MW. • Cooling production determined from district cooling statistics where: declared each production unit type and type-specific production volumes. • If: multiple production Unit representing same type, has the production volume is divided into each unit in proportion to the power. • High-volume heating, i.e. heat generated during cold production non-utilisation has been estimated to be low. Chilling, i.e. heat production connected generated cold submission
Industrial installations (over 20 MW)	• Industry CHP plants; which producing warmth district heating networks. Identified by combining: data From the Register of Power Facilities and District temperatures, namely selected Register of Power Facilities 'Industry CHP' —

Institutions are identified and listed in Annex 1. The following maps illustrate the location of installations and the emphasis on heat production in Finland. Heat production focuses on large settlements and heat generated by the generation of electricity from nuclear power plants;

Eurajoki and Loviisa (Figure 1). There are less heat-producing installations in Pohjois-Suomi, which also have less dense population than in Etelä-Suomi.

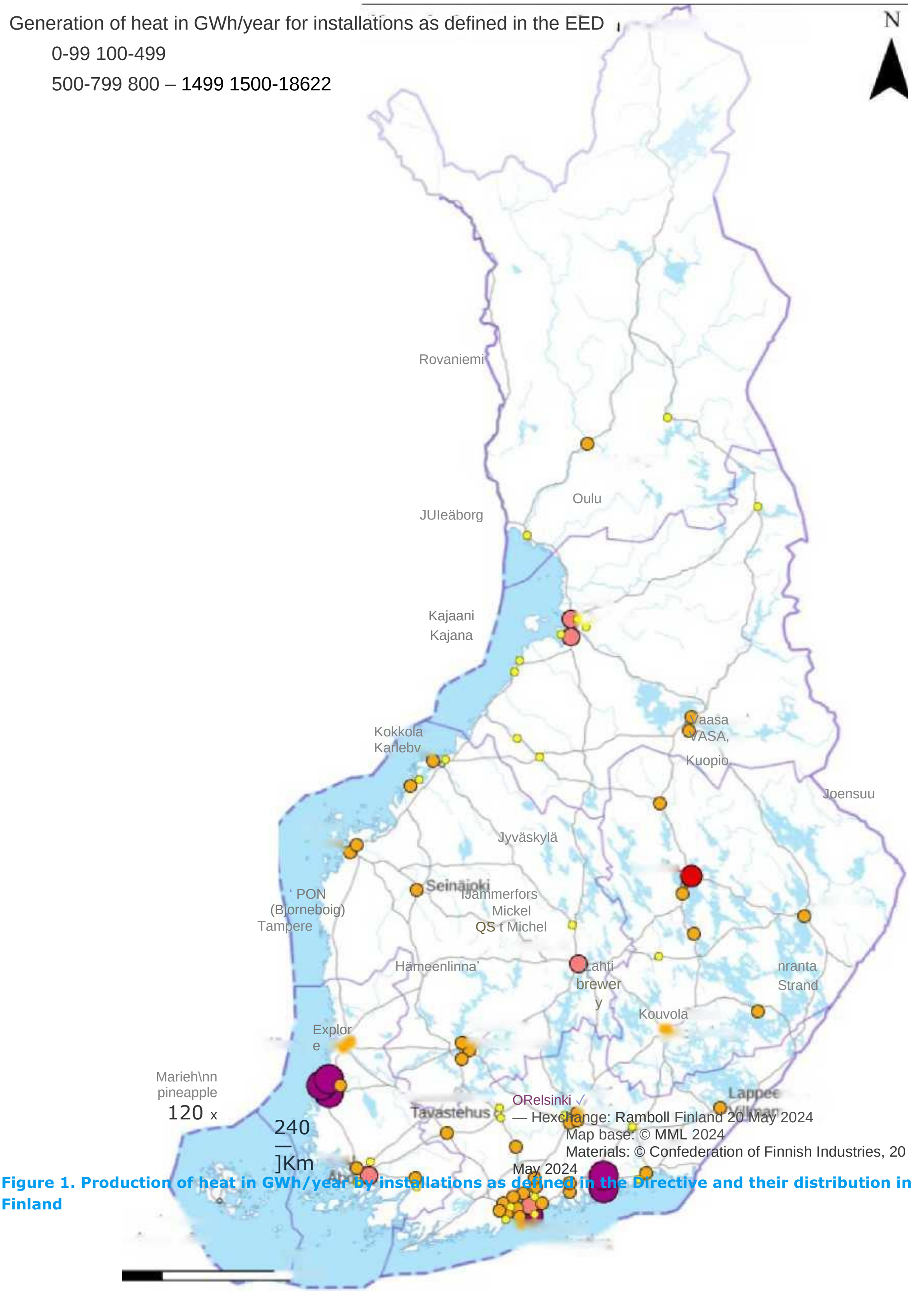


Figure 1. Production of heat in GWh/year by installations as defined in the Directive and their distribution in Finland

The amount of heat generation (GWh) shown in the previous figure (Figure 1) for different installations. The following figure (Figure 2) shows the different categories of installations.

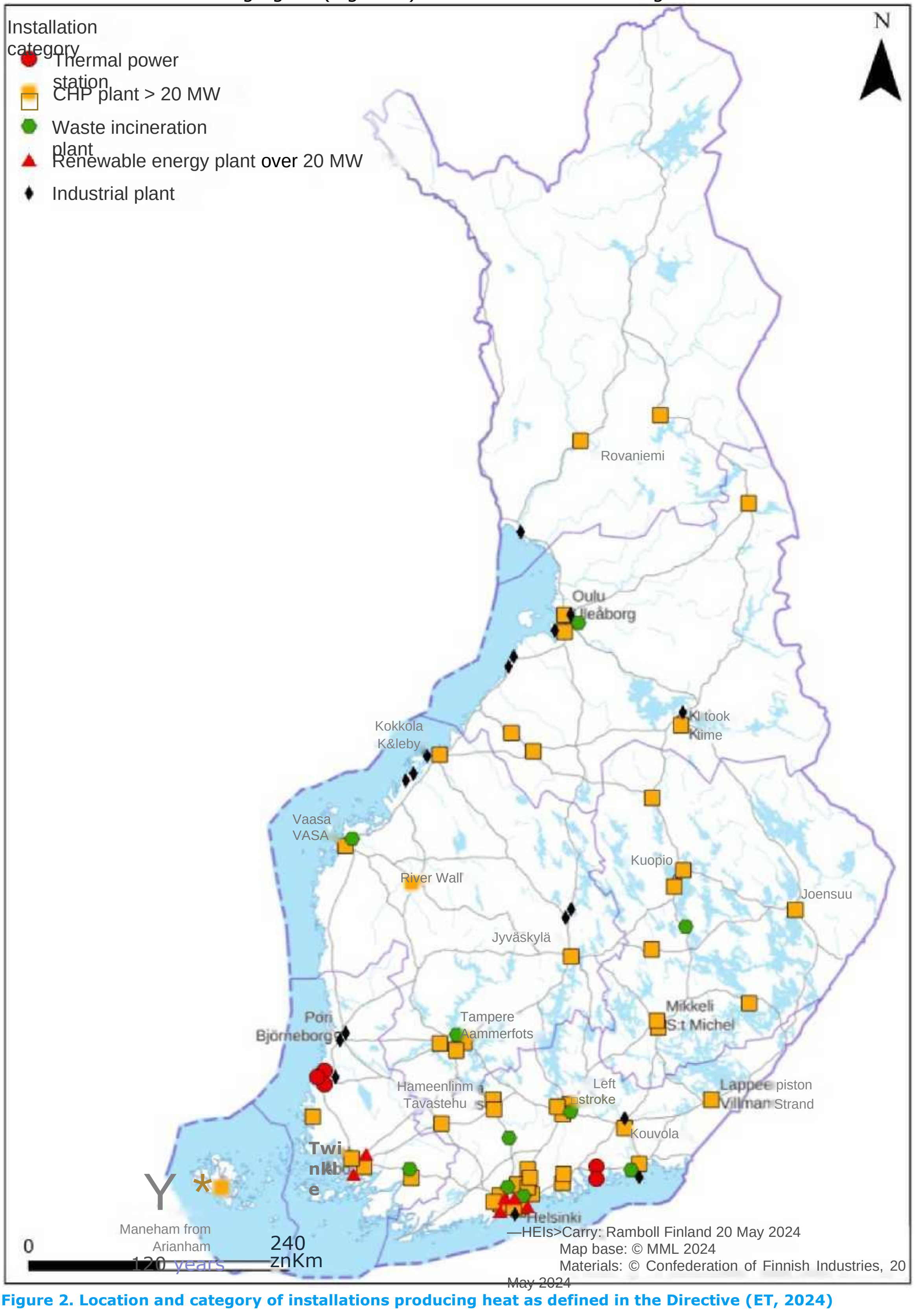


Figure 2. Location and category of installations producing heat as defined in the Directive (ET, 2024)

CHP plants are spread evenly across Finland in different cities. Waste incineration plants and renewable energy plants are concentrated in Southern Finland. Thermal power plants are the Loviisa and Rauma nuclear power plants. Industrial installations are decentralised across Finland in larger locations.

2.2 Aggregated data for existing cogeneration plants connected to the district heating network

This chapter presents data aggregated in accordance with Annex X, point 3, for cogeneration units located in existing district heating and cooling networks for five capacity categories, covering the following information:

- Primary energy consumption
- Overall efficiency
- Primary energy savings
- CO_2 emissionfactors

The calculation of primary energy consumption, overall efficiency and CO_2 emissionfactors is based on data from district heating statistics (Energy Industry 2023a). Primary energy consumption is directly available from statistics. The overall efficiency is calculated by dividing total production by primary energy consumption. CO_2 emissionfactor has been calculated using the benefit-sharing method;
the utility ratios for electricity and heat generation calculated on an installation-by-installation basis.

Primary energy savings calculation based on Energy Efficiency Directive Annex II formula:

$$PES = \frac{1}{\frac{CHPH}{Ref'Hand} : \frac{CHPE''}{REF\ EJ}} \text{I}\ 100\ \%$$

where:

PES is primary energy saving

CHPH isthe thermal efficiency of cogeneration, which means the annual useful heat output divided by the fuel input used for the sum of the useful heat output and electricity produced by cogeneration.

RefH isthe efficiency reference value for separate heat production.

CHPE ⇨is the electrical efficiency of cogeneration, which means annual electricity from cogeneration divided by the fuel input used to sum the useful heat output and electricity produced by cogeneration.

RefE isthe efficiency reference value for separate electricity generation.

The efficiency reference values for electricity and heat production have been calculated in accordance with Commission Delegated Regulation (EU) 2023/2104, which takes into account the year of construction of the installations, the fuel type and the average climate temperature.

The aggregated results are shown below (Table 2).

Table 2 Combined data for existing cogeneration plants connected to the district heating network

CHP capacity	N	Primary energy consumption [GWh]	Total efficiency	Primary energy savings	Emission factor of the heat produced [kg/MWh]
— 20 MW	8	318	64 %	32 %	31
20-50	23	3 364	79 %	45 %	52
50-150	36	11 290	76 %	37 %	112
150-300	18	12 339	93 %	24 %	92
> 300	3	3 243	86 %	14 %	228

2.3 Aggregated data for existing district heating networks connected to cogeneration plants

This chapter presents district heating and cooling networks operating with energy from existing cogeneration in accordance with point 4 of Annex X in five capacity classes, covering the following information:

- Total primary energy consumption GWh/a
- Primary energy consumption of cogeneration units GWh/a
- Share of cogeneration in the production of district heating or district cooling GWh/a
- System loss for district heating GWh/a
- System loss for district cooling GWh/a
- Connection density MWh/line km
- Proportions of systems by different operating temperature groups

The data presented are based on data from district heating and cooling statistics (Energy Industry 2023a) (Energy Industry 2020) (Energy Industry 2023b).

The aggregated results are shown below (Table 3 and Table 4).

Table 3 Combined data for district heating networks connected to existing cogeneration plants I

Capacity categories	Total primary energy consumption	Primary energy consumption of cogeneration units	Share of cogeneration in the production of district heating or district cooling
<20 MW	29	25	77 %
20 – 100 MW	4 119	3 178	41 %
100-300 MW	7 124	6 257	49 %
300-900 MW	25 344	19 102	44 %
> 900	11 993	9 105	57 %

Table 4 Combined data for district heating networks connected to existing cogeneration plants II

Capacity categories	System loss for remote heating	System loss for remote cooling	Connection density [MWh/line km]	Proportions of systems by different operating temperature groups*
<20 MW	17 %	0 %	1.2	86
20 – 100 MW	8 %	0 %	3.2	87
100-300 MW	8 %	0 %	2.8	86
300-900 MW	9 %	0 %	3.5	85
> 900	1 %	0 %	3.9	84

***100 % of the systems are in the operating temperature ranges 84 to 87 °C.**

3. HEAT AND COOLING SUPPLY OUTLOOK FOR THE FUTURE

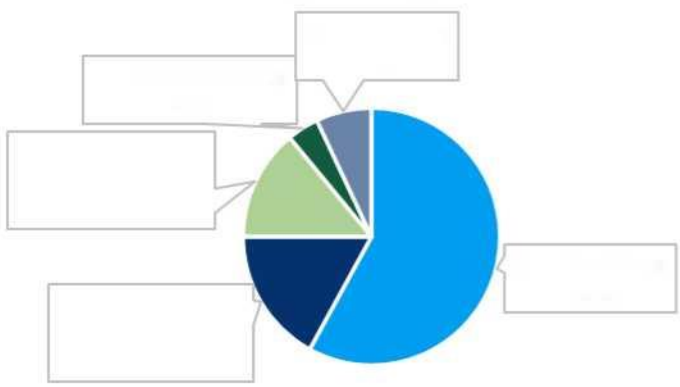
3.1 Planned new heating and cooling supply points

In Finland, heating and cooling networks are mostly implemented and their expansion is currently moderate. Finland's district heating networks are largely expanding with new regional construction sites. In Finland, many new projects are planned to generate waste heat that can be used for district heating. These include projects in the hydrogen industry, biochar manufacturing, data centres and battery industry projects.

3.2 Industrial energy use and waste heat generated in Finland

The potential of existing and new waste heat sites is very challenging to assess. This work illustrates the potential of waste heat by analysing industrial energy use by municipalities and estimating the usable amount.

Total industrial energy consumption in Finland in 2022 was 126 TWh, i.e. around 44 % end-use. Industrial electricity consumption amounted to 36 TWh. Forest-based industries account for around 58 % of industrial energy consumption, 17 % in the chemical industry and 14 % in metal processing. Industrial final energy consumption decreased by 17 % over the period 2000-



2022 (Motiva 2024).

The amount of energy that can be recovered from industrial energy use was considered by municipality (SYKE, 2024). Waste heat is defined as 40 % of the energy used by industry, which is expected to be technically and cost-effectively returned to society.

Figure 3 Distribution of industrial energy use in 2022 (Motiva, 2024)

Industrial energy use is evenly distributed throughout Finland, but with a focus on southern Finland. The largest generation of waste heat is Porvoo – Southern Eastern Finland on the axis and on the west coast. The largest demand for district heating is concentrated in the Helsinki region. There is also more demand for district heating in West and CentralFinland’s bigger towns than waste heat. The generation of waste heat for the whole of Finland and the demand for district heating are illustrated below (Figure 4). Figures 5 to 8 look more closely at regional waste heat generation (GWh) and demand for district heating (GWh). Finland is divided into the following regions: Etelä-Suomi 1/2 (Kuva 5), Etelä-Suomi 2/2 (Figure 6), Central Finland (Kuva 7) and Northern Finland (Figure 8).

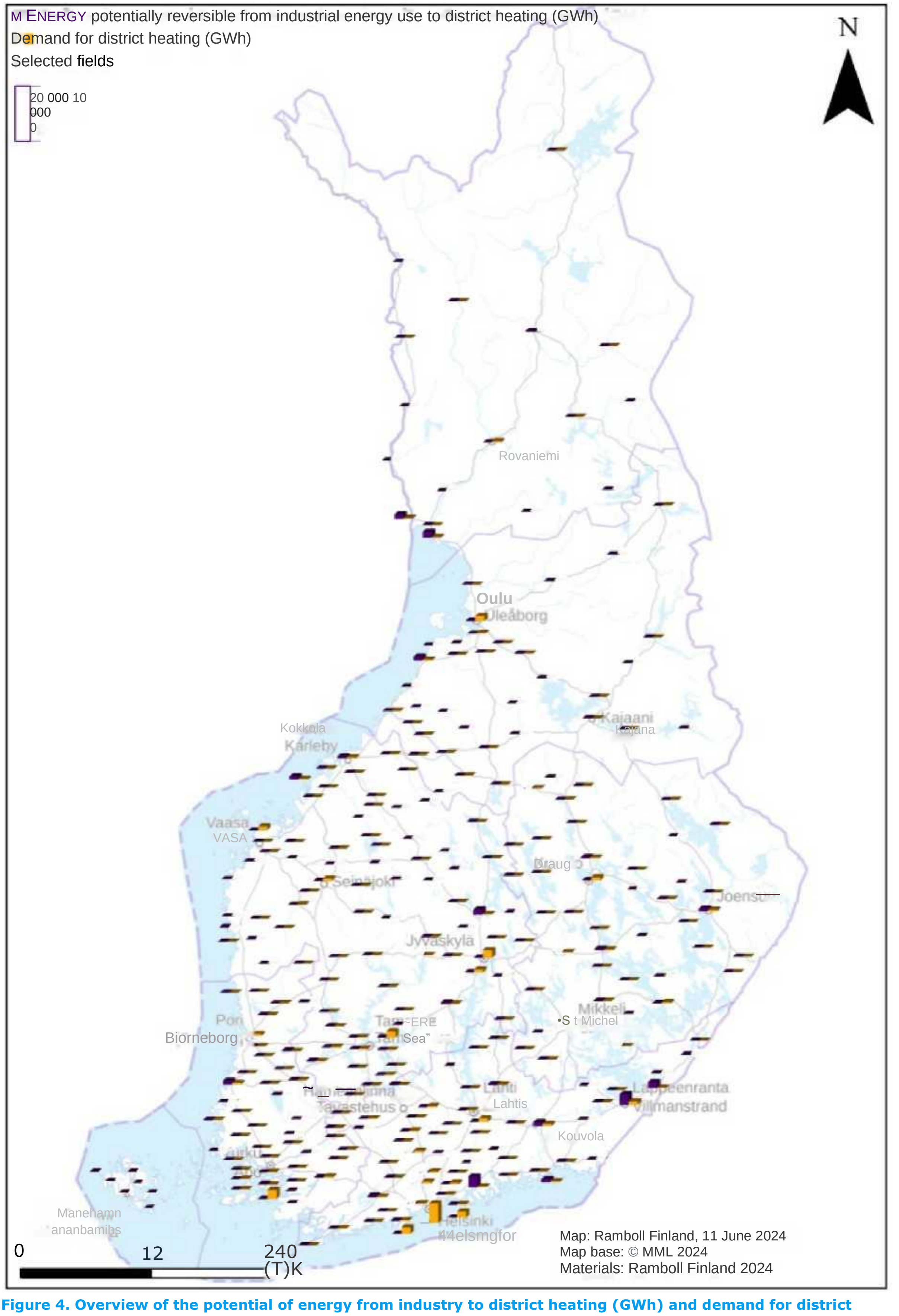


Figure 4. Overview of the potential of energy from industry to district heating (GWh) and demand for district heating (GWh) by municipality in Finland.

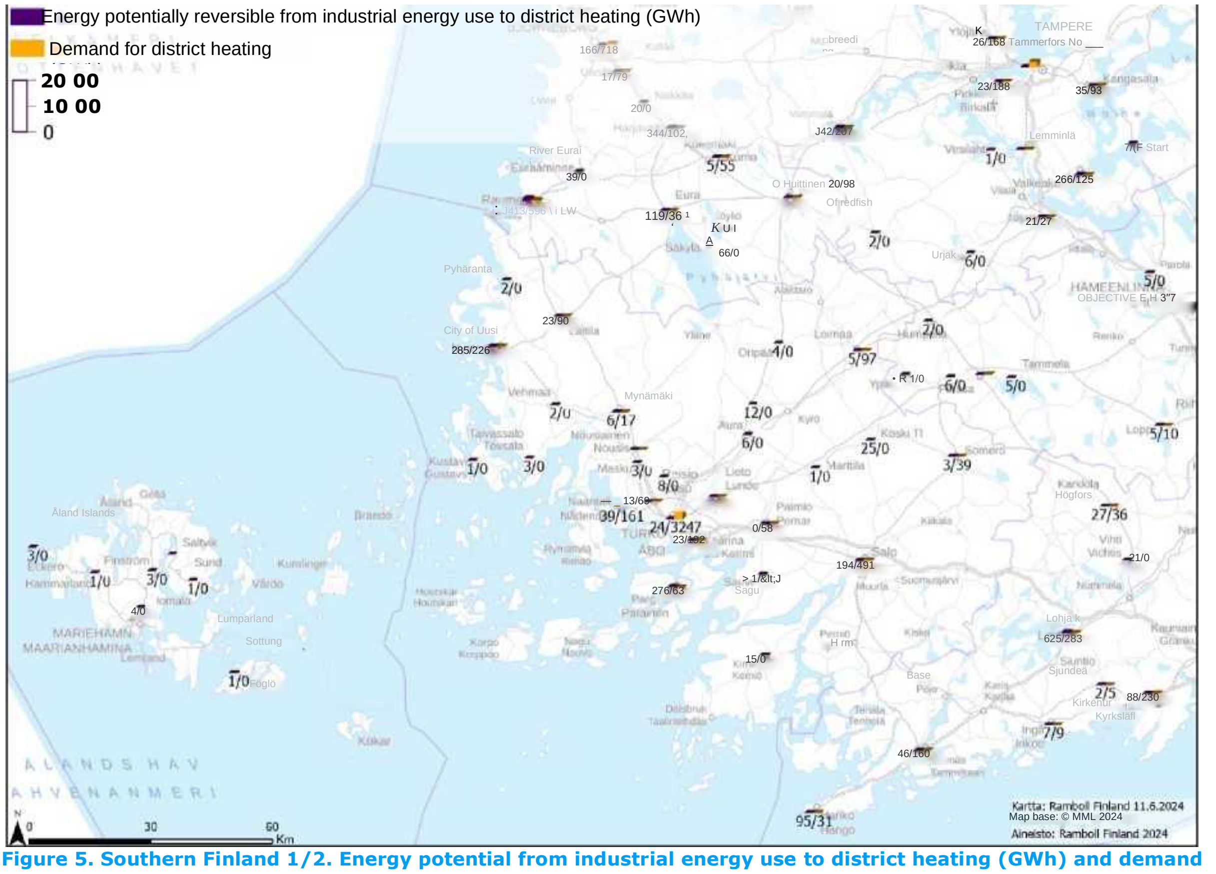


Figure 5. Southern Finland 1/2. Energy potential from industrial energy use to district heating (GWh) and demand for district heating (GWh) per municipality. The first number is the reversible energy and the number after the line is the demand for district heating.

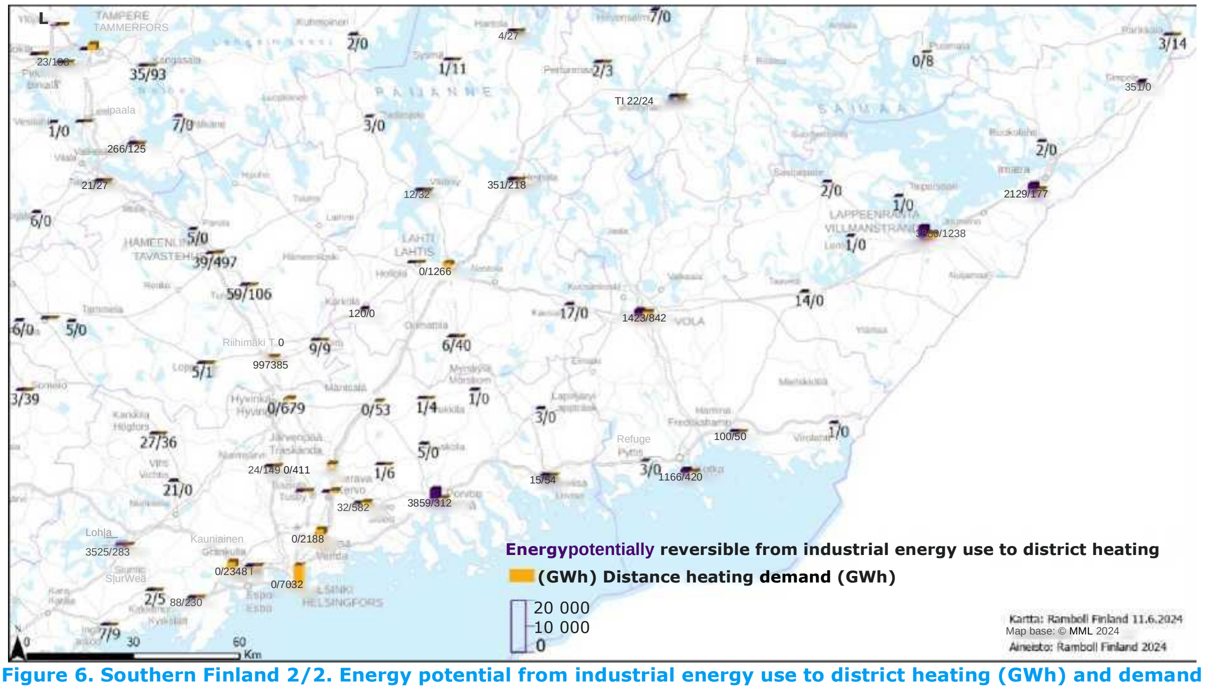


Figure 6. Southern Finland 2/2. Energy potential from industrial energy use to district heating (GWh) and demand for district heating (GWh) per municipality. The first number is the reversible energy and the number after the line is the demand for district heating.

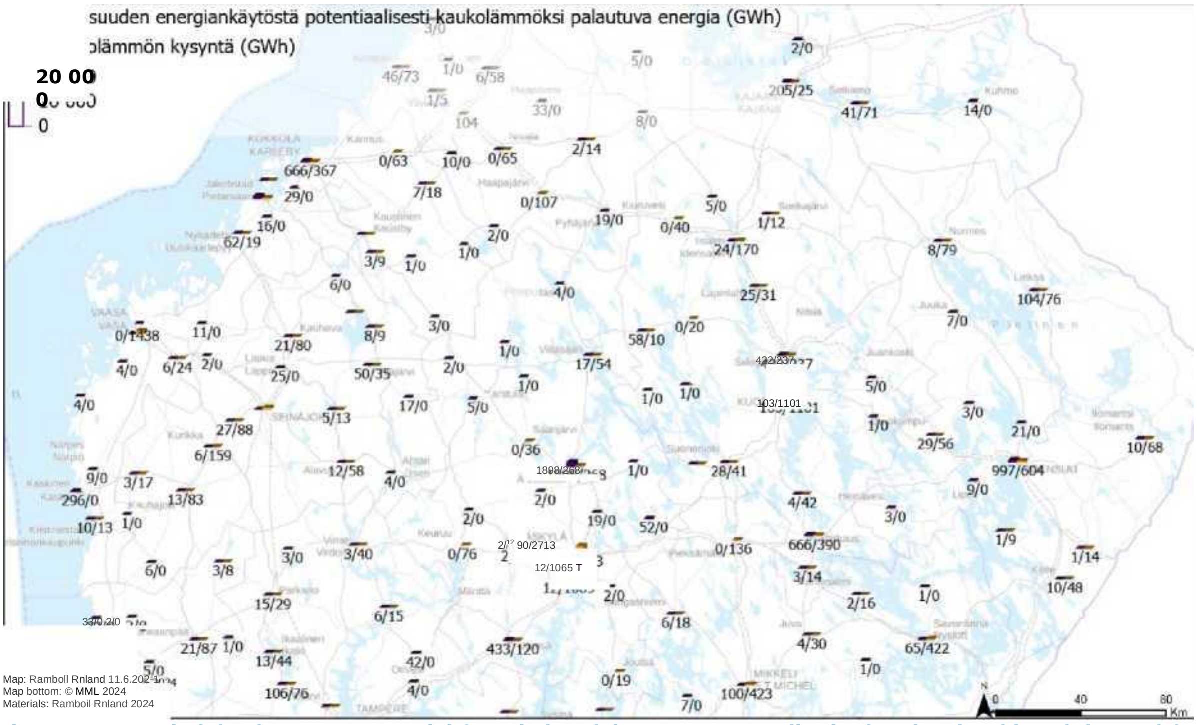


Figure 7. Central Finland. Energy potential from industrial energy use to district heating (GWh) and demand for district heating (GWh) per municipality. The first number is the reversible energy and the number after the line is the demand for district heating.

Figure 8. Northern Finland. Energy potentially recoverable from industrial energy use to district heating (GWh) and demand for district heating (GWh). The first number is the reversible energy and the number after the line is the demand for district heating.

The ratio between the energy used by industry and the demand for district heating varies significantly in municipalities. It can be observed that there are several municipalities in Finland where there is a positive relationship between industrial energy use and the need for local district heating, i.e. the heat reversible from the industry is underutilised.

3.3 Planned clean transition projects

The locations of clean transition plants producing waste heat (Figure 9) and capacity (MW) (Figure 10) are shown in the figures below. The locations of the installations are illustrated in the maps, indicating where they might be located in Finland. The stages of the institutions range from pre-screening to those under construction. The dataset is based on project information from the data window of the Confederation of Finnish Industries (EK, 2024). Hydrogen projects are currently on the move, most of which are concentrated in Southern Finland. Battery technology and green steel projects focus on Western Finland. The Biocarbon Plant Projects are located in Joensuussa, Kerava, Kotka and Lake Utajärvi and the Data Centre – projects in Espoo, Hamina and Kouvola. The Kerava Data Centre project is in the study phase. New biorefineries projects are spread evenly in Finland.

It is difficult to estimate the amount of waste heat generated by new installations. Some processes/installations can make more efficient use of waste heat generated than others. On the other hand, the need for heat in the local building stock has an impact on the usability of waste heat, as is the case for nearby industrial heat.

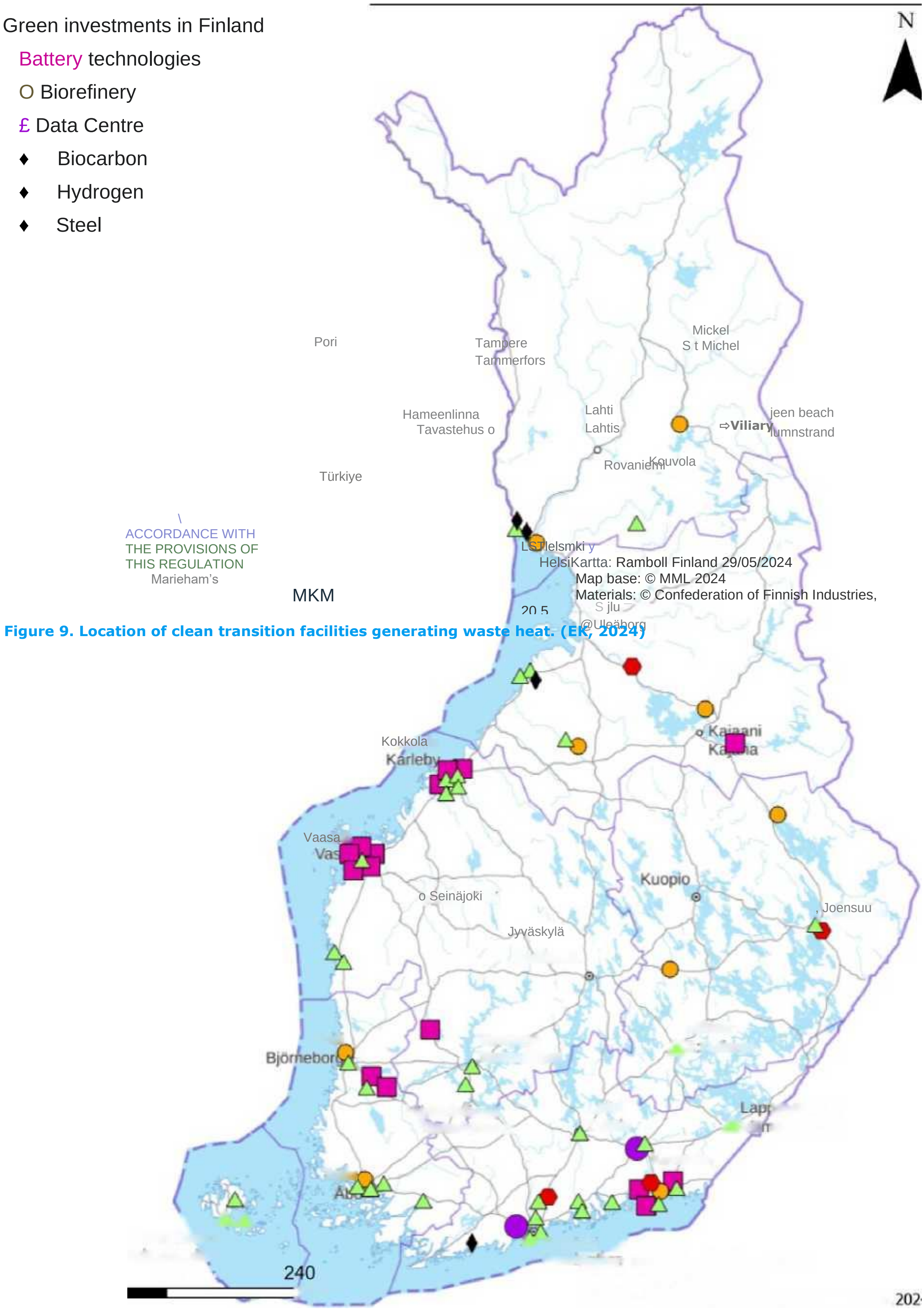


Figure 9. Location of clean transition facilities generating waste heat. (EK, 2024)

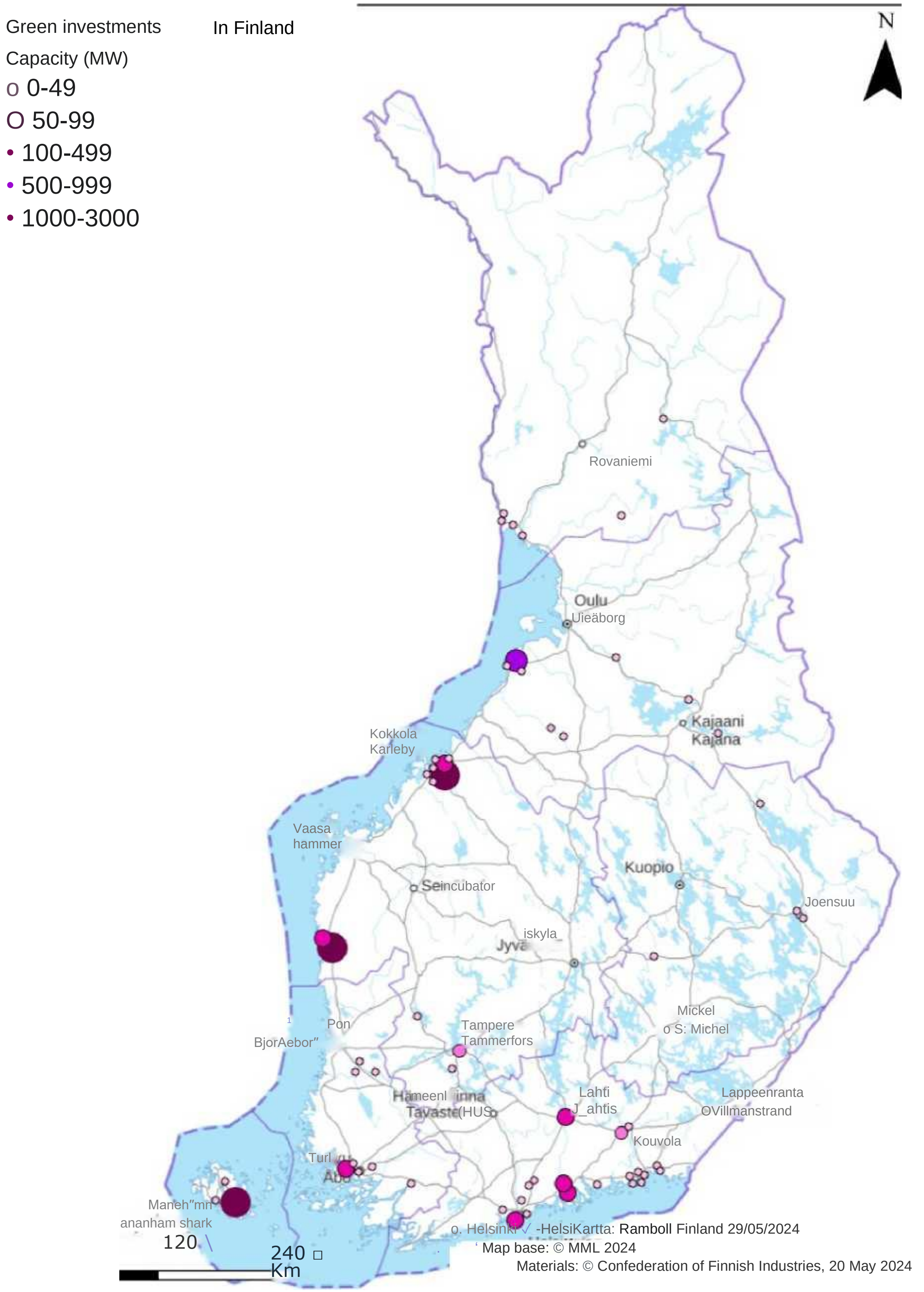


Figure 10. Size class of clean transition plants, MW (EK, 2024)

3.3.1 Waste heat capacity of clean transition projects and its use

The total waste heat capacity of the planned clean transition projects mentioned in the EK dataset is 20.5 TWh/a, including only hydrogen and data centre projects with declared power and/or other capacity. The heating demand for the whole Finnish building stock is 95 TWh/a and the demand for district heating is 43 TWh/a (VTT, 2024). The waste heat capacity of the projects planned would be sufficient to cover about 22 % of the total Finnish heating needs if they were to be used for heating purposes. Thus, it also reduces Finland's primary energy needs by such an equivalent amount of energy.

Distance map (Description (11) is: indicated distance from waste heat could: theoretically moves from potential hydrogen facilities and data centres. Public use of distance calculation known occupancy hydrogen installations and data centre power data; establishments operating hours 7500 h and 35 % share of waste heat in hydrogen plants and data centres in hours of operation, 8760 h and 20 % of waste heat. The distance calculation has estimated that the maximum transfer cost may be EUR 5/MWh, calculated on the basis of the following assumptions:

- Capital cost EUR 1500/m
- Retention period 30 years
- Estimated at 0.1 %/km

The result of the calculation is that it is profitable to transfer 0.1 km/GWh of waste heat.

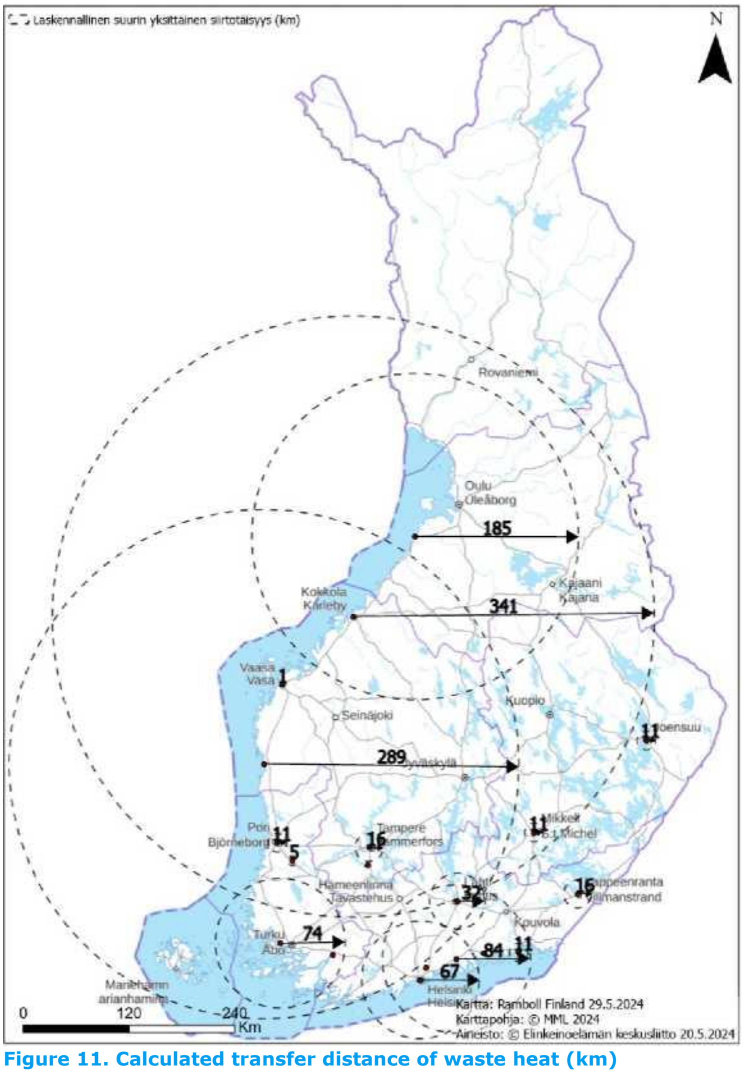


Figure 11. Calculated transfer distance of waste heat (km)

The dashed line circle depicts the distance of the district heating pipeline from the installation, i.e. the distance up to which waste heat could be transported through a single district heating pipeline. The arrow depicts the length of an example- district heating tube, i.e. the transport distance of waste heat from the plant. The number above the arrow is the distance in km. Computed distances of less than 100 km from installations are more realistic than transport distances of more than 100 km of district heating, as shown in Figure 11 the transport distances of waste heat produced by the planned installations in Raare, Kristiina and Kokkola.

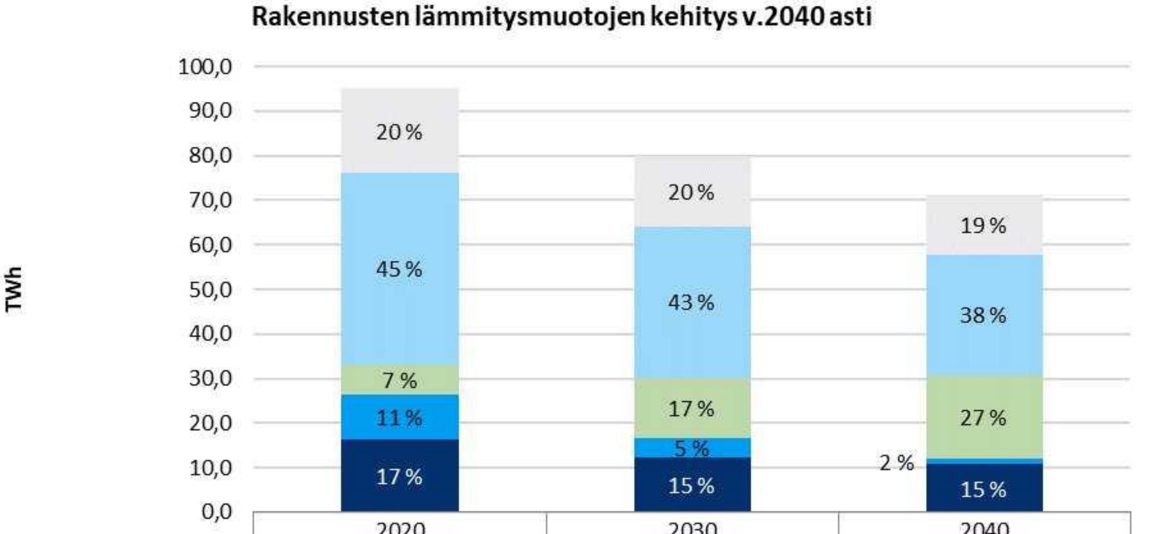
The transfer of waste heat calculated on the basis of these parameters indicates that the waste heat capacity of large GW-class installations extends to a very distance of >> 100 km from the location of the installation. The transfer of waste heat from installations for the heating of agglomerations may be possible provided that there are sufficient and justified incentives to use waste heat for both the waste heat generator and the user.

4. VIEW AMENDMENT MARKET

4.1 Heating demand for buildings

The heat demand in Finland is projected to decrease significantly over the next decades (Figure 12). By 2030, heat demand will decrease by about 16 % and by 2040 by around 25 % compared to 2020 levels. This estimate is based on VTT's calculation as part of the Pout Project (VTT, 2024).

In the calculation, the variable 'electricity' includes, in addition to electric heating, the electricity consumption of all heating systems. The variable "heat pump" includes only ambient heat.



	2020	2030	2040
Sähkö [TWh]	18,8	15,6	13,4
Kaukolämpö [TWh]	43,2	33,9	27,0
Lämpöpumput [TWh]	6,7	13,7	19,0
Fossiiliset [TWh]	10,1	4,2	1,1
Puu [TWh]	16,3	12,4	10,8

Figure 12 Development of heating modes of buildings up to 2040 (VTT, 2024)

In the heating of buildings, all forms of heating other than heat pumps will be used less in the future than in 2020. In particular, fossil and district heating will decrease significantly in the future. Heat pumps replace all other forms of heating and cover up to 27 % of the total heat output in 2040, compared to 7 % in 2020.

4.2 Change in district heating production

Similar change has observable also district heating production.
The development of district heating production was examined by dividing district heating networks into five different capacity classes and by examining how the heat generation of the different categories of district heating will evolve until 2030.

District heating networks are calculated on a city-by-city basis, i.e. capacities do not take individual small networks into account, but integrated across cities. The data are based on the 2022 district temperatures of the Energy Industry Association. It is noteworthy that 2022 was a very exceptional year due, among other things, to the energy crisis caused by Russia's war of aggression and the resulting increase in energy prices and, among other things, the collapse of biomass availability, especially in Eastern Finland. As a result, the use of peat increased somewhat compared to the previous year.

For networks of less than 300 MW, the main form of production is biomass. These networks also make use of peat. Networks between 300 and 1 500 MW also mainly use biomass, but also waste and coal. The main forms of production in the larger network are coal, natural gas and oil (Figure 13).

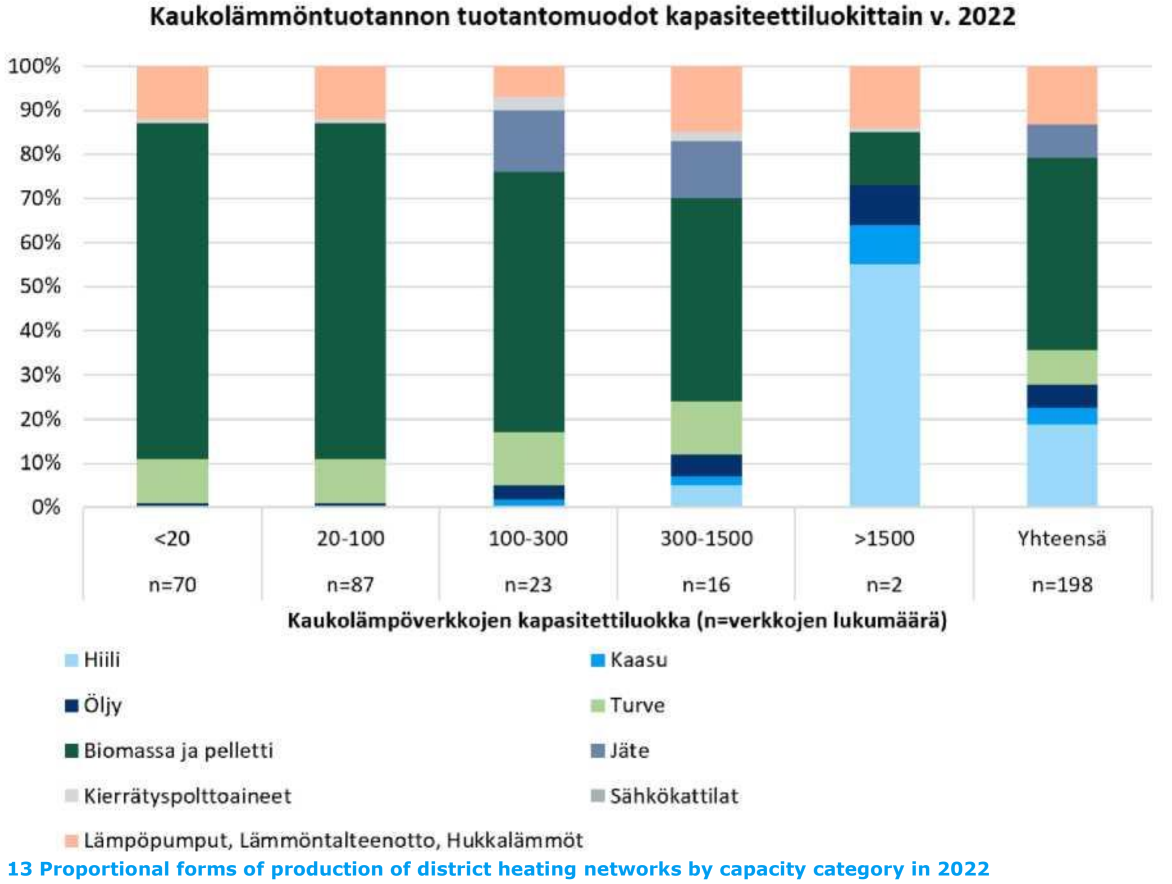


Figure 13 Proportional forms of production of district heating networks by capacity category in 2022

The district heating network calculation examined the share of efficient district heating network systems as defined in Article 26(1) of Directive 2023/1791 in 2022. The result of the calculation is that 98 % of Finland's district heating is covered by an efficient district heating network. The situation in 2022 complies with Article 26(1a) of Directive 2023/1791.

The future outlook fordistrict heating production was examined in cooperation with the Energy Industry Association. The energy industry surveyed industry about their future plans for changes to the district heating production portfolio. The Energy Industry ry estimates that the survey covered around 70-80 % of the annual energy volume of district heating, with a particular focus on networks above 100 MW. Model distributions of less than 100 MW are assumed to be similar.

The results are presented below (Figure 14).

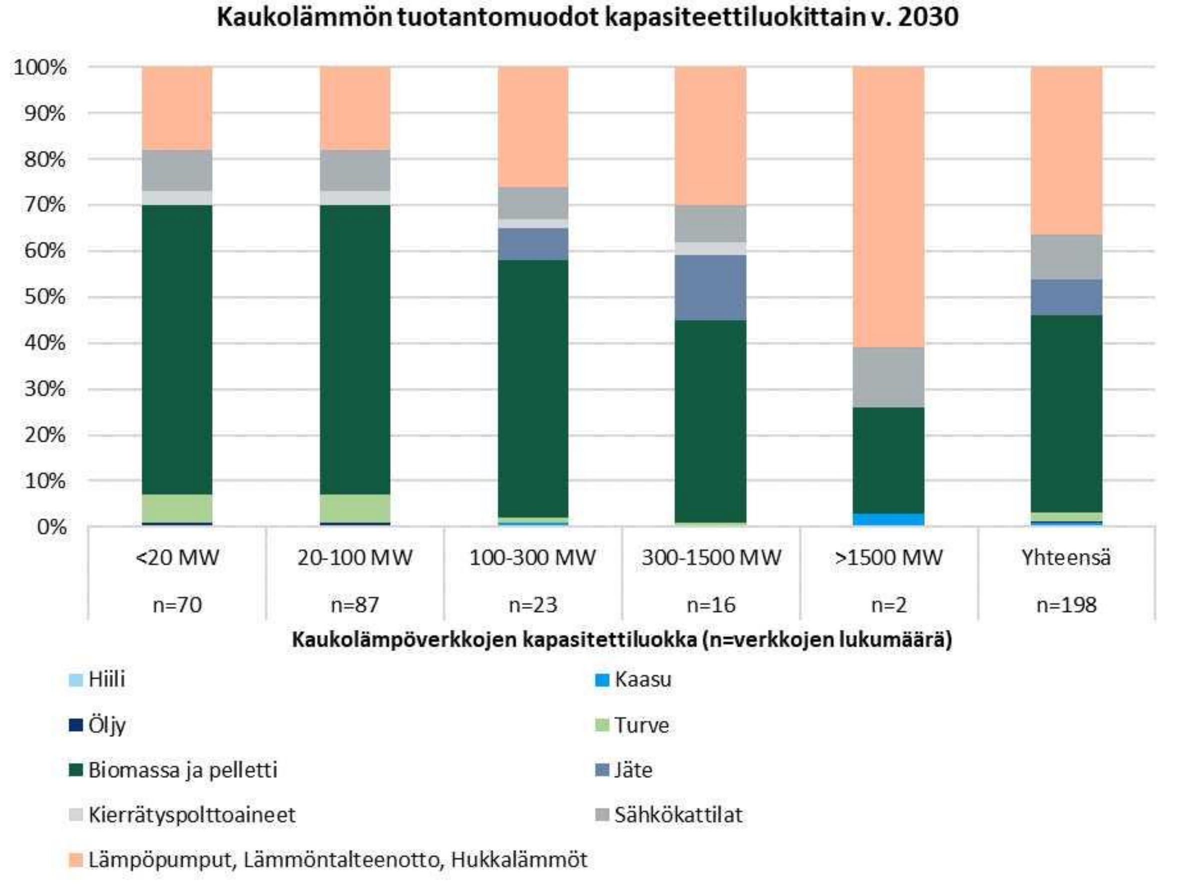


Figure 14 Production modes of district heating networks by capacity category in 2013

The main change in district heating production is the replacement of fossil fuels, in particular by heat pump production. The share of heat pump production is increasing for each capacity class. However, the most significant change occurs in the largest networks > 1 500 MW.

Changes in energy volume by capacity category are shown in the figure below (Figure 15). The figure shows how critical over 300 MW, in particular over 1 500 MW of district heating networks, are for change. The change in them is the highest, both in relative and absolute terms.

For small & 300 MW district heating networks, the main change is the replacement of peat and other fossil fuels by electricity and heat pumps. Large 300 & lt; 1 500 MW in networks, the change is similar to the one above. For the largest networks > 1 500 MW, the change is the most significant. They replace fossil fuels with electricity-based solutions.

It is noteworthy that for each capacity class the total heating demand is expected to decrease by 8 % by 2030. This will facilitate some change, as it is not necessary to invest in new capacity the same capacity as is currently available for district heating production.

The district heating network calculation examined the share of efficient district heating network systems as defined in Article 26(1) of Directive 2023/1791 in 2030, based on survey data. The result of the calculation is that 100 % of Finland's district heating is covered by an efficient district heating network.

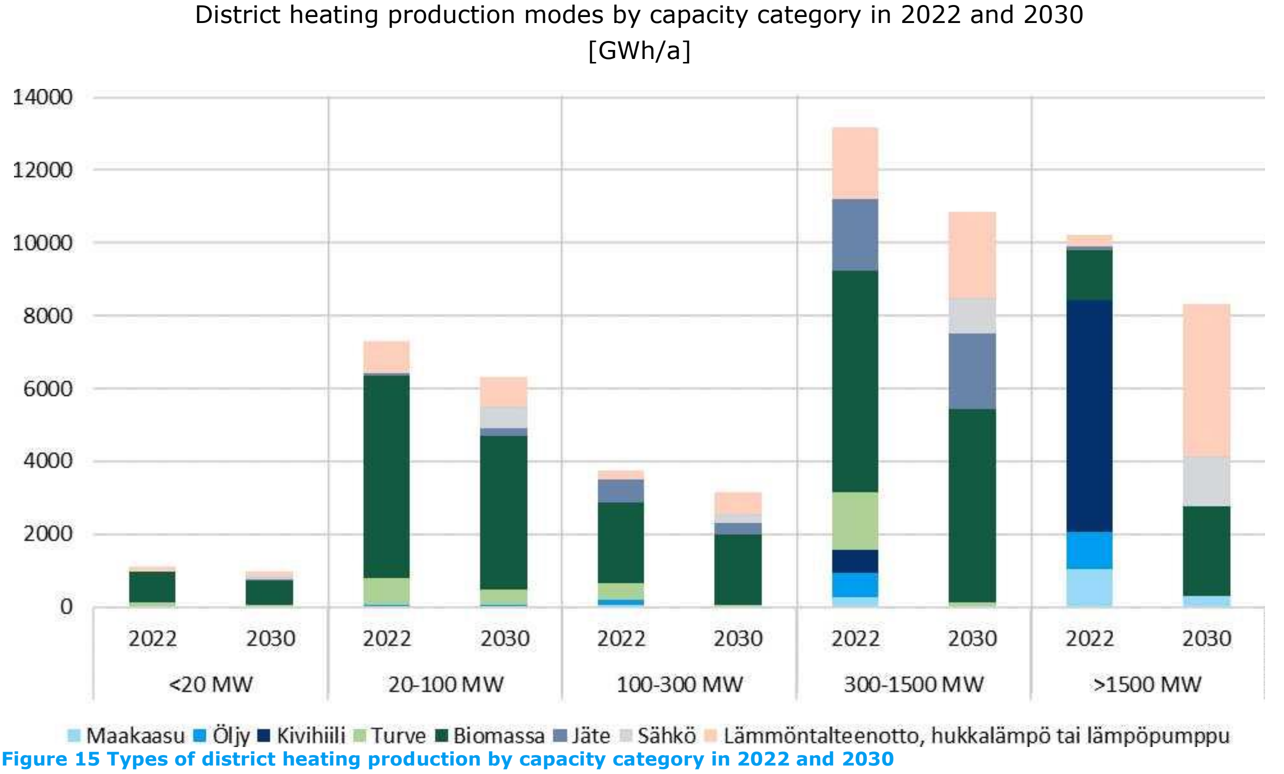


Figure 15 Types of district heating production by capacity category in 2022 and 2030

4.3 Other forms of heating

District heating competing forms of production are: mainly different property-specific heat pump solutions. Among these, air-to-water heat pumps and geothermal heat are the main forms of production chosen rather than district heating or replaced by district heating. The reason for switching is, in particular, cost-related reasons, but may also include emission factors.

Currently, in some district heating networks, heat pump solutions emit less CO2 emissions when district heating. However, this will change as district heating production replaces fossil heat production with heat pumps and biomass.

The results of the life-cycle cost of the different heat generation modes for a typical residential building (Figure 16) are presented below. The cost of district heating is based on the customers of the district heating price statistics; number weighted average (Energy industry; 2024).
Forms of heat production are assumed to be own investments in real estate and not, for example, the technology used by the service model.

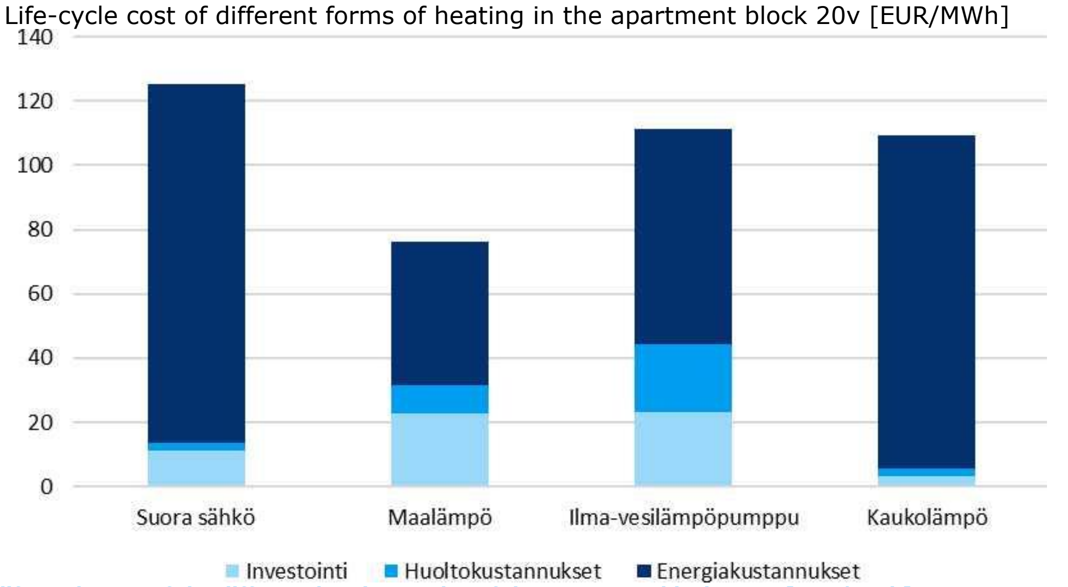


Figure 16 life-cycle cost of the different heating modes of the apartment block 20 vs [EUR/MWh]

For example, the calculation gives an indication of the average difference between the different types of heat production. The costs of district heating and electricity transmission vary from one location to another, with the result that the order of the different forms of production differs from the above. The life-cycle cost of geothermal heat is the lowest option. The advantage of geothermal is its energy-efficient heat production.

5. VIEW MARKET

Finland's electricity market is changing. Traditionally, electricity generation in Finland has relied heavily on nuclear, hydropower and cogeneration. In recent years, the share of wind and solar power in production has risen sharply and is expected to continue in the same direction in the future. This change is also driven by policies aimed at reducing emissions and slowing the pace of climate change. However, weather-dependent electricity production increases the volatility of electricity prices, which in itself increases the need for flexible electricity generation. In the long term, electricity prices are expected to fall as nuclear power and renewable energy capacity rises. A large number of electric boilers and batteries are entering the electricity market, especially for heat generation, when electricity prices are low, which in itself reduces the incidence of the lowest electricity prices. There is an increase in electricity consumption as heat generation, transport and industry become more electrified. In addition, the planned hydrogen production plants in Finland will further increase the demand for electricity.

According to the electricity market model based on Ramboll's learning network, with a wind power capacity of 9 GW and an electricity consumption of 94 TWh, the electricity price will fall to EUR 23/MWh.

If Finland's electricity use and exports increase to a level of 131 TWh in line with Fingrid's forecast, according to the electricity market model, a mere increase in wind capacity to 35 GW does not keep the electricity price at a moderate level, but the average electricity price is above EUR 70/MWh. In windless periods, electricity prices will be very high. This is due to insufficient control power on the electricity market.

The electric energy price is assumed to be EUR 48.8/MWh. This is based on the assumption of 203 015 GW of wind capacity and 115 TWh of electricity consumption in the year, where the electricity market model based on Ramboll's learning network gives an electricity price of EUR 48.8/MWh.

Table 5 Electricity energy levy for different electricity consumption and wind generation by volume

Electricity price EUR/MWh	**Wind 9 GW**	**Wind 15 GW**	**Wind 23 GW**	**Wind 30 GW**
Consumption 94 TWh	23,2	20,1	15,8	12,0
Consumption 105 TWh	38,5	34,5	29,2	24,6
Consumption 115 TWh	54,4	48,8	43,3	37,8
Consumption 131 TWh	94,4	88,7	80,7	73,4

6. COST/BENEFIT ANALYSIS

The work examined changes in Finland's heating system in different scenarios. The scenario analysis is based on a 'baseline scenario', which refers to information from district heating operators on the development of district heating production. Changes in the baseline scenario for heat generation are discussed in Chapter 4. Other scenarios are based on this scenario, always modifying a certain part of it. The scenarios are described in more detail below:

0. Baseline scenario: The current situation is modelled on the same assumptions and starting data as:
counterfactual scenarios, so that the changes in the scenarios are clearly reflected in the reviews. The baseline scenario takes into account existing policies and plans of market operators.
1. Energy companies plans in accordance with situation 2030so, that major proportion on biofuels
used for the separate production of heat, in which case cogeneration electricity for district heating would no longer exist.
2. Energy companies plans in accordance with situation 2030so, that major proportion on biofuels
used in CHP. In this case, electricity would also be produced against district heating.
3. District heating will account for a significant proportion (40 %) of the waste heat directly used in district heating.
4. For district heating, a significant share of waste heat (40 %) (including data centres; hydrogen plants), which need heat pumps to increase the temperature.
5. A large part (30 %) of electric boilers will be heated in district heating and for separate heating
6. On heating the Finnish building stock 50 % move away from district heating and the heating becomes entirely based on heat pumps at a total COP of 2,5. Same evolution of district heating production structure as in Scenario 0.

The outcome of the scenario presents:

- Primary energy consumption [GWh]
- Share of renewable energy in production [%]
- Amount of CO2 emissions [ktCO_2]
- Cost of production of district heating [EUR/MWh]
- Consumer price of district heating [EUR/MWh]
- Required investments [MEUR]
- IRR 10 and 20 years compared to current status [%]
- Net present value of 20 years against present status [EUR]

The scenarios will also be subject to a separate sensitivity analysis. The sensitivity analysis looks at the following variables:

- Price of biomass fuel cost + 30 %/-10 %
- Energy price of electricity 34.5/EUR 88.7/MWh
- Biomass investment + 30 %/-10 %
- Investment of heat pumps and electric boilers + 30 %/-10 %
- Calculation rate of 2 %/5 %/10 %

The sensitivity-checked variables are based on Rambelli's expert judgement. Biomass fuel costs and investment variables to be sensitive to + 30 % and -10 % under assumptions. A fall in prices in the future is not likely to lead to a level of -10 %. Price increases are always accompanied by higher upward pressure, which may be influenced by various factors. In investment prices – 10 % can be seen as some form of investment aid. The different parameters of electricity prices were selected on the basis of the results of Rambelli's electricity market model (see Chapter 5).

6.1 Calculation assumptions

The calculation assumptions for the calculation of the scenario are based on public sources as well as Rambelli's expert estimates. The starting values for the calculation are set out in Annex 2. The energy volumes in the baseline scenario are based on the results of a survey of the energy industry ry's district heating companies. The aim of the survey was to get an overview of energy companies' plans for changes in the production structure by 2030. The results of the survey have derived the intensification of new productive investments in order to estimate the amounts in euro. The review was carried out as a simplified model for Finland as a whole in the form of an hourly review. It is assumed that the different forms of heat generation are dispatched in order:

1. Waste
2. Waste heat and heat pumps
3. Biomass
4. Electricity
5. Peat
6. Gas
7. Carbon
8. Oil

For CHP production, the fuel consumption for heat production is: calculat
ed
the benefit-sharing method. Production of heat pumps the efficiency is: dependent outdoor temperature. In some of the scenarios, the heat generation capacity is also left with oil and gas. These are assumed to be replaced by biogas and bio-oil. This has an impact on the cost of heat production as well as on emissions. For the calculation, primary energy includes the use of fuel and the amount of electricity used for heat generation.

The CO2 emissions from heat production have been calculated on the basis of Statistics Finland's fuel classification. Electricity emission factor has calculated Energy industry According to the baseline scenario of the low-carbon-causing stimulus.

Fuel costs have been calculated using the same data for the present and for the 2030 calculation. The cost calculation is intended to show the potential impact and magnitude of the changes on production costs, rather than absolute values. Prices are associated with a high degree of speculation and forecasting, and fuel price developments are uncertain.

The investment costs of the facilities are based on expert judgement and are intended to reflect the size of the investments rather than absolute values. The calculation does not take into account any equipment renewals required by existing capacity or the costs of other maintenance activities. The investments take into account only the investments required by the new installations.

6.2 Outcome of the scenario

The results will first address the results of the energy and emissions calculations, followed by the costs and the related sensitivity analyses.

6.2.1 Energy and emissions results

Total primary energy consumption clearly decreases from the current situation in each scenario (Figure 17). This is driven by a general reduction in heat demand. The change from burning heat production to heat produced by heat pumps, both in district heating and in other buildings, also reduces the need for primary energy. Scenario 3 is the lowest primary energy consumption, but also the lowest electricity generation. Electricity generation will decrease significantly in scenarios 1, 3, 4, 5 and 6 (Figure 18). In these scenarios, CHP production is replaced by either separate biomass production, waste heat or power boilers. In scenario 6, demand for district heating halves, with CHP production too subtract and it shall be: replacing heat pump production.

Electricity consumption for district heating production will increase in scenarios 4 and 5, where heat generation is significantly replaced by heat pumps or electric boilers.

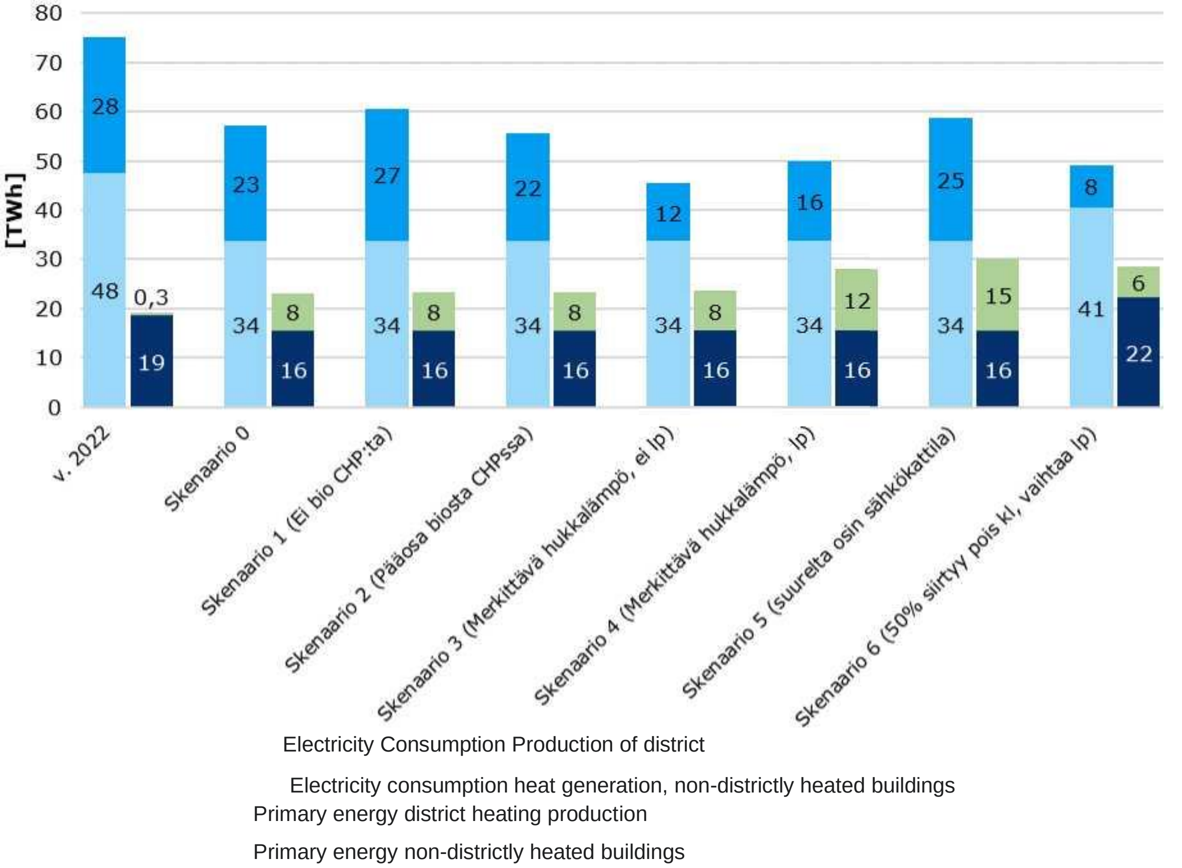


Figure 17 Primary energy and electricity consumption by scenario

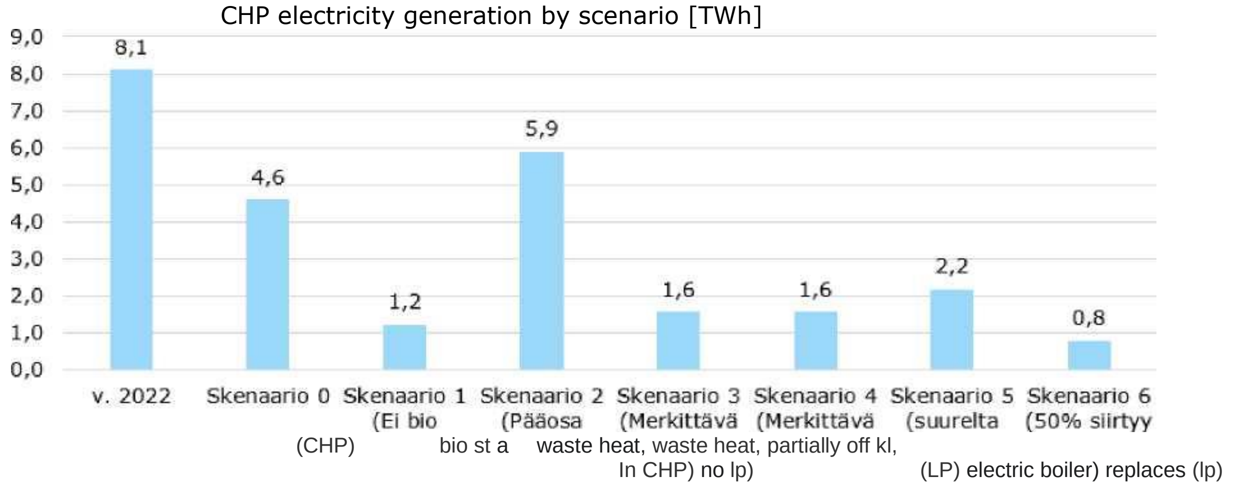


Figure 18 CHP electricity generation by scenario and 2022

There is a significant difference in the production modes ofdistrict heating between the scenarios (Figure 19). The results of scenarios 0-2 do not differ, as the changes in the scenarios only concern the variability of CHP production. Scenarios 2 and 3 show a clear share of industrial surplus heat in total production. Scenario 3 also increases the electricity used by heat pumps due to the use of low-temperature surplus heat. In both scenarios, the amount of biomass is significantly lower compared to scenario 0. In scenario 5, electric boilers account for 30 % of total production, replacing biomass in particular. In scenario 6, district heating production is halved and production is mainly based on heat pumps.

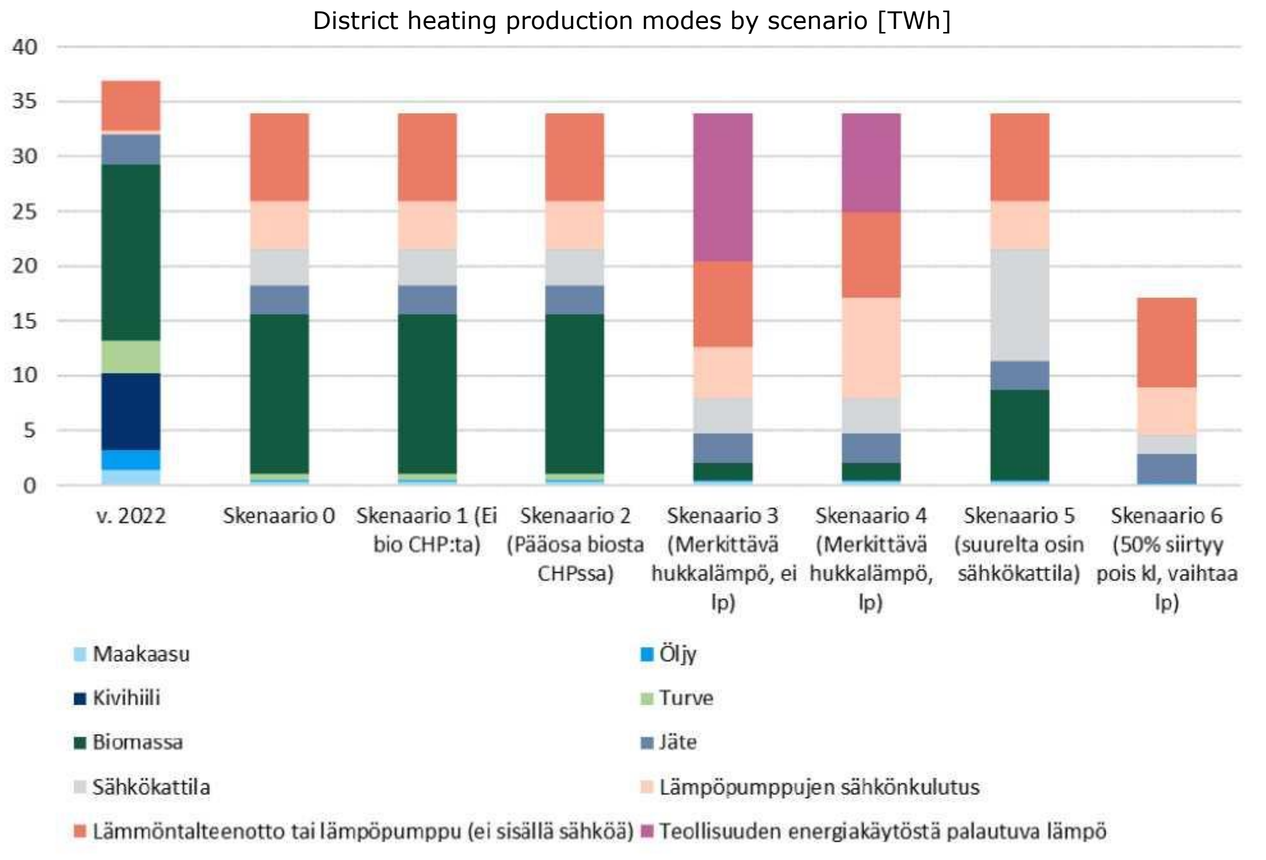


Figure 19 Types of district heating production by scenario [TWh]

There is no major difference between the scenarios in the building-specific heating modes (Figure 20). Between the status quo and the scenarios, the evolution is as set out in Chapter 4.1. The difference arises only in scenario 6, where individual heat pumps replace district heating.

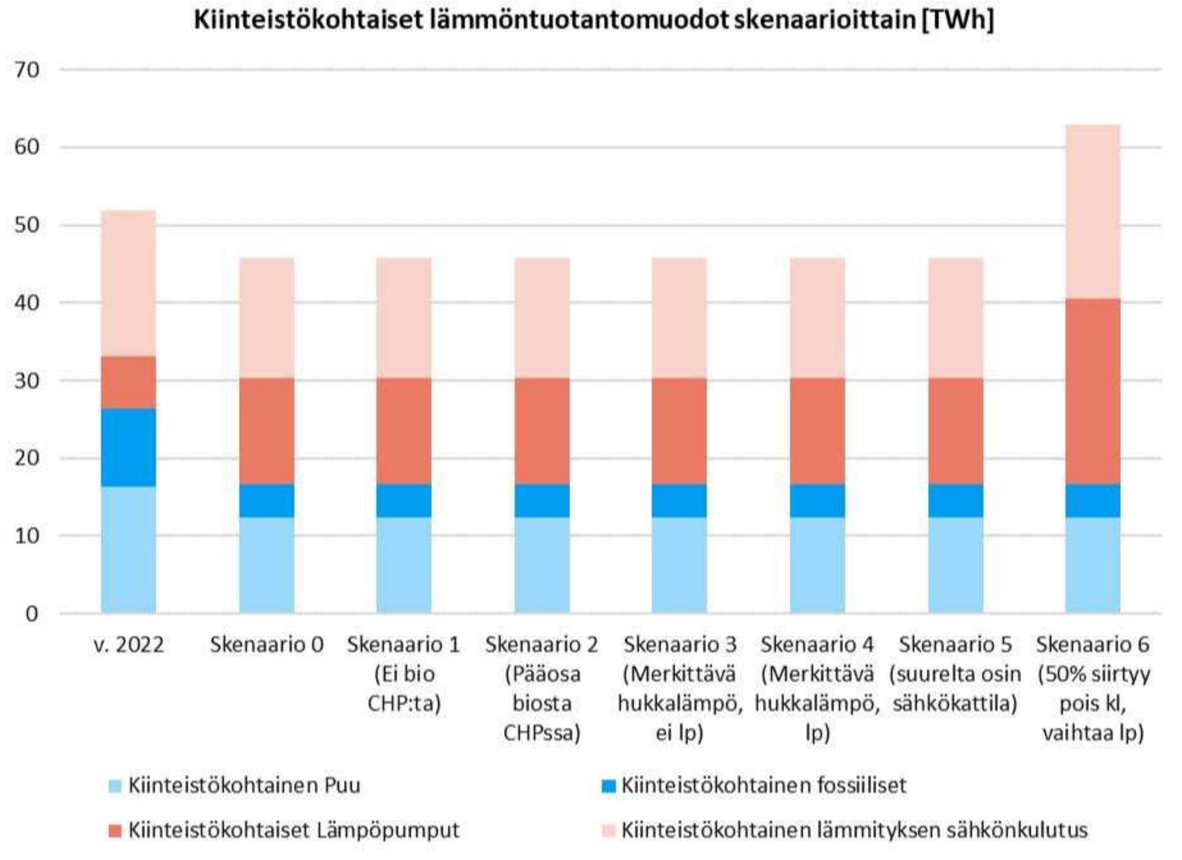


Figure 20 Real estate heat generation modes by scenario [TWh]

Annual CO2 emissions from heat production will decrease significantly (around 65 %) compared to the current state in all scenarios (Figure 21). This change is largely due to the replacement of fossil fuels with heat pump production. The emission factor for electricity is assumed to be 37kgCO2/MWh in 2030, which is about 40 % lower than the emission factor for 2022 (Fingrid, 2024). The change is also affected by a general decrease in heat demand. The difference between the scenarios is very small. The largest difference between the baseline scenario and scenario 3 is -6 %.

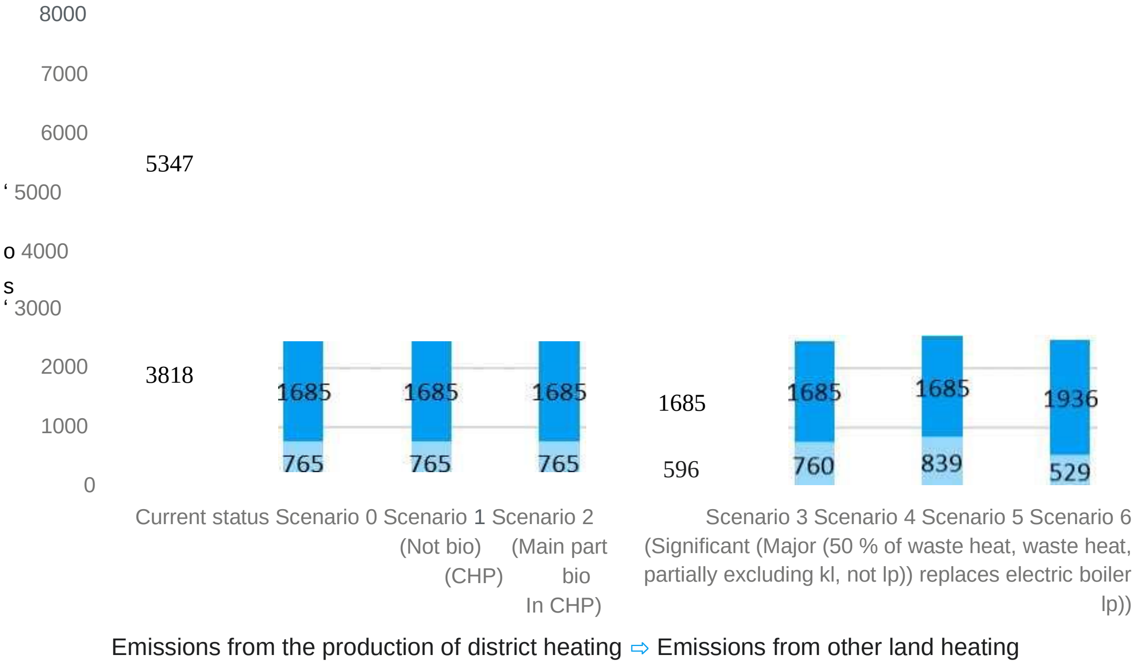


Figure 21 Total heat emissions by scenario

6.2.2 Cost results

6.2.2.1 Investments in new heat generation capacity

Investments in district heating production by 2030 will be of the same order of magnitude of EUR 3 billion for all scenarios (Figure 22). The biggest investment needs are in waste heat scenario 4 requiring heat pumps, where the investment needs are around 5.3 billion. EUR.

Minimum investment needs, 2.6 billion. EUR, is in scenario 5, where the electric boiler capacity will increase significantly. The significant difference, approximately five times, is due to the difference in specific investments, which is around EUR 1 MEUR/MW for the heat pump plant and 0.2 MEUR/MW for the electric boiler plant.

The investments required for the district heating industry’sown scenario (scenario 0) amount to

2.8 billion. EUR.

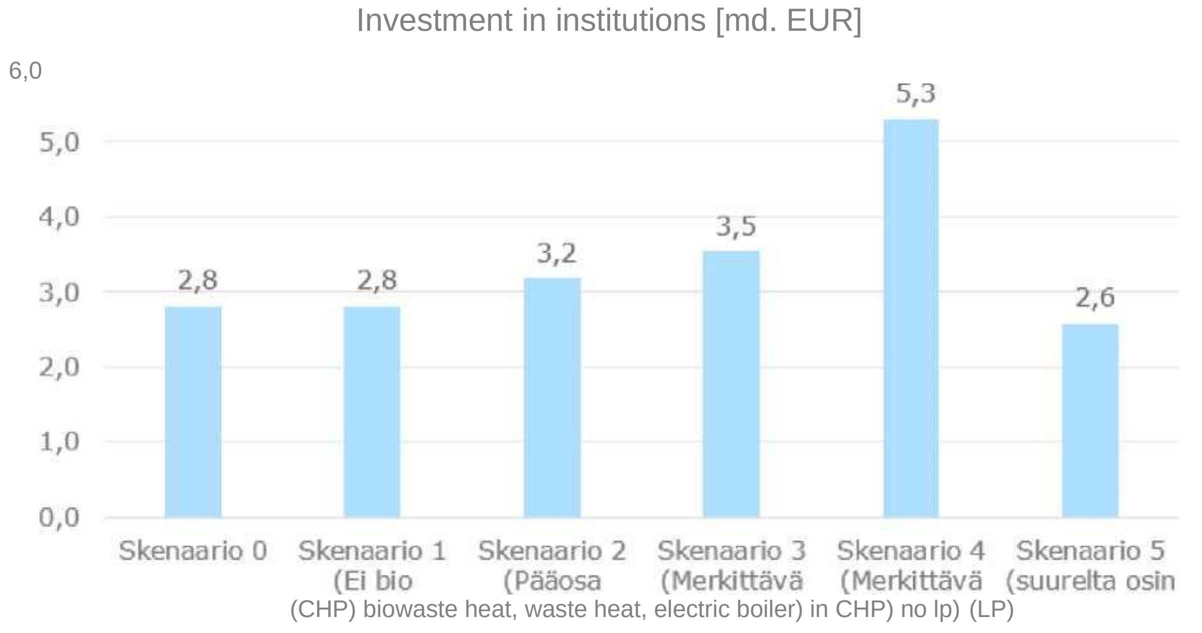


Figure 22 Investments in institutions [md. EUR]

6.2.2.2 Price of district heating

The average price of district heating in the different scenarios is at the same level compared to the current state of about EUR 75/MWh. The price fluctuation is – EUR 3/MWh and + EUR 6/MWh. In scenario 3, the price of district heating is the lowest (Figure 23).

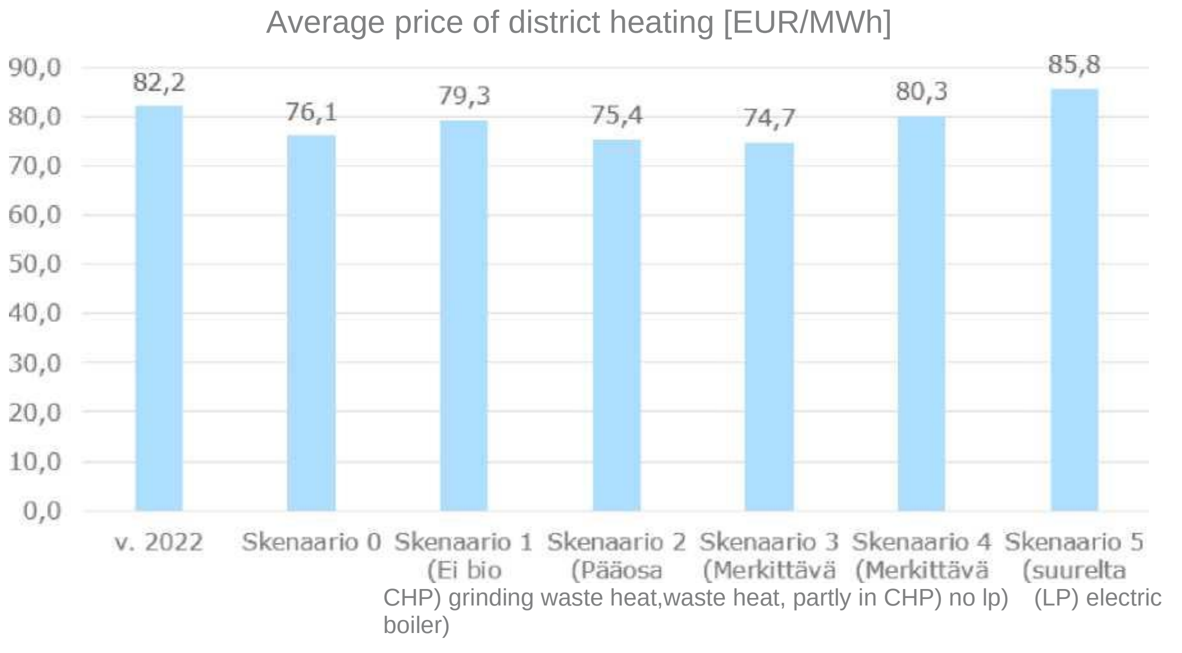


Figure 23 Average price for district heating [EUR/MWh] includes fuels, capital costs for production and distribution and maintenance and maintenance

6.2.3 Financial indicators for the scenarios

The financial ratios calculated for the scenario vary greatly. The best economic indicators are in the 0 scenario and the weakest in scenario 5 based on the use of electric boilers (Table 6).

Table 6 Intra-scenario IRRs for 10 and 20 years

Scenario	0	1	2	3	4	5
IRR 10v	10 %	5 %	9 %	9 %	—3 %	—11 %
IRR 20v	16 %	11 %	15 %	14 %	6 %	0 %

The sensitivity analysis (see Section 6.4) highlights the main factors and their impact on the ranking of the different scenarios. The net present values of the scenarios over the 20-year observation period and 2 % with a calculation rate (Figure 2424) are described below.

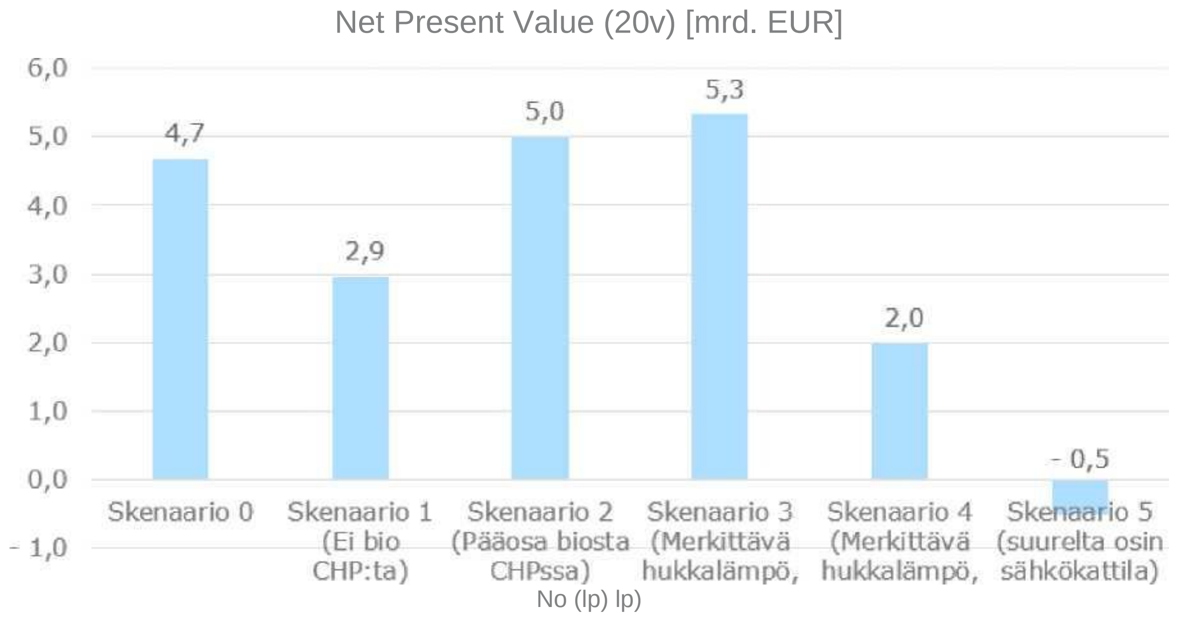


Figure 24 NPV of scenarios (20 years)

The low profitability of an electricity boiler investment is affected by the constant electricity price used in the calculation. The use of the standard price is justified by the fact that, if the majority of district heating production is based on the use of electricity, it is not possible to limit the use of electricity for heat generation in times of high price levels of electricity because of the obligation to supply heat. A decentralised production portfolio has the potential to diversify and reduce the price risk of different energy sources.

6.3 Stand-alone consideration of scenario 6

Scenario 6 assumes a 50 % decrease in district heating coverage. District heating exiting building stockassuming user heat pumps heat generation. The average heat price in current state is shown below in Scenario 0 and scenario 6 (Figure 23).

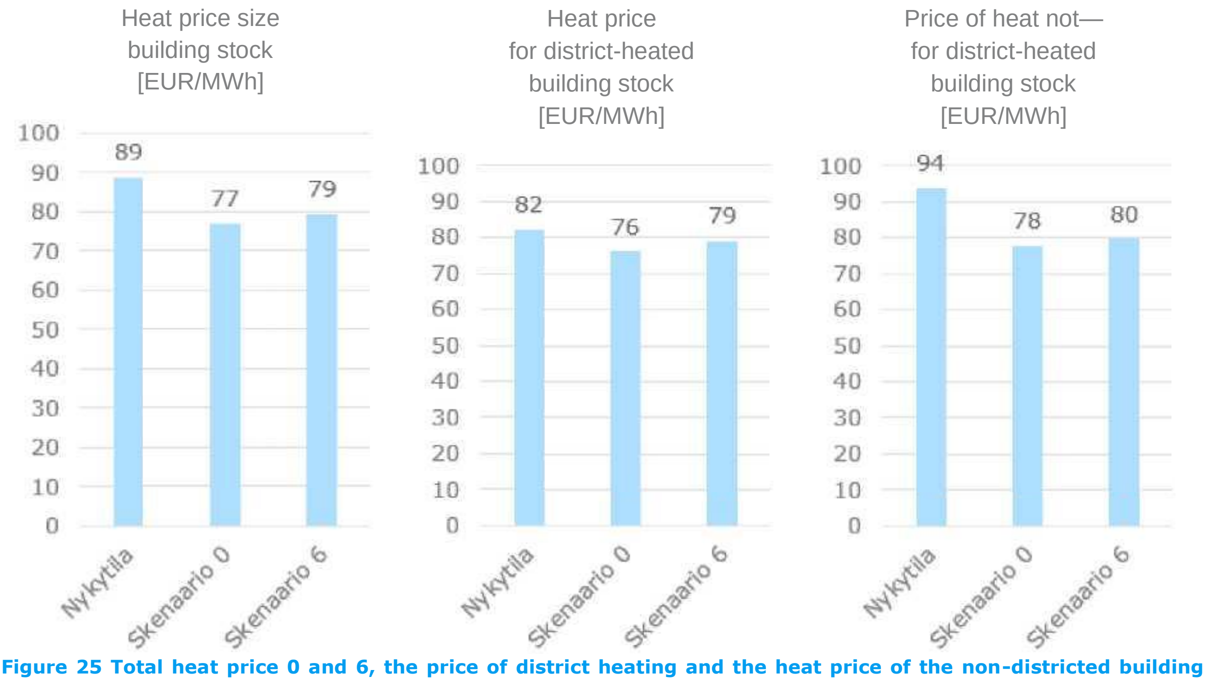


Figure 25 Total heat price 0 and 6, the price of district heating and the heat price of the non-districted building stock [EUR/MWh]

The price of heat for the building stock as a whole in 2030 is around 15 % lower than in the current state. Total price refers to the average heat cost of buildings, including district heating and individual heating solutions. In scenario 6, the price of district heating is somewhat higher, around 10 % higher compared to the price in scenario 0. The price of district heating has an upward impact on the distribution of the cost of district heating to a smaller number than in the case of a higher coverage rate of district heating.

In scenario 6, the non-districtly heated building stock includes different heat pump-based solutions (geothermal and different air heat pumps), biomass, bio-oil and direct electric heating. The price is slightly higher compared to scenario 0.

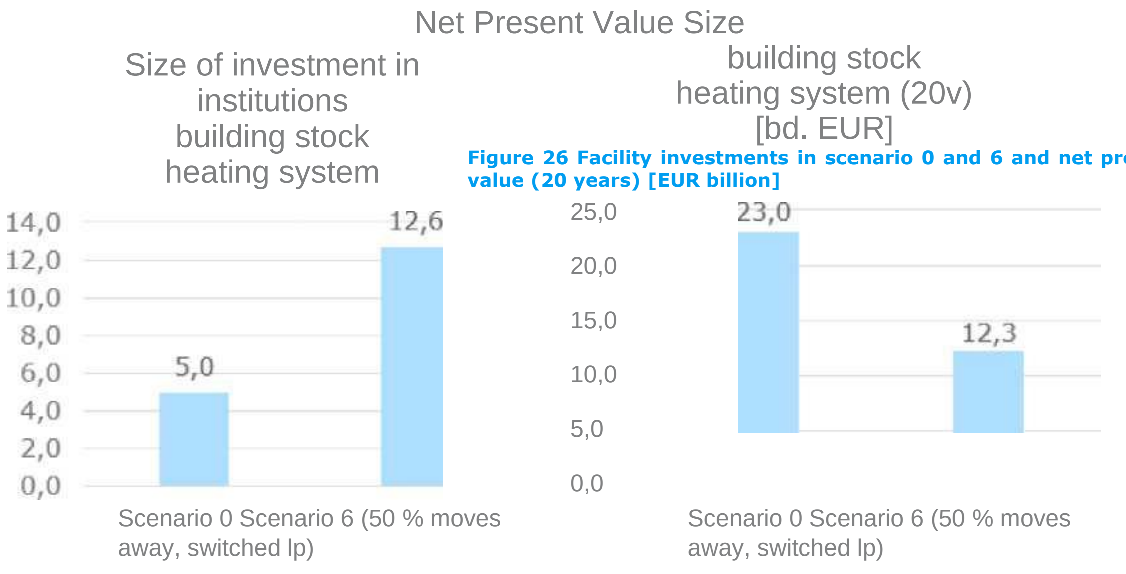


Figure 26 Facility investments in scenario 0 and 6 and net present value (20 years) [EUR billion]

The figure above (Figure 26) shows the required investments for heat generation in scenarios 0 and 6 in relation to the current state. The removal of the building stock from district heating requires a large amount of investment.

In scenario 0, investments in property-specific heating systems will also be made in line with the development of the heating market. The main changes are the greater use of heat pumps for heat generation, replacing fossil heating. The evolution of the heating market is presented in more detail in Chapter 4.

Table 7 Internal interest rates for scenarios 0 and 6 for IRR 10 and 20 years for heating investments in the whole building stock

Scenario	**0**	**6**
IRR 10v	33 %	4 %
IRR 20v	35 %	11 %

The heating investment in scenario 0 for the whole building stock is very high (Table 7). The level of the IRR is influenced, among other things, by a strong shift of the real estate stock away from fossil fuels (oil) to heat pumps and a reduction in the need for heating. This is best explained by the decrease in the average heat price of non-districtly heated buildings from EUR 94/MWh to EUR 77/MWh.

In scenario 6, the IRR is not the same due to the high investment needs of the scenario in new heat pumps. In scenario 6, investments in new heat pumps replace district heating, the profitability of which is less than the replacement of oil heating alone. As a result, there is a clear difference between the IRR levels. The total heat price for the entire building stock in 2030 is around 10 % below the current status. Total price means:
the average heat cost of buildings, including district heating and individual heating solutions.

Scenario 6 50 % removal leads 5 % for district heating above 0—
in the scenario. The price of district heating has an upward impact on the distribution of the cost of district heating to a smaller number than in the case of a higher coverage rate of district heating.
In scenario 6, the non-districtly heated building stock includes different heat pump-based solutions

(geothermal and different air heat pumps), biomass, bio-oil and direct electric heating. In scenario 6, the heating price for the non-districtly heated building stock is somewhat higher than in the 0 scenario.

6.4 Sensitivity analysis

Sensitivity analyses were carried out on the profitability of the scenarios (IRR 20 years) to identify the significance of the different variables. As a general observation, the costs of using biomass and electricity and the related investments (heat pumps and electric boilers) were identified as the main variables.

The sensitivity analysis looks at the following variables in pairs:

- Price of biomass fuel cost + 30 % & -10 %
- Energy charge for electricity cost EUR 34.5/MWh & EUR 88.7/MWh
- Biomass investment + 30 % & -10 %
- Investment of heat pumps and electric boilers + 30 % & -10 %
- Calculation rate of 2 % & 5 % & 10 %

The best results of the sensitivity reviews are presented in images (Figures 27-31) with brief observations in the section below.

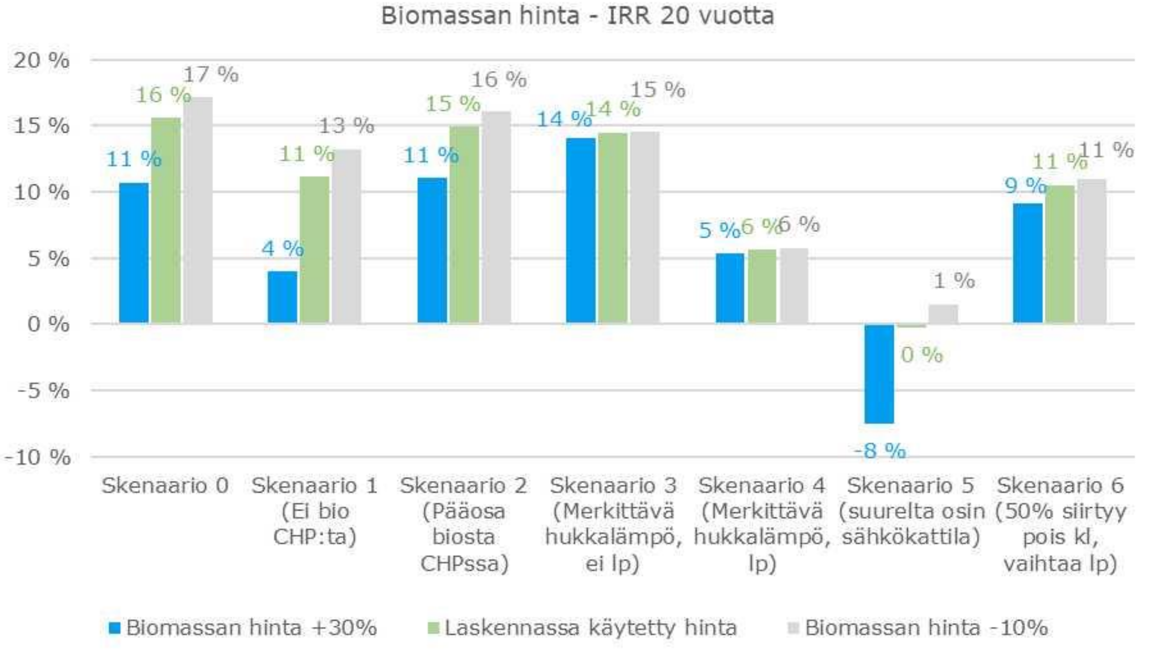


Figure 27 Scenarios 0-6 sensitised to Biomass costs (+ 30 % & -10 %)

The increase in theprice ofbiomass (+ 30 %) has a significant downward impact on scenarios 0, 1 and 2, where biomass is heavily exploited. Also, the result of scenario 5 cannot be calculated within the period under review, with yields totally negative. The lower price of biomass (-10 %) has a slight positive impact on the profitability of scenarios 0, 1, 2 and 5.

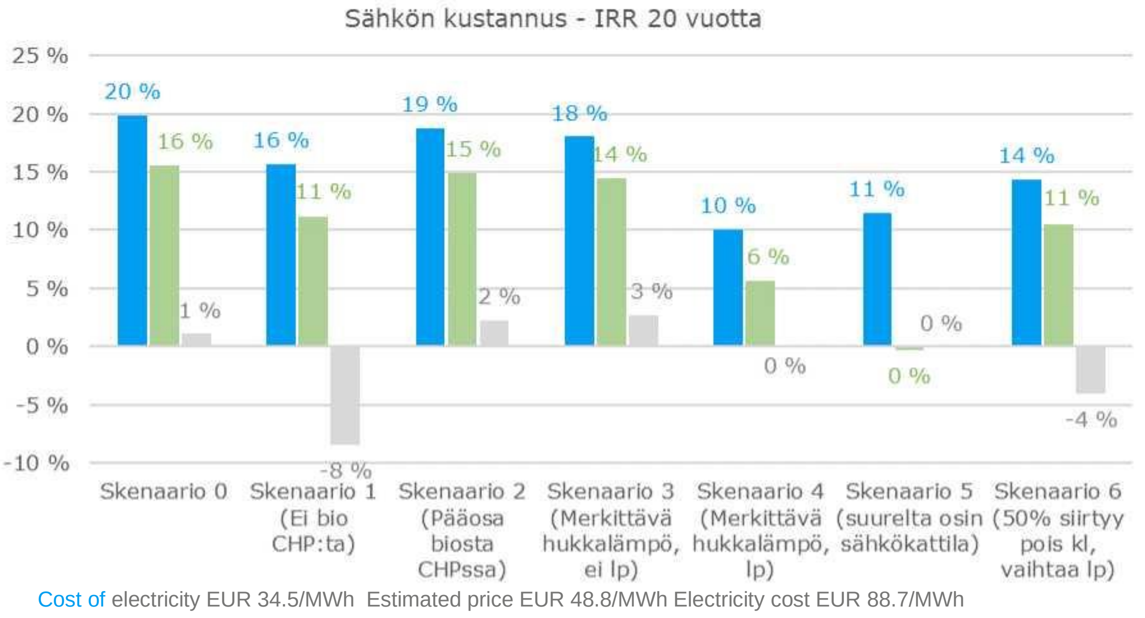


Figure 28 Scenarios 0-6 sensitised at the expense of electricity (EUR 34.5/MWh & EUR 88.7/MWh) vs Normal EUR/MWh EUR 48.8/MWh

The cost of electricity has the largest impact on all scenarios among the sensitivity options. At the expense of high electricity, almost all alternatives are unprofitable or cannot be calculated within the period considered. The decreasing cost of electricity (compared to a normal level of EUR 48.8/MWh) has a strong impact on the profitability of the scenarios. District heating production is highly electrified in all scenarios, which makes the average electricity price important for the profitability of district heating production. The average price for the whole year has been used for the calculation, which does not take into account, for example, district heating generation optimised for electricity price fluctuations through different technologies such as heat storage and other forms of production.

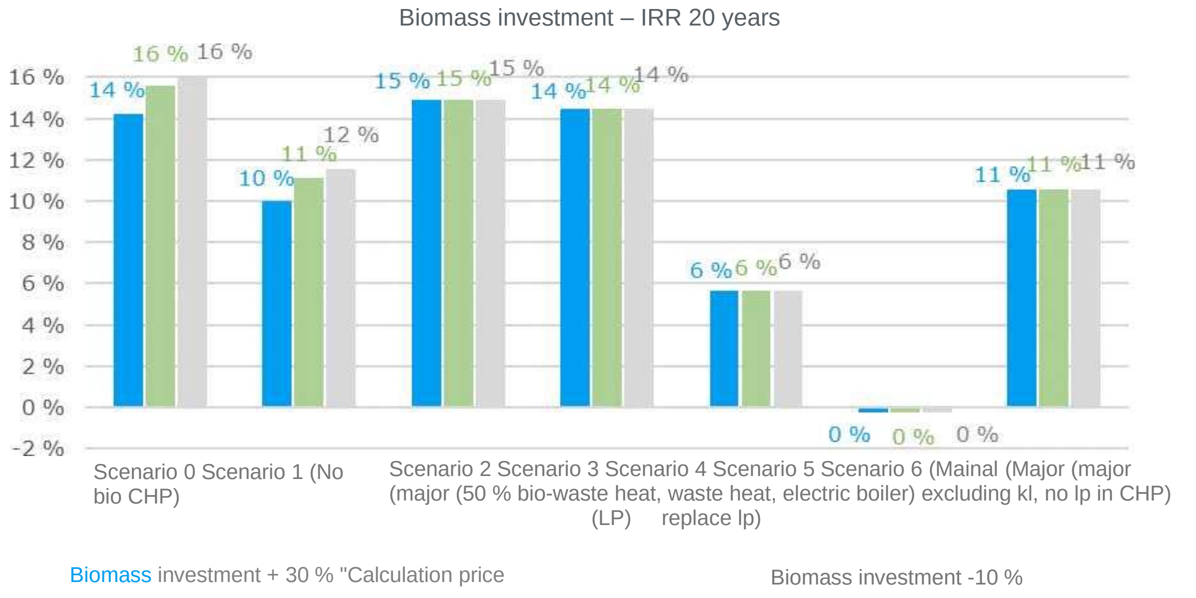


Figure 29 Scenarios 0-6 sensitive to biomass investment costs (+ 30 % & -10 %)

The different sensitivities of the biomass investment have little impact on the profitability calculation of the scenarios. The scenario does not involve large biomass-related investments, so the variation in costs will not have a major impact on profitability.

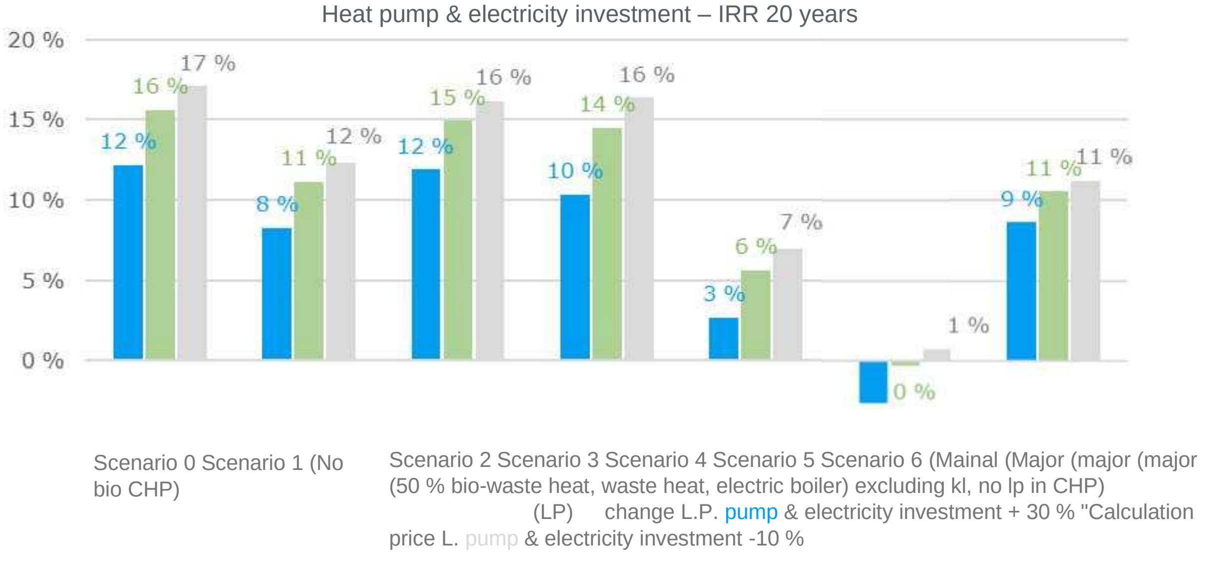


Figure 30 Scenarios 0-6 sensitive to investment costs for heat pumps and electric boilers (+ 30 % & -10 %)

The decrease in investment costs of heat pumps and electric boilers has a positive correlation with the profitability of all scenarios – as investment costs fall profitability will improve. In all scenarios, district heating production is electrified, requiring significant investments in heat pumps and electric boilers.

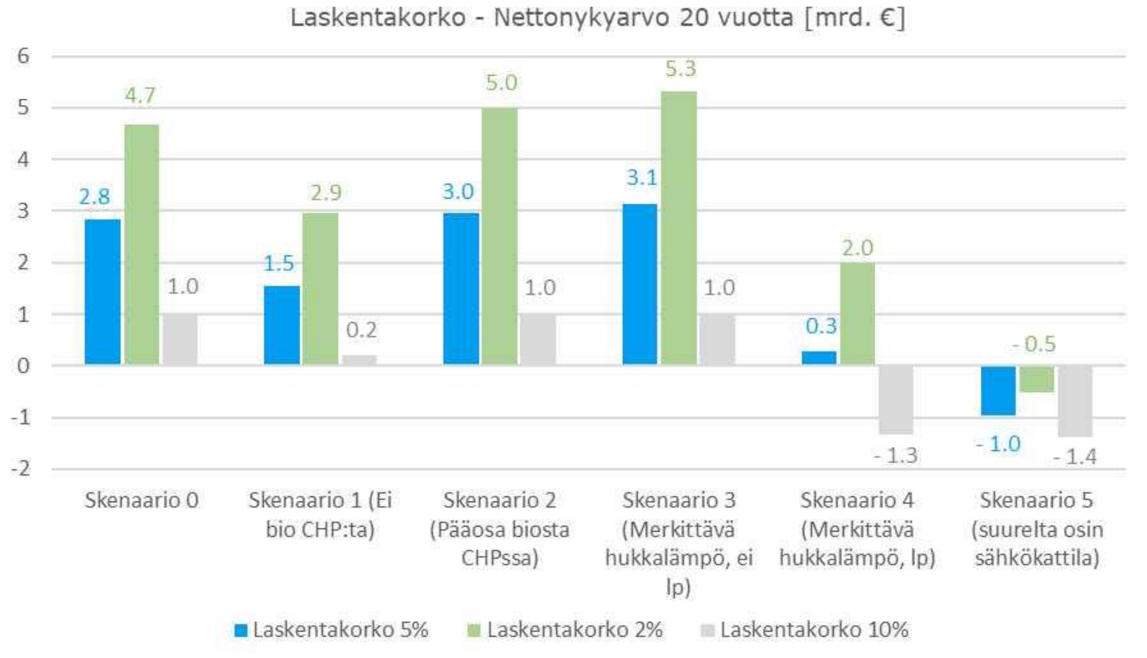


Figure 31 Scenarios 0-5 sensitised to the calculation rate (5 % & 10 %)

The effect of the calculation rate can be shown on the basis of a net present value. The 10 % calculation rate significantly reduces the positive profitability of scenarios 0, 1, 2 and 3. The interest rate of 5 % reduces the baseline position by about half of the NPV (2 %). Scenarios 4 and 5 remain unprofitable regardless of the sensitivity options for the calculation rate, but both scenarios have a downward effect on scenario 4.

7. SOCIO-ECONOMIC AND ENVIRONMENTAL FACTORS

This section looks at the socio-economic impact of three scenarios. The analysis provides an overview of the impact of the scenarios on end-user energy prices, labour market, skills and training needs; regional economic impact, energy poverty and blocking environmental factors. The scenarios under consideration are:

- Skenaario 0
- Skenaario 3
- Skenaario 6

7.1 Scenario 0

District heating is a key part of Finland's energy sector and its production has a wide impact on the country's socio-economic situation. District heating systems provide a reliable and efficient heat production method, which is particularly important in Finland's demanding winter conditions.
District heating production is currently mainly based on biomass and peat, and partly on fossil fuels such as coal, natural gas and oil (Figure 13). The energy efficiency of installations producing district heating, as well as proximity to customers, reduces the energy price from the end-user's perspective. No statistically significant energy poverty has been observed in Finland so far. However, rising energy prices and substantial tax increases increase the financial difficulties of individual households. Based on the expert interview, energy taxation should not be used as a social policy tool. Instead, existing social policy tools should be used to mitigate potential energy poverty. (Ministry of Finance, 2022)

The electricity, gas, heat and cooling business sector directly employs around 13300 people (Statistical Centre, 2024). Most of these workers work in the district heating sector, although other energy sources such as wind power, nuclear, solar and hydropower are also involved. Cogeneration makes segregation challenging, but it can be roughly estimated that a significant part of employment is in the district heating sector. According to the Energy Industry Association, indirect employment in the sector is significantly higher, approximately twice. Thus, total employment in the energy sector has over 25 000 man-years. Together subcontractors and with their partners, energy companies are important local employers. According to a study by the Ministry of Employment and the Economy, there has been little new job creation in the sector in recent years and employment can be explained by replacement schemes (Ministry of Employment and the Economy, 2023). More specifically, according to the Finnish heat pump association (Sulpu, 2020), the heat pump sector employs between 3000 and 5000 people.

From the point of view of**education**, the energy sector has grown significantly over the past 20 years. For example, the number of graduate engineers in energy engineering and AMK engineers in energy engineering, energy engineering and the environment have steadily increased from the early 2000s to the present time. The number of graduates in energy engineering in 2022 was almost four times higher than in 2004. However, the energy sector suffers from growing skills shortages. An ageing population and high levels of retirement increase the need for talent, as the electrification of society and the ongoing energy transformation create new jobs and require new skills. This creates competition for talent in the energy sector, both nationally and internationally. (Energy industry, 2023c)

From a**regional** economic perspective, the total output of the electricity, gas and heat and cooling business (including district heating) in 2021 was around EUR 10.8 billion, of which around EUR

4.8 billion was added. (Statistics Finland, 2024) Energy industry was born in the year

2019 a tax revenue of around EUR 1 billion. The highest tax revenue on energy production in the value chain is above EUR 451 million. The energy industry accounts for around 2 % of earned income tax in Finland, around 6 % of corporate income tax revenue and about 4 % of real estate tax revenue. (Gaia, 2021) In 2021, compensation of employees in the electricity, gas and heat and cooling business amounted to EUR 927 million, of which EUR 779 million consisted of wages and salaries. (Statistical Centre, 2024)

Environmentalsubsidies for electricity, gas, heat and cooling in 2022 amounted to EUR 17 million. EUR 9 million were allocated to energy production from renewable resources and EUR 8 million to heat/energy saving and management. (Statistics Finland, 2024) The greenhouse gas emissions of the sector have fallen significantly over the last 10 years. Greenhouse gas emissions in 2021 have decreased by around 60 % since 2010, from ~28 million tonnes to ~12 million tonnes. (Statistical Centre, 2024)

7.2 Scenario 3

In the waste heat scenario, Finland will invest in new hydrogen and other electro-intensive industries whose waste heat is integrated into district heating systems. This can have a negative impact on the **price of the end-user of energy**, thereby reducing energy poverty. Efficient heat pump technology allows waste heat to be used for heat generation, which can allow cost savings and thus lower energy prices for end-users. In addition, the integration of new installations can increase supply in the district heating market, which, in a competitive situation, may have a downward pressure on prices.

The impact on the labour market is positive as the construction and deployment of new industrial and societal waste heat installations, such as hydrogen and data facilities, will create jobs in installation, servicing and maintenance activities. Jobs are shifted from combustion plants to heat pump plants, which require higher levels of skills. This creates a need for additional/transformation training for the workforce. Also technology companies, and
in planning offices, demand for specialists from different sectors is increasing, contributing to employment and skills development in the region. For example, the construction of a 100 MW electrolytic hydrogen plant generates an average of 330 jobs per year and 45 permanent jobs. On the other hand, a conventional hydrogen installation is estimated to generate an average of 520 jobs and 80 permanent jobs per year. (Rhodium Group, 2023) According to Business Finland's estimate, for example, the investment by PlugPower Inc., planned to invest three hydrogen plants in Finland, would create 1000 direct jobs in Finland and more than 3000 indirect jobs. The multiplier effect of such investment on employment would therefore be threefold. (Business Finland, 2023) Overall, the multiplier effect of large energy projects on employment is often 2-3 times, according to Rambelli's estimates. While the hydrogen transition can create new jobs, it can also lead to job losses in fossil fuel and raw materials value chains (Government, 2022).

According to a US study, the need for new types of **training**programmes is wide-ranging and extends to a wide range of industries. In the future, changes in different disciplines, in particular technology-related training programmes, will be needed to enable students to become capable of working in the hydrogen industry. (Bezdek, 2019) Thermo-pump solutions emphasise system know-how, which is central to the design and management of units. This knowledge requires an in-depth understanding of the different technical solutions and the interactions between them. Designers and installers need to master the overall picture and understand the latest solutions in house technology. The creation of integrated systems, including components and technologies in addition to the heat pump, is key. This also includes the ability to assess the suitability of different options and to optimise the effectiveness and efficiency of the system according to users' needs. (Wave university, 2021)

The regional economic impact can be significant when the construction and deployment of new hydrogen and heat pump plants will generate investments and jobs in technology companies and planning offices in the region. This can contribute to the economic development of the region and increase business activity, which in turn supports the local economy and employment by increasing tax revenues. The construction and deployment of facilities can trigger significant investments in the region, such as the construction of production facilities specialised in hydrogen technology and the creation of the necessary distribution networks. These investments in turn: create new jobs for example in the construction sector; infrastructure services, as well as increasing the attractiveness and competitiveness of technology clusters and centres of excellence in the region. Compensation of employees in electricity, gas and heat supply and refrigeration businesses can increase significantly. This is due to the increased labour demand for the installation and maintenance of heat pumps.

Environmental factors are an integral part of the waste heat scenario, as the integration of new technologies into district heating systems reduces negative environmental impacts and reduces the carbon footprint. The use of waste heat in heat generation reduces the need for conventional energy sources, reducing greenhouse gas emissions and contributing to more sustainable energy production. (See paragraph 6.2.1)

7.3 Scenario 6

The scenario shifts from combustion-based district heating production to more heat pumps. Heat pump installations are more efficient than fossil fuels for district heating production for several reasons.

Employment effects are neutral or slightly positive. The closure of existing district heating plants will result in fewer jobs, but at the same time the production, installation and maintenance of heat pumps will increase demand for labour. The replacement of outgoing heat plants by new heat pump plants is unlikely to have a significant impact on the total number of jobs. The automation of new facilities can potentially address the challenges of retirement. A wave at university (2021) shows a significant increase in installed capacity of heat pumps between 2017 and 2035, increasing 4 500 from megawatt (MW) to 12 000 MW. The amount of labour required for installation and construction work will remain relatively constant in 2100 man-years (htv) per MW between 2020 and 2035, covering a total of 33500 htp. In the maintenance, operation and renewal of the system, 3600 jobs will be needed in 2035, corresponding to about 0.3 jobs per MW installed capacity. The installation of heat pumps requires an average of 5 man-years (htv) per megawatt (MW) installed capacity. (Wave university, 2021) A large-scale transition to heat pumps requires multidisciplinary **skills**, covering technical, civil, electrical, energy, educational and regulatory aspects. Although the installation phase temporarily creates significant jobs, these do not necessarily lead to a lasting increase in employment, as installation works are project-based. The number of permanent jobs is estimated to increase by 3600 jobs, corresponding to 0.3 jobs per megawatt heat pump capacity installed.

From**a regional** economic point of view, the transition to heat pumps is likely to require significant investments and possibly require support from the state, cities and municipalities. Tax revenues can decrease due to reduced harmful taxation of fossil fuels. When considering compensatory taxes, it is important to carefully assess their side-effects in order to avoid adverse impacts on the environment, the economy and society. The aim is to support a sustainable transition to renewable energy, while preserving the resources and services needed by the economy. (Ministry of Finance, 2022) At the same time, it is worth noting that switching to heat pumps may have an impact on the wage costs of electricity, gas and heat supply, as the use of heat pumps is less labour intensive. However, this can create new jobs in the heat pump installation and maintenance sector, which partly compensates for lower wage costs for conventional heat production.

The environmental impact in the scenario is significant compared to 2022. The shift away from district heating based on fossil production to heat pumps will significantly reduce CO2 emissions and improve energy efficiency, especially if heat pumps rely on renewable electricity. (See section 6.2.1) However, the difference is less significant if compared to scenario 0, where fossil production from district heating is replaced by heat pumps and biomass.

8. CONCLUSIONS OF THE RESULTS

The heating patterns of Finland's building stock will undergo major changes in the coming decade. Regardless of the scenario, CO2 emissions from heating buildings fall by more than 60 % compared to 2022. This change is largely due to the replacement of fossil fuels with electricity-based heating solutions and the increased use of biomass in large district heating networks above 1 500 MW. The amount of primary energy used for heating is significantly reduced in each scenario, due to the use of heat pumps. Primary energy needs decrease most in scenarios using waste heat. As heating electrification also replaces existing CHP production, which reduces electricity production and increases electricity consumption. This can have a local impact on electricity grids.

CHP production plays a major role in the results of the calculation. The benefit-sharing method has been used to calculate the fuel consumption of CHP plants. Using the sharing method, the use of fuels is divided between electricity and heat, taking into account their efficiency. The benefit-sharing method is a commonly used method for the calculation of CHP production. The use-sharing method can be said to favour heat production. In practice, this is reflected in the substitution of CHP production by separate heat production, such as biomass combustion or heat pumps, using more fuel per heat produced than for CHP production. In the scenarios, CHP production clearly decreases compared to the current situation.

The cost calculation calculated estimates of the investments required by the different scenarios at current prices, as well as the costs of district heating and other heat generation for consumers in the scenarios. According to the scenario, changes in the heating system will require approximately EUR 2.6-5.3 billion in investments under the different scenarios. The price of district heating varies between EUR 75/MWh and EUR 84/MWh.

Scenario 0, based on the notified plans of district heating operators, appears to be an efficient scenario in the cost calculation. Investments in this scenario, as well as the price of district heating, are the lowest among the different scenarios. Scenario 0 makes efficient use of existing generation capacity complemented by new efficient heat generation capacity (heat pumps). The low level of investment is also reflected in the overall price of district heating.

Changes in CHP production are highlighted when comparing scenarios 1 and 2. In scenario 1, where CHP production is very low, the cost of producing district heating increases by EUR 79/MWh. In scenario 2, where CHP production is maintained, the cost of production is at the same level as scenario 0, i.e. EUR 75/MWh. Scenario 2 requires more investments as the investment cost of CHP plants is higher than investments in heat-only production.

Scenario 3 captures 40 % of the total district heating demand. This is similar to scenario 0. Waste heat, which can be used directly as district heating, is assumed to be EUR 20/MWh. The use of waste heat requires moderate investment. Due to the significant amount of waste heat directly recovered, other heat pumps cannot be used as efficiently as, for example, in Scenario 0. Lower utilisation rates mean lower profitability of the investment. For these reasons, the production cost of district heating in scenario 3 remains at the same level as scenario 0.

If, for example, the price of recoverable waste heat is set at EUR 5/MWh, the production cost of district heating will change to EUR 75/MWh →EUR 69/MWh, which is clearly cheaper than scenario 0 (EUR 76/MWh). Determining the price of waste heat is challenging and will be determined on a case-by-case basis. Different industrial operators have different approaches and conditions for using waste heat. For industrial operators, waste heat is, by its name, a separate part of an activity the wider societal use of which should be incentivised in terms of responsibility or equivalent intangible value.

Scenarios 0-5 mainly address changes in the production structure of district heating. Scenario 6 explores the impact of halving the demand for district heating and the buildings investing in their own heat production mainly based on a heat pump.

Scenario 6 requires large investments compared to other scenarios. This is because existing district heating capacity is not fully utilised but needs to be invested on a large scale in new property-specific production. Individual heat pump solutions are slightly more expensive than the corresponding form of production for district heating. In the case of district heating, investments are higher in terms of unit capacity than in real estate solutions, resulting in a proportionally higher investment and a lower unit cost of investment.

The results of Scenario 6 were examined by comparing the average heat price for the whole building stock as well as separately for non-districtly heated buildings. Scenario 6 results are slightly higher compared to scenario 0, largely due to high investment levels. For example, the average heating price for the entire building stock is EUR 79/MWh in scenario 6 and EUR 76/MWh in scenario 0. The price of heating for the entire building stock is also influenced by the higher electricity price for buildings. The use of large heat pumps for district heating production falls under tax band II, while individual solutions fall under electricity tax category I. The electricity tax difference is 2.19 ct/kWh. (Tax, 2024) transfer fees are also higher for property-specific solutions compared to industrial use.

The sensitivity analysis examined the impact of the energy levy on biomass and electricity and investments in biomass and heat pumps and power boilers on the internal rate of return on investments. The increase in the energy levy for biomass has a major negative impact on scenarios 0, 1 and 2, which make the most use of biomass. In these scenarios, the IRR calculates 5 % pps – 13 %-. The lower price of the biomass energy levy has a slight positive impact on the profitability of the above scenarios. In these scenarios, the IRR will increase by 1 % pps to – 2 pps.

The fluctuation of the energy levy on electricity has a major impact on all scenarios. It is notable that, in particular, the increased electricity price is very high compared to the current price. If the energy charge for electricity is increased by EUR 49/MWh EUR 89/MWh, none of the scenarios is profitable anymore. On the other hand, if the energy charge decreases by EUR 35/MWh in each scenario, IRR increases by around 5 %-y. However, it is very likely that if the energy charge scenario for electricity were to rise to a level consistent with the sensitivity analysis, electricity-based heat generation would not be invested or, at least, not used if other heat generation capacity is available. However, electricity prices play an important role in all scenarios.

Changes in biomass investment do not have a major impact on the profitability of the scenarios. The impact is around 1 % p. of more heat pumps and electric boilers will be invested in the scenarios, which will also have a higher impact. As the investment increases by + 30 %, the IRR decreases by around 3 %-y in each scenario. With an investment of -10 %, the IRR will increase by about 1 pps.

The impact of the investment interest on the net present value was examined under three options of 2 %, 5 % and 10 %. The rate of calculation has a major impact on the profitability of the scenarios. With an interest rate of 10 %, only Scenario 0 has a positive NPV. With an interest rate of 5 %, the NPV decreases by about half compared to the 2 % rate.

9. SUMMARY

This work has carried out a comprehensive assessment under Article 25 of the Energy Efficiency Directive (EU) 2023/1791, including an analysis of the economic potential for efficiency in heating and cooling. The work provided a snapshot of the state of production of heat and cooling in Finland and considered their evolution in the scenario analysis. The assessment shows that the objectives of the Energy Efficiency Directive to use efficient district heating in Finland are achievable.

Efficient district heating systems under the Energy Efficiency Directive currently cover 98 % of Finland's district-heated buildings. According to plans in the energy industry, up to 2030 by all Finnish district-heated buildings are efficient district heating under the Energy Efficiency Directive.

Finland's large district heating network system enables the efficient use of social waste heat as part of the heating of buildings. In particular, industrial energy releases a significant amount of heat, the use of which should also be encouraged to heat small agglomerations throughout Finland. Industrial investments in the clean transition will bring a significant amount of heat energy reversible from industry to the market. The transfer of large waste heat capacities to tens of kilometres from the generation sites is economically possible, provided that the opinion of the producer and the recipient of waste heat on the value of the heat is converging and there is sufficient responsibility and other similar incentives to make waste heat available to society.

The scenario analysis examined the efficiency of the district heating industry's own plans for other potential heat market developments, such as the recovery of a wider bio-based CHP, a significant increase in waste heat, the widespread use of electric boilers, and the way in which half of district heating customers switched to property-specific heat pump solutions. The district heating sector's own plans for a strong shift from fossil fuel-based heat generation towards heat pump production; biomass exploitation
heat generation. The district heating sector's own plans are the best in terms of emissions, primary energy needs and end-user prices for all capacity categories of district heating networks. At work, the heating system was modelled at the level of Finland as a whole and does not take into account local network-specific differences.

Socio-economic impacts were analysed in support of scenario 0; 3 and 6 (district heating plans, significant use of waste heat and a significant increase in individual heat pump solutions). From an educational point of view, the electrification of society and the ongoing energy transformation create new jobs and require new skills. This applies to all scenarios, but in slightly different ways. Scenarios 0 and 3 require skills for large-scale plant investments and new electro-intensive industries, while in scenario 6 more for property-specific solutions. From a regional economic point of view, the significant growth in electro-intensive industries in scenario 3 will bring growth to the regions where the industry is located and can also lower the local consumer price of district heating.

The increase in the price of biomass poses a threat to price competitiveness for district heating. In order for district heating to be able to compete on market terms against other forms of heating, the price of district heating must be EUR 75/MWh.

In the current situation, CHP production plays a very important role in the production of district heating in Finland, covering 54 % of the total heat supply. Most CHP heat production is generated by industrial-connected power plants, mainly in the forest-based industry. The Finnish industry is undergoing transformation. As a result of this transformation, it is apparent that the unit sizes of CHP capacity built within the industry will be overstated compared to the connected district heating networks if the industrial heat demand disappears.

Shifting the current non-districtly heated stock to electricity-based heating appears to be very profitable. This transition will require the owners of the building stock to have the financial capacity to finance investments.

Maintaining the role of district heating will help to reduce the emissions of the building stock as a whole and to keep the energy price at a moderate level. The large-scale social diversion of the building stock from district heating leads to an increase in the heating cost of the entire heated building stock.

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Annex 1. EED Article 25 in accordance with point 2(b) of Annex X

Breakdown	Heat company	Establishment name	£ 5 *YEARS* 0 E ra 0 3 E:0 E: No -1	Cooling [GWh]
Thermal power plants (over 50 MW)	Fortum Power & Heat	Loviisa Y1	7029	0
Thermal power plants (over 50 MW)	Fortum Power & Heat	Loviisa Y2	7228	0
Thermal power plants (over 50 MW)	Industrial Voima Oy	Olkiluoto 3	18622	0
Thermal power plants (over 50 MW)	Industrial Voima Oy	Olkiluoto 1	10593	0
Thermal power plants (over 50 MW)	Industrial Voima Oyj	Olkiluoto 2	11617	0
Combined heat and power (CHP) installations (over 20 MW)	Adven Oy, Kuusamo	LK305 Kuusamon power plant	106	0
Combined heat and power (CHP) installations (over 20 MW)	Alva Rauhalahti Oy	Mauha Gulf power plant	332	0
Combined heat and power (CHP) installations (over 20 MW)	Etelä-Savon Energia Oy	Pursiala 2	243	0
Combined heat and power (CHP) installations (over 20 MW)	Etelä-Savon Energia Oy	Pursiala 1	175	0
Combined heat and power (CHP) installations (over 20 MW)	Fortum Power and Heat Oy, Espoo	Finland 2	458	0
Combined heat and power (CHP) installations (over 20 MW)	Fortum Power and Heat Oy, Espoo	Finland 1	348	0
Combined heat and power (CHP) installations (over 20 MW)	Fortum Power and Heat Oy, Espoo	Finnishoja 6	172	0
Combined heat and power (CHP) installations (over 20 MW)	Helen Oy	Vuary B	352	0
Combined heat and power (CHP) installations (over 20 MW)	Helen Oy	Hanasaari B	—	—
Combined heat and power (CHP) installations (over 20 MW)	Helen Oy	Salmisaari B	1526	0
Combined heat and power (CHP) installations (over 20 MW)	Helen Oy	Vuolar A	130	0
Combined heat and power (CHP) installations (over 20 MW)	Herrfors Oy Ab, Ylivieska	Tulolantie	70	0

Breakdown	Heat company	Establishment name		Cooling [GWh]
Combined heat and power plants (CHP) (over 20 MW)	Jyväskylän Voima Oy	In the Gulf of Keljo power plant	781	0
Combined heat and power plants (CHP) (over 20 MW)	Järvi-Suomen Voima Oy, Savonlinna	Järvi-Suomen Voima	190	0
Combined heat and power plants (CHP) (over 20 MW)	Kaukan Voima Oy, Lappeenranta	Kaukan Voima Oy	464	0
Combined heat and power plants (CHP) (over 20 MW)	Kemijärvi heat and water Oy	KeVo	59	0
Combined heat and power plants (CHP) (over 20 MW)	Keravan Lämpövoima Oy	Kerava bio-power plant	250	0
Combined heat and power plants (CHP) (over 20 MW)	Kokkolan Energy	Kokkolan Energia Oy Force	73	0
Combined heat and power plants (CHP) (over 20 MW)	Kotkan Energia Oy	Hovinsaari	182	0
Combined heat and power plants (CHP) (over 20 MW)	KSS Energia Oy	Hinkismäki	—	0
Combined heat and power plants (CHP) (over 20 MW)	Kuopion Energia Oy	Haapaniemi 2 and 3 (HP2 flue gas scrubber 46 MW vs. 2015)	856	0
Combined heat and power plants (CHP) (over 20 MW)	Lahti Energia Oy, Lahti	Kymijärvi 3; steam boiler	281	0
Combined heat and power plants (CHP) (over 20 MW)	Lahti Energia Oy, Lahti	Kymijärvi, steam boiler	260	0
Combined heat and power plants (CHP) (over 20 MW)	Lahti Energia Oy, Lahti	Kymijärvi, gas turbine	0	0
Combined heat and power plants (CHP) (over 20 MW)	Loimua Oy, Hämeenlinna	Vanaja (gas turbine)	0	0
Combined heat and power plants (CHP) (over 20 MW)	Loimua Oy, Hämeenlinna	Vanaja (broad-boiler)	0	0
Combined heat and power plants (CHP) (over 20 MW)	Mariehamns Energi Ab	Dieselkraftvärmeverk G4	—	0

Breakdown	Heat company	Establishment name		Cooling [GWh]
Combined heat and power (CHP) installations (over 20 MW)	Polar district Energia and Vesi Oy	Suosiola	391	0
Combined heat and power (CHP) installations (over 20 MW)	Nevel Oy, Forssa	Kiimassuo	146	0
Combined heat and power (CHP) installations (over 20 MW)	Nevel Oy, Salon Energy Production Oy	Salo power plant	37	0
Combined heat and power (CHP) installations (over 20 MW)	Nivalan Kaukolä Oy	Industrial Village	48	0
Combined heat and power (CHP) installations (over 20 MW)	Nokianvirta Energia Oy	Nokia power plant	—	0
Combined heat and power (CHP) installations (over 20 MW)	Oulun Energia Oy	Toppila 2	725	0
Combined heat and power (CHP) installations (over 20 MW)	Oulun Energia Oy	Lanila Biopower Plant	540	0
Combined heat and power (CHP) installations (over 20 MW)	Porvoon Energia Oy	Tolkkinen 2	142	0
Combined heat and power (CHP) installations (over 20 MW)	Porvoon Energia Oy	Tolkkinen	128	0
Combined heat and power (CHP) installations (over 20 MW)	Savon Voima Oyj, Iisalmi	Energy Kuja, VL2 power plant	131	0
Combined heat and power (CHP) installations (over 20 MW)	Savon Voima Oyj, Joensuu	Joensuu CHP	391	0
Combined heat and power (CHP) installations (over 20 MW)	Savon Voima Oyj, Pieksämäki	VL1, Kutteritie	98	0
Combined heat and power (CHP) installations (over 20 MW)	Seinäjoen Voima Oy, Seinäjoki	SEVO	308	0
Combined heat and power (CHP) installations (over 20 MW)	Tampere Electrical Authority, Tampere	Gulf of Women	423	0
Combined heat and power (CHP) installations (over 20 MW)	Tampere Electrical Authority, Tampere	Lielahti	197	0
Combined heat and power (CHP) installations (over 20 MW)	Turku Seudun Energy Production Oy	NA 4	782	0

Breakdown	Heat company	Establishment name		Cooling [GWh]
Combined heat and power (CHP) installations (over 20 MW)	Turku Seudun Energy Production Oy	NA 3	376	0
Combined heat and power (CHP) installations (over 20 MW)	Vantaa Energia Central—Uusimaa Oy, Järvenpää	Järvenpää power plant	222	0
Combined heat and power (CHP) installations (over 20 MW)	Vantaa Energia Oy	Martin Valley 2	295	0
Combined heat and power (CHP) installations (over 20 MW)	Vantaa Energia Oy	Martin Valley 1 (bio)	172	0
Combined heat and power (CHP) installations (over 20 MW)	Vantaa Energia Oy	Martinlaakso 4 (combined gas)	25	0
Combined heat and power (CHP) installations (over 20 MW)	Vaskiluodon Voima Oy, Vaasa	Risk Credit 2	276	0
Combined heat and power (CHP) installations (over 20 MW)	VSV Energia Oy	ONKA	—	0
Waste incineration plants	Fortum Waste Solutions Oy, Riihimäki	Fortum Waste Solutions Oy, Riihimäki	435	0
Waste incineration plants	Kotkan Energia Oy	High-efficiency power plant	15	0
Waste incineration plants	Lahti Energia Oy, Lahti	Kymijärvi 2, steam boiler	122	0
Waste incineration plants	Lounavoima Oy, Salo	Korvenmäki	157	0
Waste incineration plants	Oulun Energia Oy	Eco-power plant	82	0
Waste incineration plants	Riikinvoima Oy	Riga force	150	0
Waste incineration plants	Tampere Electrical Authority, Tampere	Tammerforce utility plant	387	0
Waste incineration plants	Vantaa Energia Oy	Waste power plant 1	572	0
Waste incineration plants	Vantaa Energia Oy	Waste power plant extension	166	0
Waste incineration plants	Westenergy Oy, Mustasaari	Westenergy	251	0

Breakdown	Heat company	Establishment name		Cooling [GWh]
Renewable energy installations (over 20 MW) not included in groups (i) and (ii)	Fortum Power and Heat Oy, Espoo	Finland 4	27	21
Renewable energy installations (over 20 MW) not included in groups (i) and (ii)	Fortum Power and Heat Oy, Espoo	Finnishoja 4 LP3	0	0
Renewable energy installations (over 20 MW) not included in groups (i) and (ii)	Helen Oy	Katri Vala	203	158
Renewable energy installations (over 20 MW) not included in groups (i) and (ii)	Helen Oy	Esplanade	32	24
Renewable energy installations (over 20 MW) not included in groups (i) and (ii)	Turku Seudun Energy Production Oy	Kakola	22	17
Industrial installations (over 20 MW)	Alholmens Kraft Oy, Jakobstad	COR2	125	0
Industrial installations (over 20 MW)	Alholmens Kraft Oy, Pietarsaari	COR1	63	0
Industrial installations (over 20 MW)	Kainuun Voima Oy, Kajaani	Kainuu Voima	649	0
Industrial installations (over 20 MW)	Kokkolan Energy	Kokkolan Energia Oy Power	133	0
Industrial installations (over 20 MW)	Kymin Voima Oy	Kymin Voima Oy	307	0
Industrial installations (over 20 MW)	Forest Fibre Oy, Kemi	Recovery boiler SK-1	16	0
Industrial installations (over 20 MW)	Forest Fibre Oy, Vonectoski Bio-product factory	Forest Fibre Oy, Vonectoski Bio-product factory	36	0
Industrial installations (over 20 MW)	Forest Fibre Oy, Äänekoski	Äänevoima Oy, Äänekoski	—	0
Industrial installations (over 20 MW)	Mm Kotkamills Boards Oy	Combined-cycle power plant	—	0
Industrial installations (over 20 MW)	Pori Energia Oy, Pori	Pori Processive Power	343	0
Industrial installations (over 20 MW)	Pori Energia Oy, Pori	Pori Processive Power	343	0
Industrial installations (over 20 MW)	Raahen Voima Oy	Raahen Voima, K4	0	0
Industrial installations (over 20 MW)	Raahen Voima Oy	Raahen Voima, K5	0	0

Breakdown		Heat company	Establishment name	£ 5 *years o* E ra o 3 E: O E:r o	
Industrial installations (more than:	20 (MW)	Rauman Biovoima Oy	Rauman Biovoima Oy	273	0
Industrial installations (more than:	20 (MW)	Stora Enso Oulu Oy	Recovery boiler SK7	40	0
Industrial installations (more than:	20 (MW)	Stora Enso Oulu Oy	Fluidised bedroom K3	12	0
Industrial installations (more than:	20 (MW)	Stora Enso Publication Papers Oy Ltd, Kouvola	Power plant overall package	1	0

Annex 2. Scenario calculation assumptions

Fuels and energy levies, including taxes and other similar payments (VAT 0 %)		**Source**
Natural gas	110.9	Statistics Finland, 2024
Oil	137.3	Statistics Finland, 2024
Coal	90.6	Statistics Finland, 2024
Peat	52.3	Statistics Finland, 2024
Biomass	30.8	Statistics Finland, 2024
Waste		Rambollin expert judgement
Industrial electricity	73.5	Statistics Finland, 2024
Property-specific electricity	145.2	Statistics Finland, 2024
Heat reversible from industrial energy use (directly recoverable) district heating)	□ n n	Rambollin expert judgement
Industry on energy use reversible heat (no directly recoverable district heating)	C n	Rambollin expert judgement

Other operating and maintenance costs of district heating	**EUR/MWh**	
Fixed production costs	5	TEM, 2021
Transfer costs	5	TEM, 2021
Return on capital on transfer	9	TEM, 2021
Return on capital production	11.4	TEM, 2021
Other expenses and other income	11	TEM, 2021
Total	41.4	TEM, 2021

Individual schemes use and maintenance		
Heat pump systems	7	Rambollin expert judgement
Wood		Rambollin expert judgement
Fossil		Rambollin expert judgement

Investments	**EUR/kW**	
Natural gas	Not new investment in the scenarios:	
Oil	Not new investment in the scenarios:	
Coal	Not new investment in the scenarios:	
Peat	Not new investment in the scenarios:	
Biomass (separate production)	1000	Rambollin expert judgement

Biomass (CHP production)	1500	Rambelli's expert judgement
Waste	3000	Rambelli's expert judgement
Electricity	200	Rambelli's expert judgement
Heat pumps	1000	Rambelli's expert judgement
Heat regenerated from industrial energy use	50	Rambelli's expert judgement
Individual heat pump system	1250	Rambelli's expert judgement
Building-specific electric boiler	200	Rambelli's expert judgement

CO2 emissions	**Emission factor tCO2/GWh**	
Natural gas	199	Statistics Finland, 2024
Oil	250	Statistics Finland, 2024
Coal	335	Statistics Finland, 2024
Peat	387	Statistics Finland, 2024
Biomass	0	Statistics Finland, 2024
Waste	144	Statistics Finland, 2024
Electricity 2030	37	Energy industry, 2022

Energy production values		
Average heat ratio of a CHP plant	35 %	Rambelli's expert judgement
Heat ratio of CNG-CNG plant	70 %	Rambelli's expert judgement
Efficiency of separate heat generation	90 %	Rambelli's expert judgement
Electricity efficiency of the CHP plant	39 %	Rambelli's expert judgement
COP for district heating production	2.7 TO 2.9	Rambelli's expert judgement
Building-specific heat pump COP	2.7	Rambelli's expert judgement
Energy coverage of the individual heat pump	95 %	Rambelli's expert judgement

Customer: Ministry of Employment and the Economy

Project: Assessment of the potential for energy from renewable sources and waste heat in heating and cooling

AFRY

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Ministry of Employment and the Economy

Assessment of the potential for energy from renewable sources and waste heat in heating and cooling

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Content

1 Background

Article 14(1) of the EU Energy Efficiency Directive requires Member States to prepare a comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling. According to Article 15(7) of the EU Renewable Energy Directive (EU) 2018/2001, Member States must carry out an assessment of their potential of energy from renewable sources and of the use of waste heat and cold in the heating and cooling sector. That assessment must, where appropriate, include spatial analysis of areas suitable for low-ecological-risk deployment and the potential for small-scale household projects and shall be included in the second comprehensive assessment required pursuant to Article 14(1) of Directive 2012/27/EU.

The purpose of this report is to provide additional information for the assessment relating to the EU Energy Efficiency Directive for national reporting. The report describes, at a general level, assessments of the demand for renewable energy and its likely potential as well as major constraints. The report is mainly based on statistics and public sources.

2 Energy from renewable sources related Potential

The main sources of renewable energy whose use for heat production could be increased in Finland are biomass and geothermal energy. This chapter assesses the potential for biomass and geothermal energy in Finland's heating and cooling system. The assessment for both takes demand into account, with maximum demand assessed first, and then production potential in relation to that.

According to the assessment, the potential use of biomass could be a maximum of around 60 TWh in 2030, a level which is not limited by the theoretical availability of biomass in Finland. The theoretical potential of both ground heat and geothermal heat exceeds Finland's heating energy need several times over, but this potential is currently largely untapped.

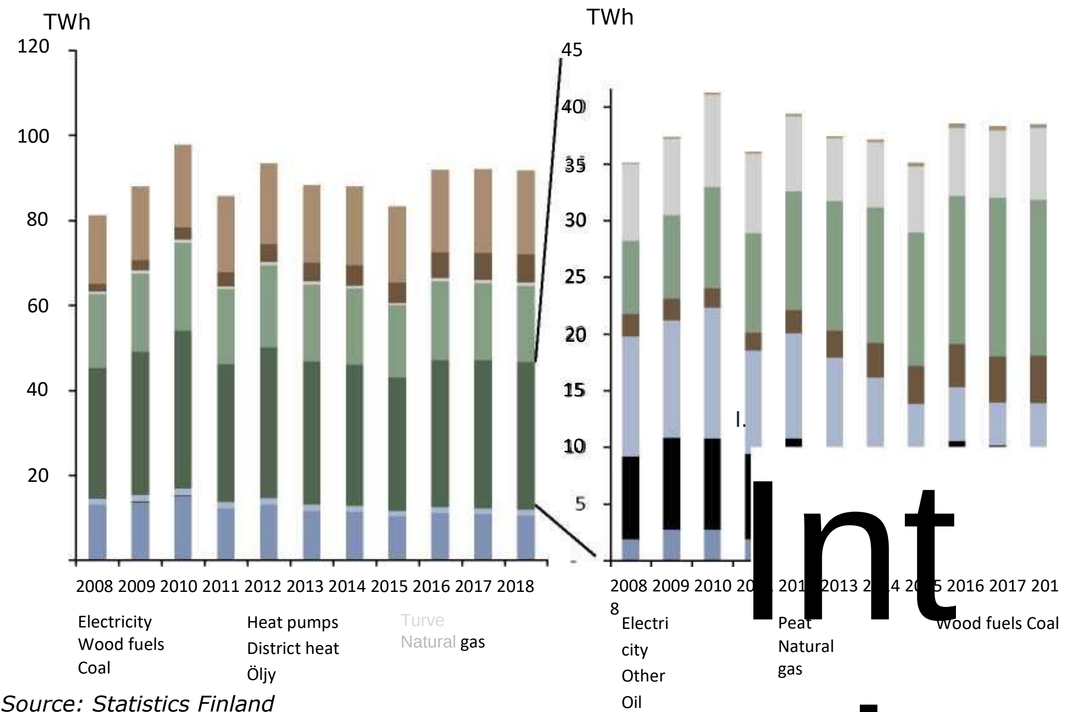
2.1 Potential for biomass

Demand for biomass

In this report, the maximum demand for biomass for property heating and industrial heat generation is assessed based on the amount of heat produced from incineration and the need up to 2030. The demand estimate is at a very rough level, based on the heating need forecasts provided by the Ministry of Economic Affairs and Employment, Statistics Finland's data and other reports. In the assessment of maximum demand, it is assumed that current biomass energy use will continue and the additional potential is based on fuel changes in boilers to replace peat, for example, and new installations that use biomass to replace fossil fuel and peat. Overall, this work has sought to identify the potential maximum biomass demand.In Finland similar to the current one and energy production industrial production structure.

The use of solid biomass has increased between 2008 and 2 018 in total heating consumption (Figure 1). Biomass use in property-specific heating amounted to 18 TWh in 2018, while the total energy need of buildings for heating in 2018 was 92 TWh. A total of 12 TWh in fossil fuels, mainly oil, was used in property-specific heating. In 2018, district heating production consumed 38.5 TWh in fuels, of which some 36 % was biomass and some 36 % was fossil fuels.

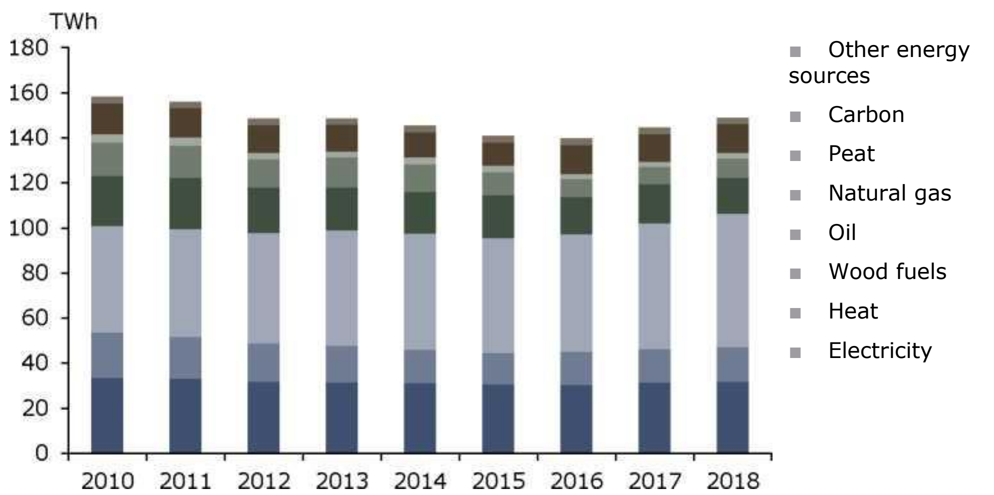
Figure 1: Building heating and district heating production by energy consumption source 2008–2018



Source: Statistics Finland

Total energy use in industry in Finland amounted to 149 TWh in 2018, with the forest industry being the largest industrial energy user with a share of 58 %. In 2018, wood fuels accounted for 4[illegible] % of total industrial energy use (Figure 2). In 2018, around 21 % of the energy used was electricity, 10 % was externally purchased heat and the rest consisted of other energy sources, which were used for the production of electricity and heating in industrial installations. The share of fossil fuels in heating in industry is decreasing and is expected to decrease further.

Figure 2: Energy use in industry by energy source 2010–2018



Source: Statistics Finland

Industrial heat production has remained fairly stable over the last decade, reaching around 55 TWh (Figure 3) in 2018. Over 75 % of heat generation is produced using renewable energy sources. The share of fossil fuels was 19 %. The main renewable energy source is black liquor, which is generated in the forest industry.

Figure 3: Industrial heat production by energy source 2010–2019

TWh Other energy sources

Source: Statistics Finland

Total property-specific for heating, district heating production, and industrial heat production accounted for 53.3 TWh of biomass in 2018.

Biomass availability

Overall, this report aims to outline the potential for solid biomass in Finland in the current type of energy production and industrial production structure. In 2019, the use of solid wood fuels from heat and power plants was around 36 TWh (Table 1). According to AFRY's estimate, the additional potential for solid biomass would be around 10 TWh in 2030, which raises the total potential of solid biomass to about 46 TWh by 2030. The additional potential is based on the assumption that industrial timber harvesting will remain at the level of 2019. The harvesting potential of low-grade timber is taken into account in accordance with the roundwood removal estimates of Natural Resources Institute Finland. The additional potential does not take into account possible changes in the production volumes and production structures of the forest industry, and the by-product supply is assumed to remain at the level of 2019. The additional potential related to imported timber is not taken into account in this report.

Table 1: Solid biomass use in heat and power plants in 2019 and estimate of additional potential by 2030, TWh

	TWh (2019)	TWh (2030)
Forest chippings, total	15,1	15,1 + 10
Forest industry by-products, total	21,2	21,2
Biomass used for heating, total	36,3	46,3

Source: Statistics Finland, AFRY

The cost and environmental factors associated with the purchase of biomass affect the availability of biomass and how much of it is used. Estimated the potential is: from energy wood chips collected from the forest (e.g. branches and non-industrial wood), small wood collected from thinning logging and forest-based by-products (mainly crushing and bark). The use of stumps is not included in the aforementioned potential. The use of stumps has decreased significantly in recent years, partly due to the emphasis on environmental values in forestry.

The trend in the price development of biomass affects its competitiveness as a fuel, which is ultimately reflected in the price of the heat generated from it. As the price of district heating increases, alternative heat production methods will become more competitive and attractive in the heating sector. In addition to the domestic supply of biomass, supply can be increased through import markets. The main wood biomass import markets for Finland are currently Russia and the Baltic countries. The potential for imported biomass is not assessed in this report.

The Natural Resources Institute Finland estimates the highest concentration of wood to be maintained at 79 million m[3] for 2030 (Table 2). Timber yield refers to the timber available for the forest industry. Energy wood yield refers to fractions used for energy, such as logging residues and low-grade timber. The Natural Resources Institute Finland has assessed the accumulation of energy trees amount 48 TWh year 2030.

The energy wood yield estimated by Natural Resources Institute Finland does take into account industrial by-products, but does include stumps. Furthermore, the energy wood yield estimate of Natural Resources Institute Finland is based on the assumption that the timber yield would be fully utilised. In reality, the realised logging volumes of industrial wood determine the usable logging residue potential. Different on the method of calculation and hypotheses due to:

The Natural Resources Institute Finland's estimate is not fully comparable to AFRY's estimate of 203 025 TWh.

Table 2: Maximum sustained timber and energy wood yield

	2016-2025	2026-2035	2036-2045
Volume of accumulation of timber 1 000 m³/v	74 595	79 001	79 531
Energy wood accumulation total volume 1 000 m³/year	19 373	23 783	24 424
Energy wood yield TWh	39	48	49

Source: Natural Resources Institute Finland (Luke) 2020

Note: Energy wood accumulation includes stumps, branches and crowns and classified as energy wood basketwood. The energy wood yield does not include import or industrial by-products such as bark and shavings).

2.2 Potential for geothermal heat

The theoretical potential of both geothermal and geothermal energy exceeds Finland's heating energy demand several times[1]. According to the GTK, the aggregate theoretical energy potential of the Finnish Chamber of Land at the top 300 m is around 300 000 TWh, which corresponds to about 1000 times Finland's total energy consumption.[2 3] Geothermal energy is thermal energy that can be used directly for the production of district heating.

Currently, geothermal projects are largely still in the development phase and only a fraction of the available geothermal energy is used in Finland[3].

1GTK Geo-energy customer service group
2 GTK. Geothermal and geothermal potential mappings: Finland has a huge clean energy storage facility. Available at https://www.gtk.fi/geoenergian-ja-geotermisen-energian-potentiaalikartoitukset-suomessa- on-intensive-clean energy storage/
3 Helen. In Geolä much opportunities. Available https://www.helen.fi/helen-Oy/responsibility/times/blog/2020/geolampo

Geothermal energy projects are based on both medium-deep and deep energy wells. St1's Deep Heat pilot project for a deep energy well in Otaniemi will soon be launched, with a plant that can generate 40 MW of energy, or 200 GWh/a. The well reaches a depth of 6.4 kilometres. Fortum will purchase the heat produced by the geothermal heating plant for its district heating network. In Finland, other projects are under development in Espooon Koskelo, Mäntta-Vilppulan Kolho and Tampere in Nekala and Hiedanranna, of which the QHeatt Koskelo plant is already operating at 500 kW instantaneous power[4]. Large projects such as St1's are still at the letter of intent stage.

It is estimated that the production potential for geothermal energy will be around 2 TWh by 2030. A rvio **is based on the assumption that by 2030 there would be a few installations such as Deep Heat, which, due to the production volume, can be better used in big cities, as well as more medium-deep geothermal wells. The estimate is rough and takes into account the change in energy production needs and the development in drilling capacity by 2030. This estimate is in line with the low-carbon roadmap for the energy industry[5].**

Operational experiences will determine the future of deep geothermal energy in Finland. Geothermal heat is still a very uncertain area with regard to technological functionality and costs, for example. However, the Deep Heat project has had a considerable impact on the drilling sector. The project has involved developing drilling technology, introducing medium-deep (1–3 km) geothermal wells into the industry. The cost structure of a medium-deep geothermal well is considerably lighter compared to deeper wells, but it is not yet entirely competitive as an investment. State intervention will have an impact on the exploitation of geothermal energy by 2030.

Figure 4: Potential of geothermal heat at 6-7 km depth[6]

Thermal energy 6–7 km (TWh)

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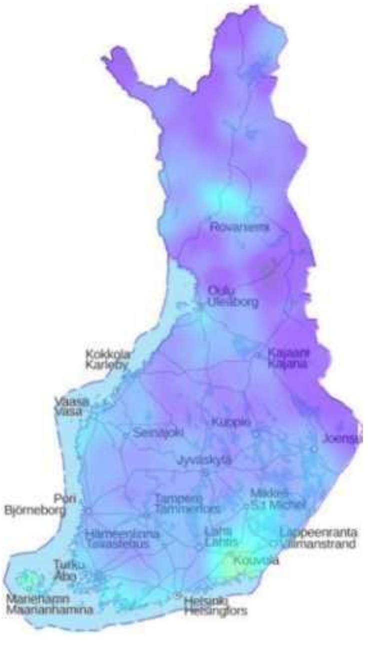


2.3 Potential for ground heat

Property-specific heating uses ground heat obtained with heat pump technology and heat obtained from outdoor air with air-water and air-source heat pumps.

4 YLE. Finland's first geothermal plant started. Available at https://yle.fi/uutiset/3-11158359
5Energy industry Low carbon roadmap 2020. Available
https://energia.fi/files/4943/Finnish_Energy_Low_carbon_roadmap_FINAL_2020-06-01.pdf
6 Source: GTK. The map application service can be found at http://gtkdata.gtk.fi/Maankamara/index.html

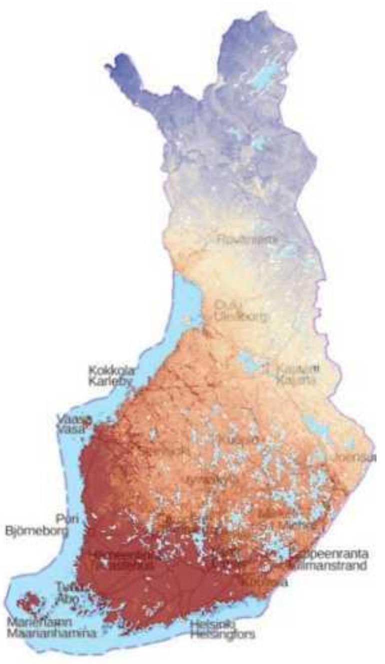
Ground heat is usually obtained by drilling an energy well 100–300 metres deep. According to Statistics Finland, the amount of heat generated by ground-source heat pumps in residential and service buildings has increased in the past decade, reaching a level of 380 GWh in 2000 and 3.6 TWh in 2018. In 2018, heat pump energy, including both geothermal and air-to-water heat pumps, met around 8 % of the building heatingdemand a[1]. In Sweden, ground-source heat pumps produced about 10 % of the heat required by properties in 2018. Increasing the use of ground heat depends essentially on how many of the remaining oil-heated properties switch to ground heat by 2030. Phasing out oil heating is described in more detail in Chapter 5.

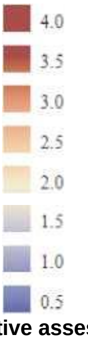
If the growth rate of ground-source energy can be assumed to continue, AFRY's rough estimate is that 11 TWh of ground heat could be used in property-specific solutions in 2030. The estimate of the energy generated by ground-source heat pumps in 2030 is based on the assumption that the production of ground heat will increase by 9.8 % per year in the 2020s. This is the same annual growth rate as the average growth in energy generated by ground source heat pumps in the period 2010–2018. The popularity of ground source heat pumps has been on the increase in Finland, as properties are transitioning away from other heating methods, such as oil heating, and the installation of ground source heat pumps has been subsidised. Transitioning from oil heating is described in more detail in Chapter 5. New properties are increasingly being fitted with ground source heat pump systems.

The growth in energy generated by ground heat may be limited by the long intervals between changing the heating method, as the transition is typically made in connection with a major renovation. The rapid increase in the use of ground heat may be constrained by drilling capacity. The use of ground heat may also be restricted by groundwater areas, which are described in more detail in Chapter 4.

Figure 5: Geothermal potentli[6] at 300 m depth

Thermal energy at 300 m depth (GWh)





3 Related to the use of waste heat and cold potential in the heating and cooling sector

This chapter presents the potential for property-specific waste heat, which can be found in properties both in the groundwater and exhaust air. The property-specific waste heat potential was estimated through the potential of exhaust-air heat pump systems in residential buildings. The potential for waste cold is described as a qualitative assessment.

3.1 Potential for waste cold

The waste cold potential in Finland is considered to be very small. In industrial cooling, cold escapes through various surfaces, which means that the waste cold is technically very difficult to recover. The amount of waste cold could possibly be reduced with better insulation. In industrial processes requiring cooling, the recovery of waste energy focuses on waste heat. The temperature and technology of the coolant circuit for cooling do not easily allow the separate use of cold energy. In heating-cooling processes, such as the pasteurisation and recooling of milk, the sector is more commonly concerned with the use of

waste heat or improving energy efficiency with heat recovery rather than utilising waste cold

Given conditions in Finland, free cooling has a far greater potential. Free cooling means that cold ambient temperatures are used for industrial cooling so that the process does not require the use of a compressor.

The potential for waste cold for cooling buildings is also negligible in practice, as cooling is still very rarely used in Finland. In district cooling, for example, utilisation is related to district heating production using the thermal energy of the cooling network, which could be counted as the use of waste heat.

3.2 Potential for waste heat in district heating

For district heating, the potential of waste heat is described in the AFRY study on the potential of waste heat under the Energy Efficiency Directive and a cost-benefit analysis for efficient heating[7].

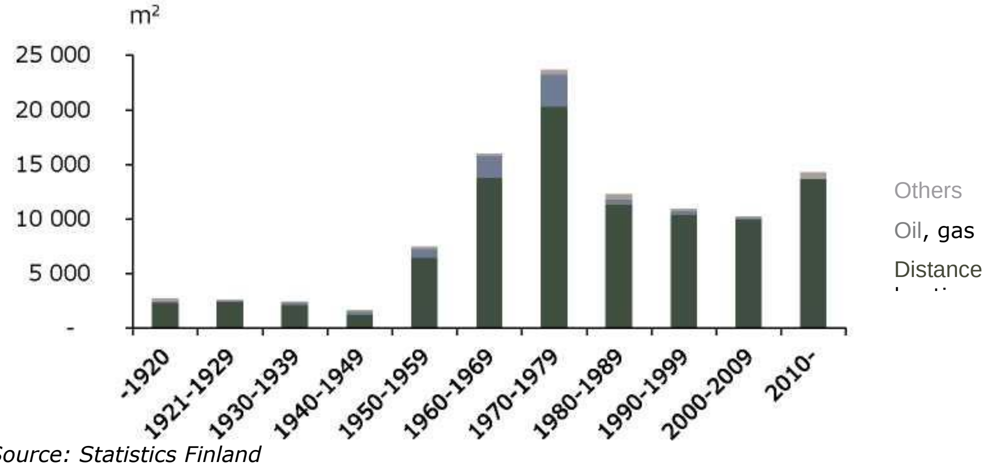
3.3 Waste heat potential property-specific for heating

Waste heat from buildings consists mainly of sewage water and exhaust air heat, which can be examined to assess the amount of waste heat in properties. Exhaust air heat pump systems using heat recovery (PILP systems) have become more widespread, especially those built between 1960 and1990[8]. The same properties are often also connected to district heating, and the system significantly reduces the consumption of district heating.

Buildings claim employed waste heat examination focus here the potential of exhaust air heat pumps, the total potential of which is estimated using the building stock and energy captured by example properties. The assessment of the total potential of waste heat per property is based on the VTT's work on off-air heat pumps in the district heating[system 8]. The assessment of the potential of property-specific waste heat uses Statistics Finland's data on buildings and their heating methods.

The potential for waste heat recovered in Finland by means of exhaust-air heat pump systems was assessed by establishing the total floor area of residential buildings connected to district heating and other heating methods and using the specific consumption of buildings in VTT's study. Buildings completed after 1990 and connected to district heating have a low specific consumption reflecting their better energy efficiency, which reduces the potential for heat recovered from exhaust air. Figure 6 shows the total floor area of blocks of flats by heating method and construction year. Figure 7 shows the total floor area of detached houses by heating method and construction year.

Kuva 6: Asuinkerrostalojen kerrosala lämmitysmuodoittain ja rakennusvuosittain

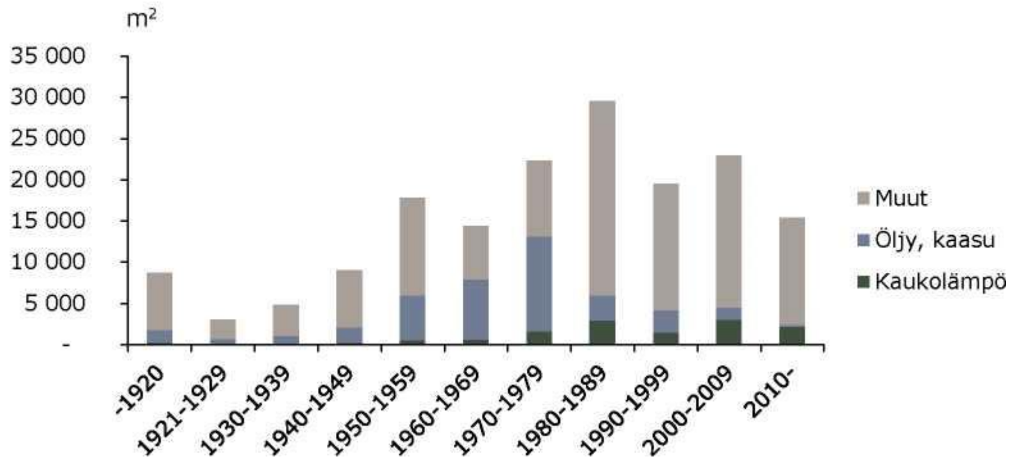


Source: Statistics Finland

7AFRY, EED study on waste heat potential and cost-benefit analysis heating, 2020, https://tem.fi/documents/1410877/2897650/EEDselvitys+l%C3%A4mmityksest%C3%A4_loppuraportti+2020 pdf/88a0e63b-e2b6-eef9-1b4c-8c5411a0e531/EED Study+l%C3 %A4mmationksest%C3 %A4_final report+ 2020.pdf?t=1601627038073

8 VTT 2015. Exhaust air heat pumps district heating. Available https://www.vttresearch.com/sites/default/files/julkaisut/muut/2015/VTT-CR-00564-15.pdf

Kuva 7: Erillisten pientalojen kerrosala lämmitysmuodoittain ja rakennusvuosittain



Source: Statistics Finland

Table 3 presents the calculated waste heat potential for heat recovered from exhaust air. The utilisation of heat from exhaust air reduces the amount of heat needed from district heating or other heating systems. The reduction in buildings connected to district heating after the installation of exhaust-air heat pumps is expected to bring savings of 50 % in heating energy. For other forms of heating, it is assumed that the exhaust air system will save: 30 %.

Exhaust-air heat pumps can considerably reduce the need for heating, and the potential of heat from exhaust air might be as high as 13 TWh, if 80 % of buildings were fitted with an EAHP system.

Table 3: Potential for waste heat from exhaust air in residential buildings

Assumed proportion of built area with EAHP system installed	Amount of waste heat from exhaust air in residential buildings with district heating (GWh)	Amount of waste heat from exhaust air in buildings heated using other heating methods (GWh)
10 %	868	784
20 %	1 735	1 587
30 %	2 603	2 381
40 %	3 471	3 174
50 %	4 339	3 968
60 %	5 206	4 761
70 %	6 074	5 555
80 %	6 942	6 348

Source: Statistics Finland, VTT Technical Research Centre of Finland, AFRY

It should be noted, however, that this report only very roughly assesses the potential for exhaust air heat in property-specific heating, and the potential for using the heat from sewage water, for example, has not been calculated. Neither does the report assess the utilisation rate of exhaust air in buildings of different ages at a detailed technological level.

4 Spatial analysis of renewable energy production areas with low ecological risk

The greatest location-related ecological risk with the utilisation of renewable heating technologies is related to ground heat and geothermal heat. Groundwater aquifers may restrict their potential for use in some areas, as the risks involved in well drilling include the contamination of groundwater due to surface water

runoff or changes in groundwater flow, for example. Figure 8 presents Finland's groundwater areas. Less than 4 % of Finland's land area is a groundwater area[9]. The areas are typically located in the vicinity of sandy eskers. The Salpausselkä ridge system extending from Joensuu to Hanko, in particular, passes through a number of towns. Approximately 80 applications for permits submitted to the Regional State Administrative Agencies for ground-heat wells between 2014 and 2019 were[10] rejected or submitted in order to: % of all 57 applications[11]. Heat wells are unlikely to come in the future
plan for groundwater areas, as according to the rejection decision of the Council of State in the 2019 Annual Book Decision, wells pose a significant risk to groundwater quality[12]. However, groundwater areas tend to face very

9Finnish Environment Centre
10Geothermal wells require a permit for action to be carried out by the city's building inspection. In the case of groundwater areas, the permit application may be forwarded for a decision to the Centres for Economic Development, Transport and the Environment (ELY Centres) and on to the Regional Sate Administrative Agencies.
11Energy wells and groundwater, Juha Helin, Regional State Administrative Authority of Southern Finland, Presentation 30.1.2020.
https://docplayer.fi/181043468-Energiakaivot-ja-pohjavesi-luvittajan-nakokulmasta-juha-helin-esavi.html
12KHO:2019:37 (Türkiye)

local constraints and it is challenging to assess the extent to which groundwater areas offer the full potential for geothermal use at the level of Finland as a whole.

Figure 8: Finnish groundwater areas[13]

The use of oil involves ecological risks especially relating to oil spills. Oil may be required as a start-up fuel in installations using biomass, and peak power plants may use bio-oil. The possibility of oil spills can be prevented by leak protection measures, and the use of oil does not significantly restrict the use of renewable energy. However, the locations of new installations are considered carefully due to the presence of groundwater areas, among other factors. Local restrictions do not, however, restrict the total potential for installations using biofuels.

The construction of new heating and cooling installations may involve risks to the habitats of endangered species. The risks depend on the case, and, overall, they do not significantly limit the use of renewable energies for heating in Finland.

5 Small-scale households projects potential

Small-scale household projects under the REDII Directive are interpreted here as changing the heating method of a detached house. Detached houses have a significant potential for increasing the share of renewable energy in heating by replacing oil or gas heating with heating methods based on renewable energy. Detached houses may switch their heating method to a more cost-effective one, such as ground source heat or air-water heat pumps. It should be noted, however, that the total investment required to change the form of heating may limit the willingness to change the form of heating away.

[13] Source: Finnish Environment Institute. The map service is available at https://kartta.paikkatietoikkuna.fi/, where the groundwater-related map layer options can be found under the Geology map layer options.

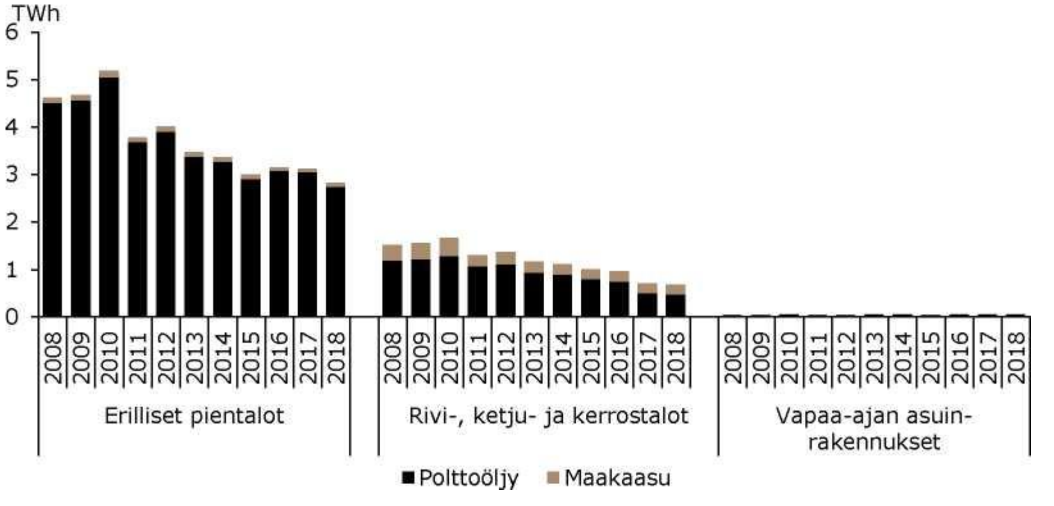
oil or gas heating. This supplementary report does not take into consideration the share of renewable fuels in energy production.

Oil heating in households and phasing out oil heating

Oil, coal and natural gas constitute the fossil-based property heating fuels. Of the fossil duels, coal is negligible, as it only accounts for 0.3 %. The overall shares of oil and natural gas heating in the context of

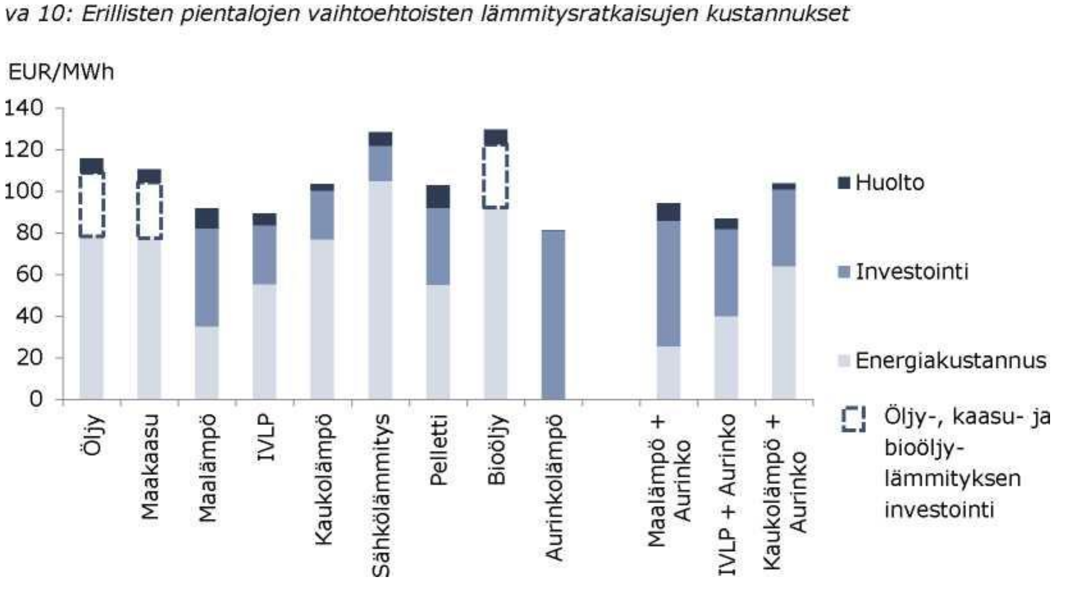
the total energy need for heating residential buildings are also small compared to other energy sources. In 2018, oil heating only accounted for 8 % of the total energy need of detached houses. In terraced and linked houses and blocks of flats, the share was 2 %, and in leisure-time residences, it was 2 %. In 2018, gas heating only accounted for 0.2 % of the total energy need of detached houses. In terraced and linked houses and blocks of flats, the share was 0.9 %, and in leisure-time residences, it was 0.03 %. In 2018, the total need for oil and gas for the heating of residential buildings was 3.6 TWh, of which oil accounted for 3.3 TWh. Figure 9 shows the figures for oil and gas heating in residential buildings by building type.

Figure 9: Heating of residential buildings with fuel oil and natural gas by type of residential building 20082018



Source: Statistics Finland

Heating technologies in detached houses include oil heating, gas heating, district heating, ground heat, air-water heat pumps, bio-oil heating, pellet heating, electric heating, solar thermal, and hybrids consisting of solar thermal and other heating technologies. A comparison of the costs of different heating methods employs LCOE (levelised cost of energy) calculation, where different heating methods are assigned mutually comparable production prices (EUR/MWh), including variable costs (such as fuel or electricity costs and the associated taxes) and investment costs. The calculation shall take into account: the cost of capital when the entire heating system is replaced. Figure 10 presents the costs of alternative heating solutions for detached houses.



Remarks: The LCOE values do not include VAT. The example building is a detached or semi-detached house with an annual energy need of 18 MWh. Lifetime is modelled as 20 years in the LCOE calculation, and the WACC value is 3 %.

AWHP and solar thermal technologies require a backup system, which is not taken into account in *the LCOE calculation for the respective technology. Hybrid forms of solar thermal and other heating technologies take the required backup capacity into account.*

The price assumptions are EUR 97.3 per MWh for oil, EUR 44.0 per MWh for electricity and EUR 47.7 per MWh for the electricity network charge. Investment costs indicated with a dashed line refer to oil, gas and bio-oil heating investments, which are not needed in properties already equipped with an oil heating system.

Source: AFRY, Finnish Energy, Nordpool, Statistics Finland, technology suppliers

Based on the LCOE calculations, switching from oil heating to other heating methods is often a cost-effective alternative in detached houses, if the investment costs of oil heating are also taken into account. Oil-heated detached houses are often outside built-up areas, which means that joining district heating may not be an option. Of renewable energy sources, pellet heating, air-water heat pumps and ground-source heat pumps have lower costs than oil heating. Bio-oil heating is more expensive than ordinary oil heating, as the fuel costs are higher. If there is no need to replace the oil boiler, switching to bio-oil could be a more attractive option than other renewable energy heating methods. The availability of bio-oil for heating is currently very limited. If the investment costs of oil heating are not taken into account, the costs of other heating methods are higher than the fuel and maintenance costs of oil heating.

Adding solar thermal heating to the heating methods may lower overall costs, but the more heating needs solar thermal heating can cover and the larger the collector area, the greater is the benefit of its addition. Solar thermal heating has a low LOCE value, as there are no energy costs. It should be taken into account, however, that solar thermal energy requires backup capacity, as there is practically no solar thermal heat available during the heating season. This backup capacity must be another heating system, such as district heating, which increases the total costs. Air-water heat pumps also require backup capacity.

Households usually also consider the property's value trend when changing heating methods. In sparsely populated areas, for example, the total investment involved in replacing oil heating with a ground-source heat pump may be considerable relative to the value of the property, which makes the change of heating method less attractive. For oil heating in stand-alone small houses, it is profitable to switch from renewable energy to geothermal, IVLP technology, or

for pellet heating, if oil heating has reached its useful life and requires a new investment. Adding solar thermal heating reduces the relative production price, but the benefit will be greater in larger properties with a greater need for energy than detached houses.

In 2018, oil consumption in the heating of residential buildings was the equivalent of 3.3 TWh, which can be entirely generated with renewable energy.