Ministry of Employment and the Economy
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REPORT UNDER DIRECTIVE 2004/8/EC:

- ANALYSIS OF THE NATIONAL POTENTIAL FOR THE APPLICATION OF HIGH-EFFICIENCY COGENERATION, ARTICLE 6(1);
- EVALUATION OF AUTHORISATION PROCEDURES AND ADMINISTRATIVE BARRIERS APPLICABLE TO HIGH-EFFICIENCY COGENERATION UNITS, ARTICLE 9 (1 & 2)
- REPORT ON INCREASING THE SHARE OF HIGH-EFFICIENCY COGENERATION, ARTICLE 6(3)

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1 Introduction

This report presents an analysis of the national potential for high-efficiency cogeneration of heat and power, in accordance with Article 6(1) of Directive 2004/8/EC (the CHP Directive). The report also presents an interim progress report under that Directive [Article 10(2) and Article 6(3)], as well as a report on administrative barriers to CHP [Article 10(1) and Article 9(1 & 2)].

Among other things, the report is based on Finland's National Energy and Climate Strategy (ECS 2005), Finland's official statistics and the report on the potential for cogeneration and for district heating and cooling in Finland (Gaia Oy, July 2007). The report created a background scenario to describe Finland's energy future from the perspective of the energy policy guidelines at the time and other factors affecting energy consumption and production. The basic assumptions of the background scenario were based on national and international reports prepared by, for example, Ministries, higher education institutions and other research institutes.

While the report was being finalised, the Long-term Climate and Energy Strategy approved by the Finnish Government in 2008 was completed. The report has been updated where necessary. For the production of combined heat and power, the guidelines of the Long-term Climate and Energy Strategy have pretty much stayed the same.

Estimates for the potential for cogeneration are obtained on the basis of the background scenario for the review years 2010, 2015 and 2020 defined in the CHP Directive. In some cases, estimates are also presented for the more distant future right up to 2050. The estimates of the future picture for cogeneration and district heating are supplemented by a questionnaire addressed to the management of the district heating companies. The report also presents the results of previous reports on the potential for cogeneration.

In addition to estimating the potential for cogeneration and district heating, the analysis contains a description of the objectives of Finland's energy policy and of the current structure of energy production and consumption, as well as a separate estimate of barriers to cogeneration. A discussion of these topics is a prerequisite for justifiably being able to define Finland's national strategy for promoting cogeneration.

The structure of the report is as follows. Chapter 2 presents a summary of the report and its results. The chapter contains a summary of the objectives of the national energy policy, the estimated potential for cogeneration, the energy savings that can be achieved, barriers to cogeneration that have been identified and the necessary support systems and national cogeneration development strategy. The objectives of Finland's energy policy and national development trends are described in Chapter 3. Chapter 4 reviews the statistics on the current structure of Finland's energy production and consumption. The assumptions for the background scenario are described in Chapter 5. The estimates of the potential for district heating and cogeneration obtained on the basis of those assumptions are presented in Chapter 6. The results of the reports presented in this report are compared, among other things, with the scenarios in Finland's National Energy and Climate Strategy (2005). Chapter 7 discusses barriers to cogeneration. Chapter 8 defines Finland's national development strategy for promoting the cogeneration of heat and power on the basis of the factors presented in the previous chapters.

2 Summary

The tables below comprise the background scenario, the view of players in the sector and the Ministry of Trade and Industry's [MTI] WM scenario for the trend in demand for district heating, electricity generated by cogeneration, and heat and power generated by cogeneration in industry.

Table 1. Trend in demand for district heating, according to the background scenario, players in the district heating sector and the MTI's WM scenario.

[TWh]	Background scenario	View of players in the sector	MTI's WM scenario
2005	29.8	29.8	29.8
2010	31.6	32.6	30.1
2015	32.1	33.8	31.2
2020	32.3	34.9	32.3

Table 2. Trend in electricity generated by cogeneration according to the background scenario, players in the district heating sector and the MTI's WM scenario.

[TWh]	Background scenario	View of players in the sector	MTI's WM scenario
2005	13.9	13.9	-
2010	15.3	16.0	18.0
2015	16.3	16.4	19.5
2020	17.2	16.9	20.9

Table 3. Trend in heat and power generated by cogeneration in industry, according to the background scenario. [1]

	Cogenerated heat		Cogenerated power	
	TWh	growth %	TWh	growth %
2005	44.2		13.0	
2010	47.7	8%	14.3	3%
2015	48.7	10%	15.1	9%
2020	49.7	12%	15.9	15%

[1] 2004 is used as the basis for comparison, owing to the industrial conflict in the forestry industry in 2005.

2.1 Energy saving that can be achieved by cogeneration

The energy saving that can be achieved by cogeneration in 2020 is estimated to be a total of 60 000 TJ, which is approximately 4% of total primary energy procurement in 2005. Figure 1 presents the primary energy savings achieved by cogeneration, based on replacing separate production.

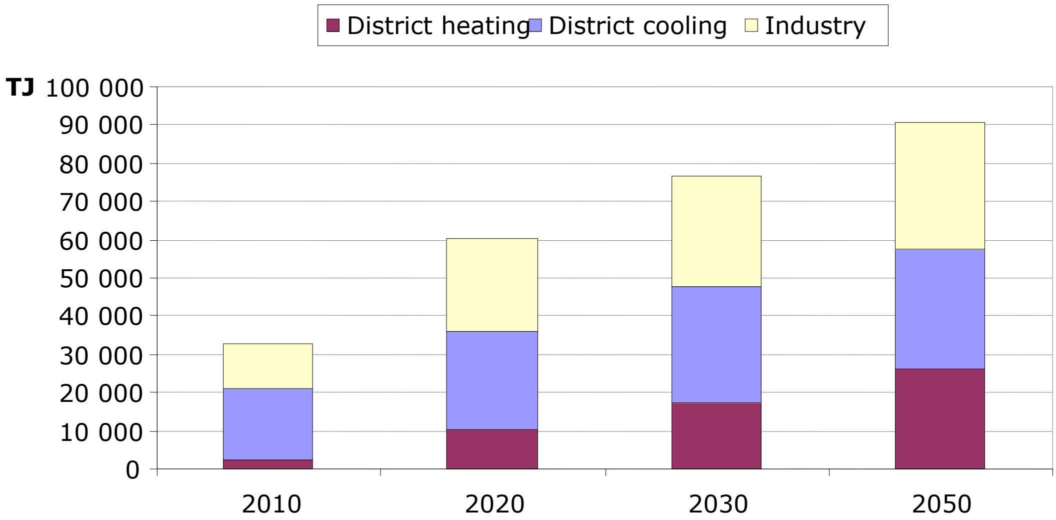


Figure 1. Primary energy savings achieved by cogeneration, based on replacing separate production

3 Objectives of Finland's energy policy and national development trends

3.1 Objectives of Finland's energy policy

3.1.1 General

In line with the programme of Matti Vanhanen's second government, the government drafted a long-term climate and energy strategy right at the start of its term, which defines the key targets and means of Finland's climate and energy policy for the next ten years as part of the European Union and its targets (Long-term Climate and Energy Strategy, 6/11/2008).

The objective of the new national strategy is to help ensure the implementation of the Kyoto Protocol and to fulfil its obligations, as well as to start implementing the post-Kyoto obligations rapidly and flexibly in 2013. It is therefore sensible to ensure that the post-Kyoto action to reduce emissions is adequate and to propose additional action that may be necessary for the 2020 obligations, so that the obligations relating to the timetable laid down for implementation by the EU and to the effectiveness of the action are fulfilled.

Two scenarios have been created as the background to the energy and climate strategy. One of these is the so-called basic scenario, and the other is a scenario that fulfils the international emissions obligations, among other things. The basic scenario describes the trend in the light of the policy activities already in force (in 2005). If the measures in the basic scenario do not achieve the set targets, new policy activities are needed. A scenario created from such a starting point is called a WAM scenario (With Additional Measures scenario). The designation WM scenario (With Measures scenario) is used for the basic scenario.

The share of renewable energy in Finland in 2005 was 28.5% of final consumption according to the European Commission's statistics office, Eurostat. The target is to increase this share to 38% by 2020, according to the target that the Commission has set for Finland. The target is challenging, and achieving it will basically depend on final energy consumption taking a downward turn. Finland's natural resources will enable the additional use of renewable energy, but in order to set this in motion, the current support and guidance systems need to be made more effective, and structures need to be changed.

In the Commission's draft Directive on promoting renewable energy, the flexible mechanisms are based on trade under the original guarantees between the Member States on the one hand and operators on the other. On the basis of the report by the European Parliament's rapporteur, the Commission's opinions and the discussions that took place in the Energy Council in early autumn 2008, it looked as though the flexible mechanisms of the Directive would be based on voluntary collaboration between Member States. In these examples, for instance, renewable energy consumption could have been moved from one Member State to another in the statistics, or Member States could jointly agree to enter the renewable energy from an aided facility under the countries' renewable energy consumption, irrespective of the country in which the facility is located. The key principle of the systems is that the Member States would keep control of the use of flexible mechanisms. However, there are many reasons supporting the fact that Finland ought primarily to aim for the additional use of national renewable energy sources. Nevertheless, it is sensible to prepare for forms of collaboration with other Member States to increase the renewable energy supply. In particular, Finnish expertise should be exploited in the cost-effective use of biomass in the production of combined heat and power.

> *Finland is prepared for achieving the renewable energy targets by its own means, without the flexible mechanisms between Member States that are outlined in the Directive. Where necessary, Finland may exploit the flexible mechanisms, either as a purchaser or as a vendor, depending on the costs of increasing renewable energy in Finland and in other Member States.*

The following table summarises the quantities of different renewable energy sources in the target path.

Table 4. The use of renewable energy as primary energy for each energy source and as final consumption in the target path, TWh.

	2005	**2006**	**2020**	
			Basic path	Target path
Fuels depending on industrial production				
Waste liquids	36.7	43.3	38	38
Industrial waste wood	23.1	26.7	22	22
Total	59.8	70.0	60	60
The object of policy measures				
A. No need for support				
Hydroelectric power	13.6	11.3	14	14
Recycled fuels and cheaper biogases	1.7	1.9	2	3

B. Minor need for support				
Forest chips [1]	5.8	7.2	18	21
Small-scale use of wood	13.4	13.6	12	13
Wood pellets and field biomass	0.1	0.1	0.7	3
Heat pumps	1.8	2.4	3	5
C. Major need for support				
Other biogas	0	0	0.1	0.5
Liquid biofuels [2]	0.0	0.0	6	6
Wind power and solar power	0.2	0.1	1	6
Total	**94.9**	**102.7**	**115**	**128**
- of which wood-based fuels total [3]	19.4	19.3	33	37
Final consumption of renewable energy	**86**	**92**	**106**	**118**

[1] In addition to this, forest chips are assessed as a raw material to be used by bio-refineries.
[2] Includes biofuels for transport and work machinery, as well as biofuel oil for use in heating
[3] Does not include industrial waste liquids or waste wood

3.1.2 Carbon dioxide emissions and targets

According to the 2005 energy and climate strategy, primary energy and electricity consumption in Finland are expected to increase in the years to come. Carbon dioxide emissions will also increase thanks to the rise in energy consumption. The growth in emissions will be caused almost exclusively by growth in emissions by the emissions trading sector in the sense of the EU's Emissions Trading Directive, in other words, mainly energy production and industrial processes. Without additional measures, Finland's greenhouse gas emissions for the Kyoto period 2008–2012 would be on average 11 million tonnes greater per year than the Kyoto Protocol permits. The Finnish Government is preparing to reduce emissions using Kyoto's flexible mechanisms for 10 million tonnes for the whole period, i.e. an average annual value of 2 million tonnes. The need for reductions will thus remain at an annual level of approximately 9 million tonnes, of which the need to make reductions in the emissions trading sector will be approximately 8 million tonnes on average.

3.1.3 Cogeneration targets

The quantities of electricity to be produced by cogeneration of heat and power for the years 2010 and 2025 according to the WAM (With Additional Measures) scenario in the 2005 energy and climate strategy appear in the following table (Table 5). In the WAM scenario, the quantity and share of electricity produced by cogeneration of heat and power will increase. The share of electricity produced by cogeneration in all electricity procurement in this scenario will be approximately 40% in 2025. The table also shows the production targets and shares for other forms of production.

Table 5. Electricity procurement in the WAM scenario, TWh and % shares (ECS background report).

	TWh			Shares, %		
	2003	2010	2025	2003	2010	2025
Nuclear power	21.8	31.1	34.6	25.6	33.3	33.0
Hydroelectric power	9.5	13.3	14.0	11.2	14.2	13.4
Cogeneration, district heating	15.1	19.7	23.5	17.8	21.1	22.4
Cogeneration, industry	12.7	15.2	18.4	14.9	16.3	17.5

Total cogeneration	**27.8**	**34.9**	**41.9**	**32.7**	**37.4**	**39.9**
Condensate production	21.1	4.5	6.2	24.7	4.9	5.9
Wind power	0.1	0.9	2.9	0.1	0.9	2.8
Production	**80.3**	**84.7**	**99.6**	**94.3**	**90.7**	**95.0**
Net imports	4.9	8.6	5.2	5.7	9.2	5.0
Total	**85.2**	**93.3**	**104.8**	**100.0**	**99.9**	**100.0**

In the WAM scenario, it is attempted to increase the quantity of electricity produced by cogeneration in both the industrial and the district heating sectors. Both absolute and relative growth are slightly greater in the district heating sector. The trend in the share of electricity produced by cogeneration for each sector is illustrated by Figure 2.

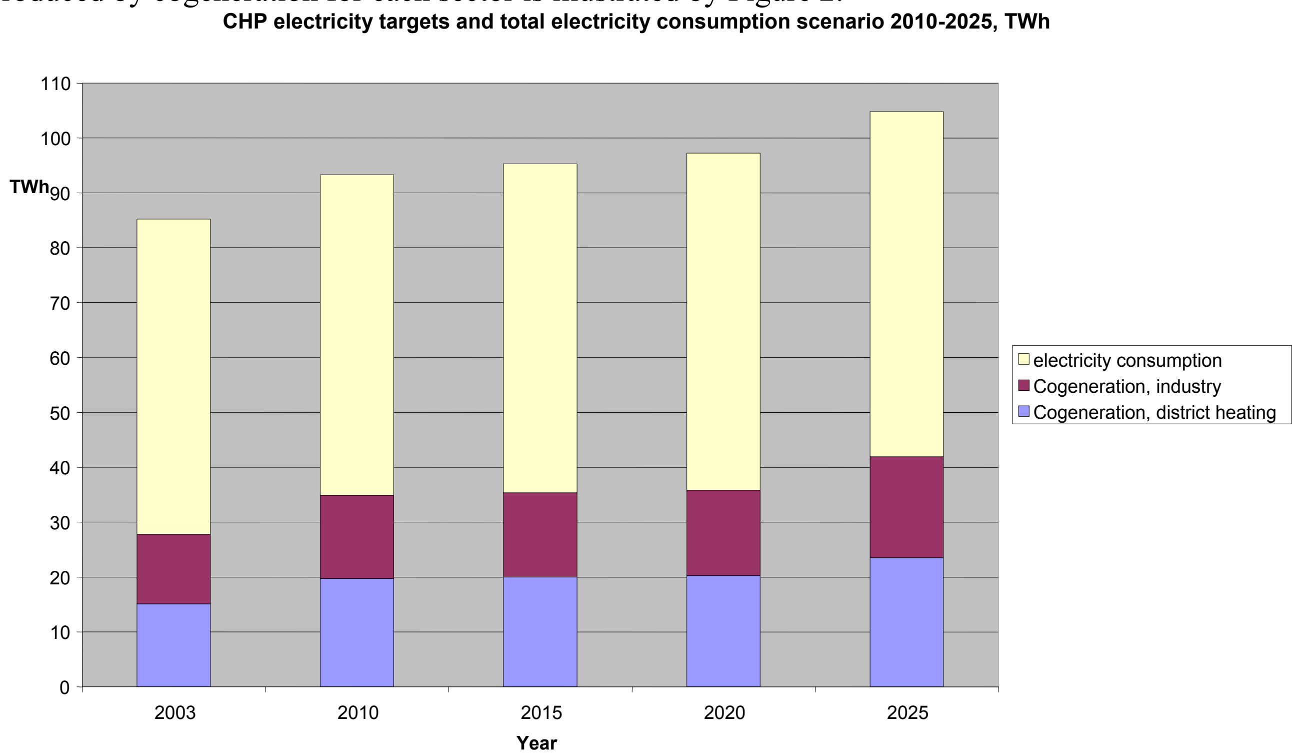


Figure 2. CHP electricity targets and total electricity consumption scenario 2010-2025, TWh

In the trend indicated by the WAM scenario, the majority of cogenerated electricity produced in connection with district heating production in 2025, a total of approximately 67%, will be produced using imported fuels, the most important of which will be natural gas and coal (Figure 3).

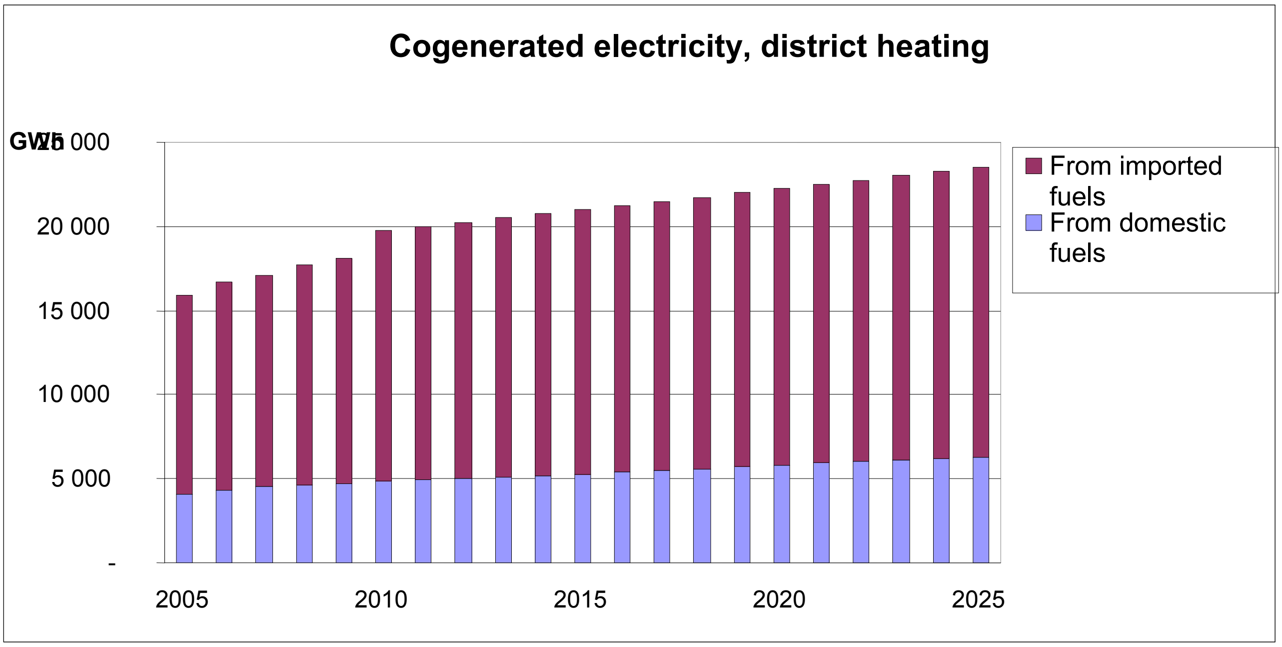


Figure 3. Trend for imported and domestic fuels in domestic heating production in the WAM scenario

In the trend indicated by the WAM scenario, the growth rate for cogenerated electricity produced in connection with district heating is slowing down. This is partly explained by the fact that the share of district heating in the heating of new properties is falling in the trend indicated by the scenario, as illustrated by (Figure 4).

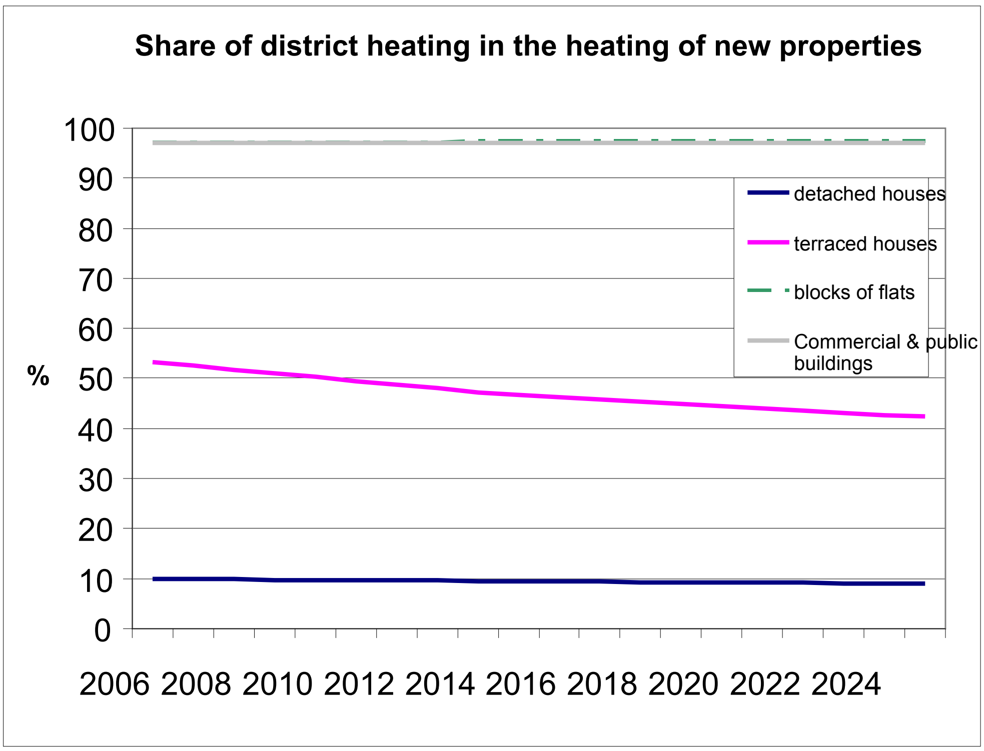
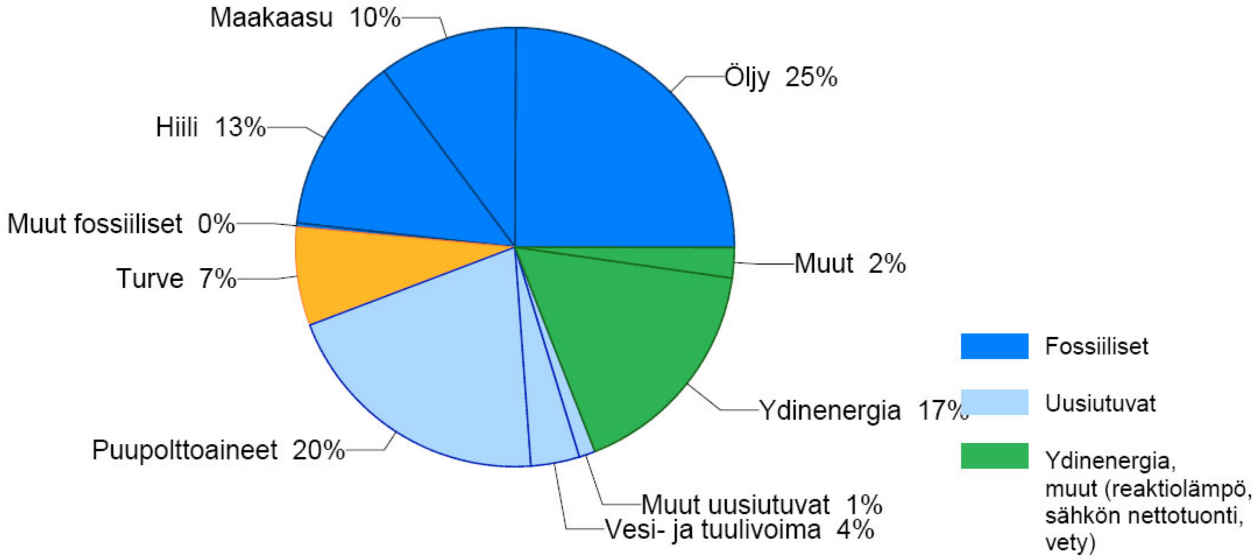


Figure 4. Share of district heating in the heating of new properties in the WAM scenario.

4 Current structure of Finland's energy production and consumption

4.1 Primary energy sources and consumption

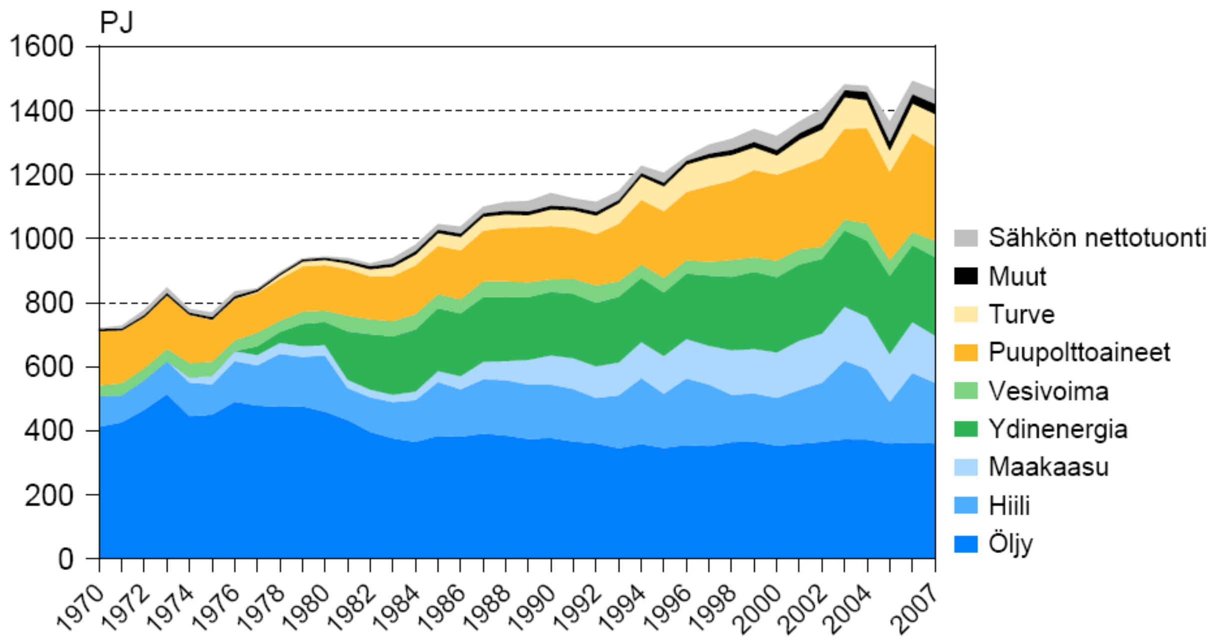
Many different energy sources and production types are used in various ways to produce energy in Finland. In 2005, the total consumption of primary energy in Finland was 1 366 295 TJ or 379 557 GWh (Statistics Finland, 2006). In 2007, the total consumption of primary energy was 1 480 800 TJ or 411 333 GWh (Statistics Finland, 2008), divided among energy sources as in the figure below (Figure 5).



Maakaasu = Natural gas
Hiili = Coal
Muut fossiiliset = Other fossil fuels
Turve = Peat
Puupolttoaineet = Wood-based fuels
Öljy = Oil
Muut = Other
Ydinenergia = Nuclear energy
Muut uusiutuvat = Other renewables
Vesi- ja tuulivoima = Hydroelectric and wind power
Fossiiliset = Fossil fuels
Uusiutuvat = Renewables
Ydinenergia, muut (reaktiolämpö, sähkön nettotuonti, vety) = Nuclear energy, other (reaction heat, net imports of electricity, hydrogen)

Figure 5. Total energy consumption in Finland in 2007. (Source: Statistics Finland)

Figure 6 illustrates the change in the structure of total consumption for each source of energy since 1970. The diversification of available energy sources and the consequent reduction in dependence on oil are the most noteworthy factors in the trend for total energy consumption. The significance of oil as a primary energy source has been reduced by the introduction of nuclear power and natural gas and by the increase in the use of wood-based fuels.



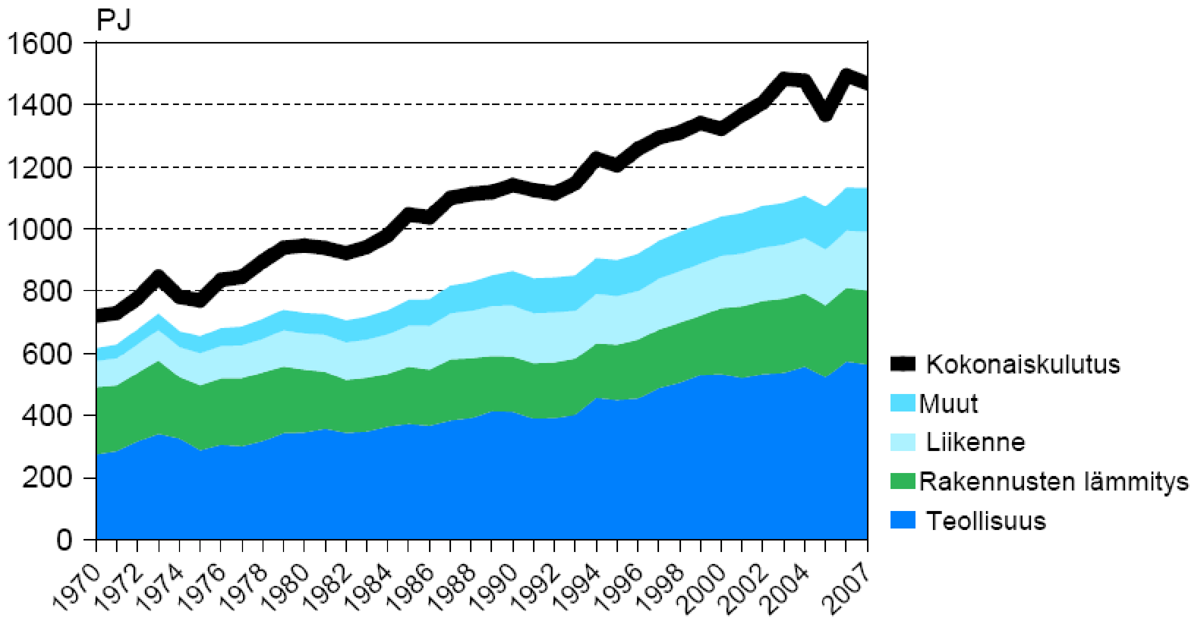
Sähkön nettotuonti = Net electricity imports
Muut = Other
Turve = Peat
Puupolttoaineet = Wood-based fuels
Vesivoima = Hydroelectric power
Ydinenergia = Nuclear energy
Maakaasu = Natural gas
Hiili = Coal
Öljy = Oil

Figure 6. Total energy consumption 1970-2007. (Source: Statistics Finland)

In 2005, final energy consumption in Finland was 1 083 277 TJ (Energy Statistics 2006). With regard to 2005, which is regarded as the example year in many places in this report, it is wise to take into consideration the lengthy industrial conflict in the forestry industry and the warm weather. Partly because of the industrial conflict and warm weather, Finland's energy consumption fell in comparison with the previous year. Final consumption means the final energy consumption of different sectors (electricity, district heating, direct fuel consumption), so it does not include losses to heat and power production. By sector, 48% of final energy consumption was aimed at industry, 21% heating, 17% transport and 14% other consumption. The "other" sector includes the consumption of electricity and fuels by the household, public and private service sector, by agriculture and forestry and by construction.

In an international comparison, the share of industry in Finland's final energy consumption is remarkably large. Finland's comparatively large need for energy for heating purposes owing to the climate is also worth noting.

The historical trend in the distribution of final energy consumption is illustrated by Figure 7. The share of industry has remained at approximately 50% of final energy consumption for the whole 1970-2007 period. On the basis of the final consumption trend, it may be stated that there has been a fall in the relative significance of energy used for the heating of buildings. Even in the 1960s, more energy was used to heat buildings than was used for the needs of industry. The trend is a consequence of an increase in the use of district heating to heat buildings and increased efficiency in the energy economy of new buildings.

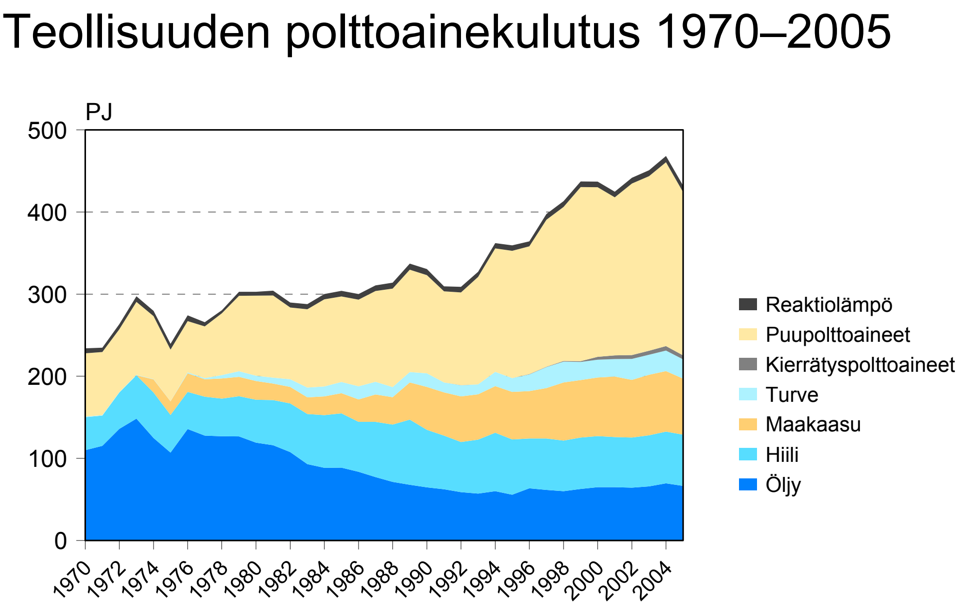


Kokonaiskulutus = Total consumption
Muut = Other
Liikenne = Transport
Rakennusten lämmitys = Heating of buildings
Teollisuus = Industry

Figure 7. Total energy consumption and final consumption for each sector 1970–2007 (Source: Statistics Finland).

The final energy consumption of the transport sector has grown (Figure 7), although fuel consumption per vehicle has fallen, since the number of cars has increased more than tenfold over the last three decades. The majority of energy consumption in the transport sector occurs in road traffic, and car fuels, petrol and diesel oil together account for more than 90% of the fuels used in domestic transport.

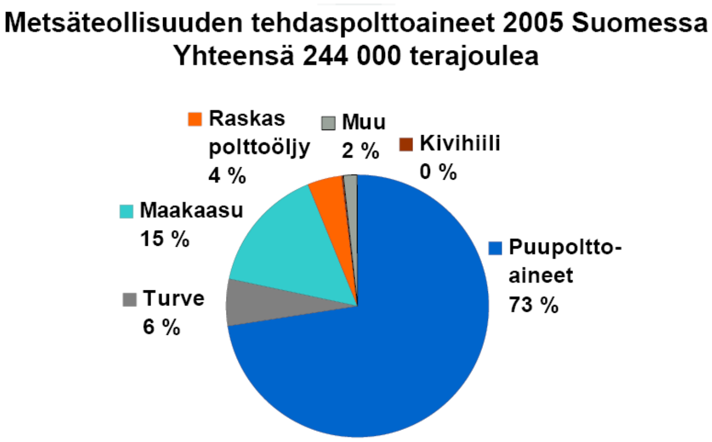
Because industry has been the largest final energy consumption sector, its energy consumption and procurement have had the most significant impact on Finland's energy sector as a whole. Of the industrial sectors, the largest energy consumer is the forestry industry. Figure 8 presents comprehensively the consumption of fuels by industry, the production of heat and power for industry, production processes and heating for industrial buildings over the years 1970-2005.



Teollisuuden polttoainekulutus 1970-2005 = Industrial fuel consumption 1970-2005
Reaktiolämpö = Reaction heat
Puupolttoaineet = Wood-based fuels
Kierrätyspolttoaineet = Recycled fuels
Turve = Peat
Maakaasu = Natural gas
Hiili = Coal
Öljy = Oil

Figure 8. Industrial fuel consumption 1970-2005. (Source: Statistics Finland)

The trend for industrial fuel consumption (Figure 8) shows that the use of wood-based fuels and their relative share have grown during the period examined. This is due above all to an increase in their use within the forestry industry. As Figure 9 indicates, nearly three-quarters of the fuels used in the forestry industry are of wood origin. In 2005, the use of fuels in the forestry industry was 67.8 TWh (244 PJ). The increased use of wood-based fuels in industry largely explains the growth in the share of wood-based fuels in Finland's total energy consumption (Figure 6).



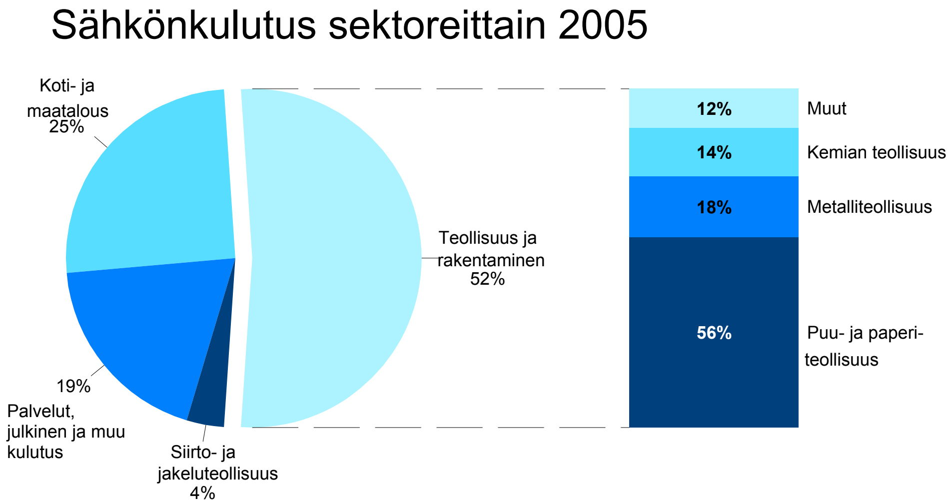
Metsäteollisuuden tehdaspolttoaineet 2005 Suomessa = Factory fuels in the forestry industry in Finland in 2005
Yhteensä 244 000 terajoulea = Total 244 000 terajoules
Turve = Peat
Maakaasu = Natural gas
Raskas polttoöljy = Heavy fuel oil
Muu = Other
Kivihiili = Coal
Puupolttoaineet = Wood-based fuels

Figure 9. Fuels used by the forestry industry in 2005[2]

4.2 Electricity consumption and procurement

In 2005, total electricity consumption in Finland was 84 797 GWh. A good half of this (52%) was for the needs of industry. The forestry industry (wood and paper industry in the figure), the metals industry and the chemicals industry together account for nearly 90% of industrial electricity consumption (Figure 10).

[2] Source: Finnish Forest Industries Federation

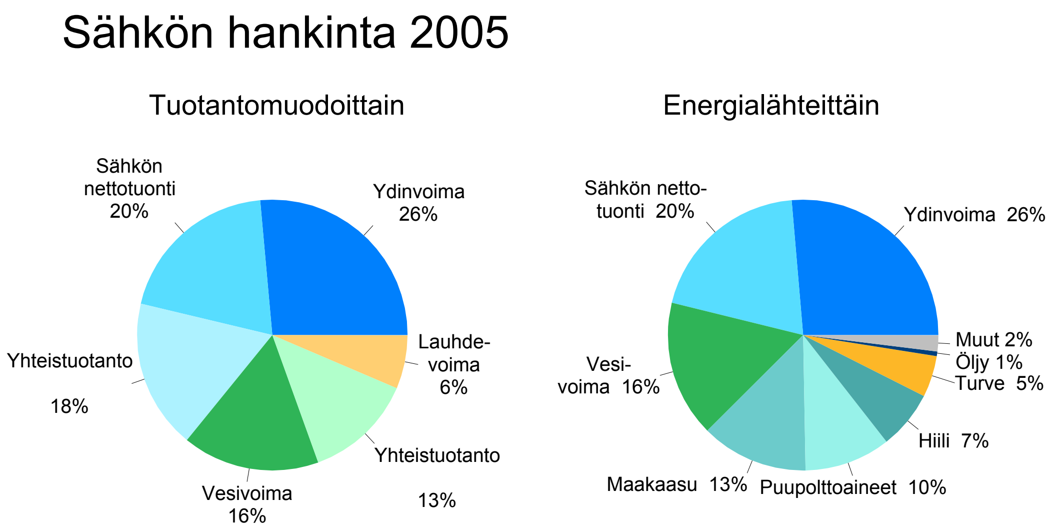


Sähkönkulutus sektoreittain 2005 = Electricity consumption per sector, 2005
Koti- ja maatalous = Domestic and agriculture
Palvelut, julkinen ja muu kulutus = Services, public and other consumption
Siirto- ja jakeluteollisuus = Transmission and distribution industry
Teollisuus ja rakentaminen = Industry and construction
Muut = Other
Kemian teollisuus = Chemicals industry
Metalliteollisuus = Metals industry
Puu- ja paperiteollisuus = Wood and paper industry

Figure 10. Electricity consumption per sector, 2005. (Source: Statistics Finland)

The share of electricity production in primary energy approached a level of 40% in the early 2000s. This high proportion is one of the special features of Finland's energy system.

The most important energy sources for the production of electricity in Finland are nuclear power, hydroelectric power, coal, natural gas, wood-based fuels and peat. Finland is part of the common Nordic electricity market, and the share of net electricity imports in electricity production largely varies depending on how much hydroelectric power from Norway and Sweden is available on the Nordic electricity market. Through this, the share of fossil fuels, mainly coal, in energy sources for the procurement of electricity also varies. Electricity procurement for each type of production and for each energy source in 2005 is illustrated by Figure 11. The diagram on the left, which divides electricity procurement up by production type, separates the cogeneration of heat and power for the production of district heating (share 18%) and industrial heating (share 13%).



Sähkön hankinta 2005 = Electricity procurement 2005
Tuotantomuodoittain = Per production type
Sähkön nettotuonti = Net electricity imports
Ydinvoima = Nuclear power
Lauhdevoima = Condensate power
Yhteistuotanto = Cogeneration
Vesivoima = Hydroelectric power
Energialähteittäin = Per energy source
Muut = Other
Öljy = Oil
Turve = Peat
Hiili = Coal
Puupolttoaineet = Wood-based fuels
Maakaasu = Natural gas

Figure 11. Electricity procurement 2005. (Source: Statistics Finland)

4.3 Industrial heat consumption and production

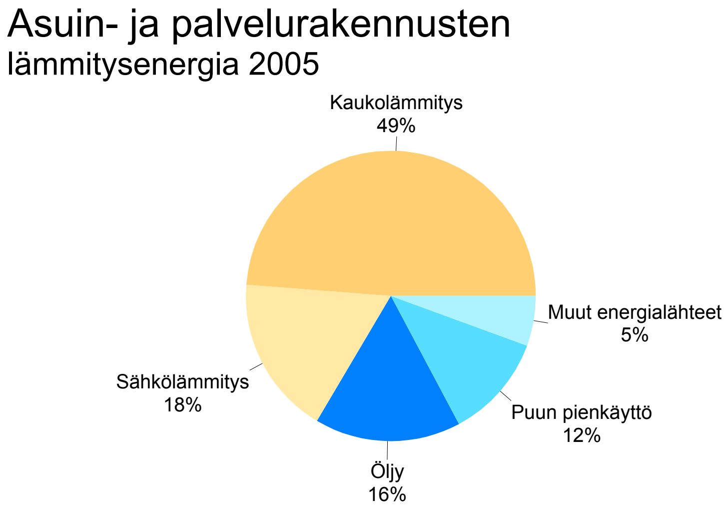
Industry needs heat energy (steam) to maintain its production processes, and it is often useful to produce this heat in conjunction with industrial facilities. In 2005, industry in Finland produced 58.1 TWh of heat (Energy Statistics 2006). This includes heat energy produced by industry for the heating of industrial buildings and for industrial processes.

Most industrial heat (approx. 76% in 2005) is cogenerated when electricity is produced, and this will be discussed in a separate section. The fuels used in the production of industrial heat will be discussed in the section on cogeneration.

4.4 District heating consumption and production

District heating is mainly the centralised production of heat required for heating buildings and hot water, and its distribution for general consumption to large areas, metropolitan districts or whole towns.

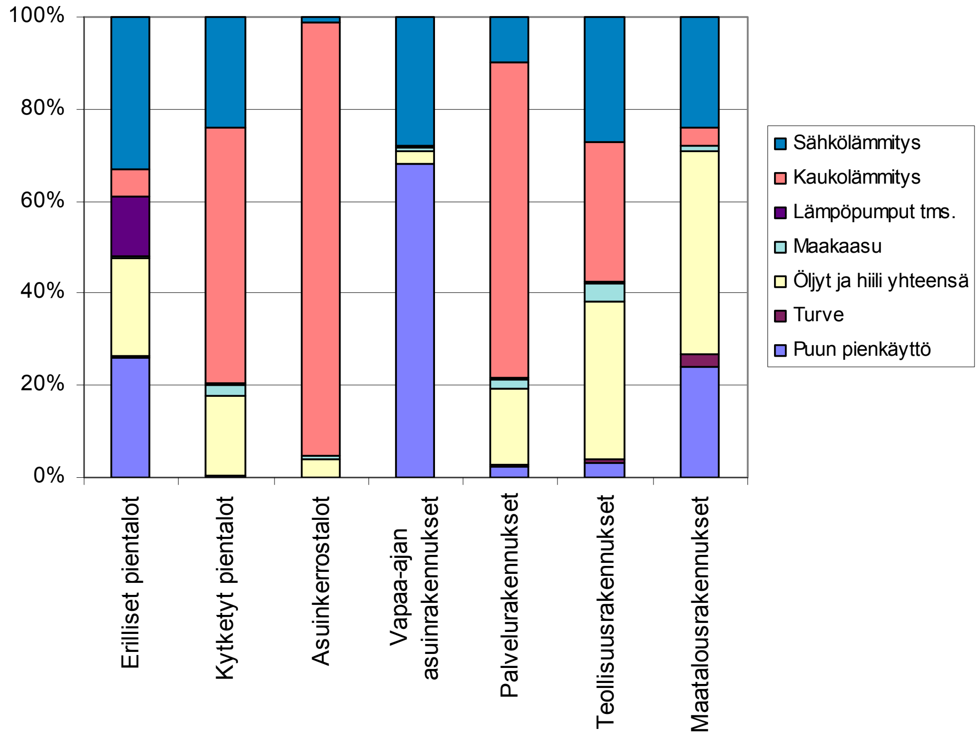
In 2005, 56.1 TWh of heat energy, calculated as useful energy, was used in Finland for the heating needs of residential and service buildings. The share of district heating in the heat energy consumed by residential and service buildings was the greatest (Figure 12).



Asuin- ja palvelurakennusten lämmitysenergia 2005 = Heat energy for residential and service buildings 2005
Kaukolämmitys = District heating
Muut energialähteet = Other energy sources
Puun pienkäyttö = Small-scale use of wood
Öljy = Oil
Sähkölämmitys = Electric heating

Figure 12. Heat energy for residential and service buildings 2005. (Source: Statistics Finland)

The distribution per building type for the relative share of useful energy for building heating methods is presented in the following figure (Figure 13). Nearly half of the residential and service building stock in Finland is connected to district heating. More than 90% of blocks of flats, approximately half of all terraced houses and the majority of public and business buildings are heated by means of district heating. In larger towns, the share of district heating is more than 90%. Altogether, there are 1.2 million homes in Finland that are heated by means of district heating, and a total of 2.5 million people live in them.



Sähkölämmitys = Electric heating
Kaukolämmitys = District heating
Lämpöpumput tms. = Heat pumps, etc.
Maakaasu = Natural gas
Öljyt ja hiili yhteensä = Total oil and coal
Turve = Peat
Puun pienkäyttö = Small-scale use of wood
Erilliset pientalot = Detached houses
Kytketyt pientalot = Semi-detached/terraced houses
Asuinkerrostalot = Blocks of flats
Vapaa-ajan asuinrakennukset = Recreational residential buildings
Palvelurakennukset = Service buildings
Teollisuusrakennukset = Industrial buildings
Maatalousrakennukset = Agricultural buildings

Figure 13. Useful energy for the heating of buildings 2005[3]

The district heating capacity (Figure 14) and the use of district heating in Finland have grown continuously in recent decades. Finland's capacity for district heating has increased by nearly 60% over the last twenty years.

[3] Energy Statistics, 2006 yearbook. The following efficiencies are assumed for the heating energy sources: small-scale use of wood 55%, peat 60%, coal 60%, heavy fuel oil 83%, light fuel oil 78%, natural gas 90% and a factor of 1.5 for geothermal heat. District and electric heating are calculated as useful energy as they stand.

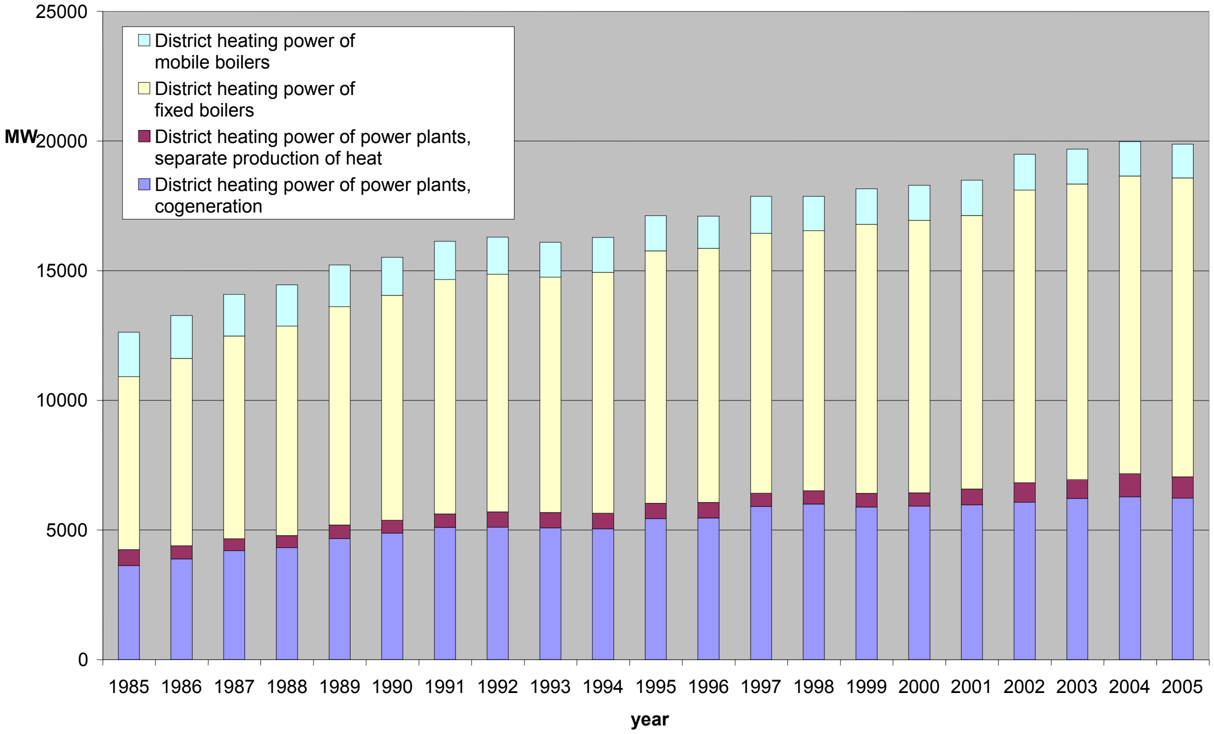


Figure 14. District heating capacity in Finland 1985-2005 (Source: Statistics Finland, 2006).

The net production of district heating in Finland in 2005 was 32 783 GWh. The fuels used for the production of district heating in Finland will be discussed in the section "Cogeneration of heat and power". The production of district heating roughly trebled during the 1976–2004 period. The powerful growth in the production of district heating that dominated the 1970s and 1980s has evened out in recent years, since most potential building stock is already connected to the district heating network. The need for district heating has also been evened out by thorough renovation of old buildings, which reduce the need for heating power thanks to the buildings' improved energy efficiency. The growth in district heating consumption and its share in the energy used for the heating of residential and service buildings are illustrated by Figure 15.

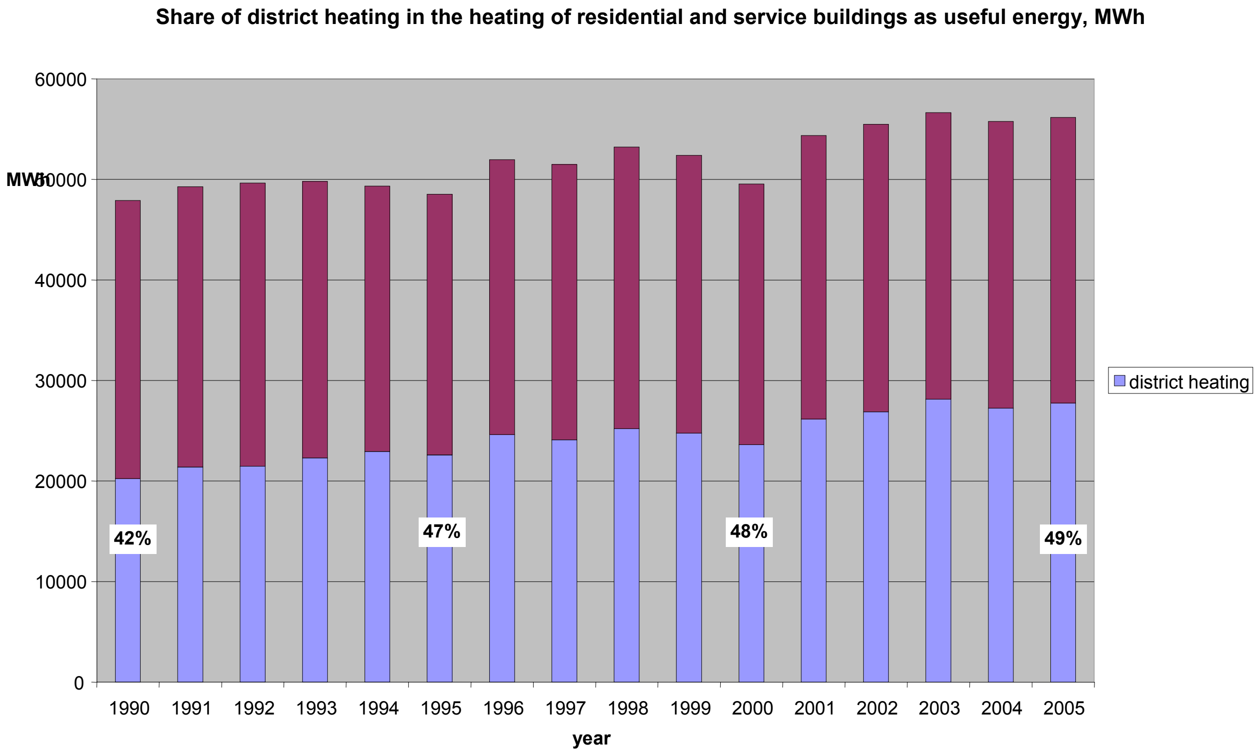


Figure 15. Share of district heating in the heating of residential and service buildings as useful energy, 1990–2005. (Source: Statistics Finland, 2006)

The net consumption of district heating in 2005 was distributed among the sectors such that 56% of consumption was by homes, 34% by other consumer groups, such as public and service buildings, and 10% was by industrial buildings.

District cooling has only been available in Finland for less than ten years. It is currently available in three towns. In 2005, the sale of energy for district cooling amounted to 26 GWh, which is less than one-thousandth of the sale of energy for district heating.

4.5 Cogeneration of heat and power

The cogeneration of heat and power has a significant role in Finland's energy system. It makes energy production more efficient in comparison with separate production. It achieves greater total efficiency, with less fuel use and reduced carbon dioxide emissions.

The basic requirement for the viability of cogenerating heat and power is a sufficiently large, even heating burden. Cogeneration is used in Finland for production to meet the heat and power needs of both industry and communities. Table 6 distinguishes between the cogeneration and separate production of heat and power in 2005, according to production by industry and production from district heating.

Table 6. Cogeneration and separate production of heat and power in Finland in 2005 (TWh) (Source: Statistics Finland, 2006).

	Power		**Heat**	
	Produced from production of industrial heat	Produced from production of district heating	Industrial heat	District heating
Cogeneration	11.3	15.1	44.2	25.3
Separate production	41.4		13.9	7.3
Total	**67.8**		**58.1**	**32.6**

Most of the heat produced by cogeneration in Finland (approx. 64% in 2005) is produced by industry. Approximately three-quarters of the heat produced by industry and that produced by district heating is cogeneration.

Of the electricity produced by cogeneration, a slightly larger part was produced by district heating in 2005 (15.1 TWh) than by industry (11.3 TWh). In total, nearly one-third of Finland's electricity procurement is cogeneration, which produces on average less than 10% of the EU's total electricity procurement.

The trend in the share of cogenerated power in total electricity procurement and its distribution among cogeneration from industry and district heating is illustrated by Figure 16. The figure shows the long-term growth trend for cogenerated power. This appears as growth of both the relative and the absolute share. This growth might continue, but it will no longer be powerful growth since the majority of the centralised heating burden is already cogeneration.

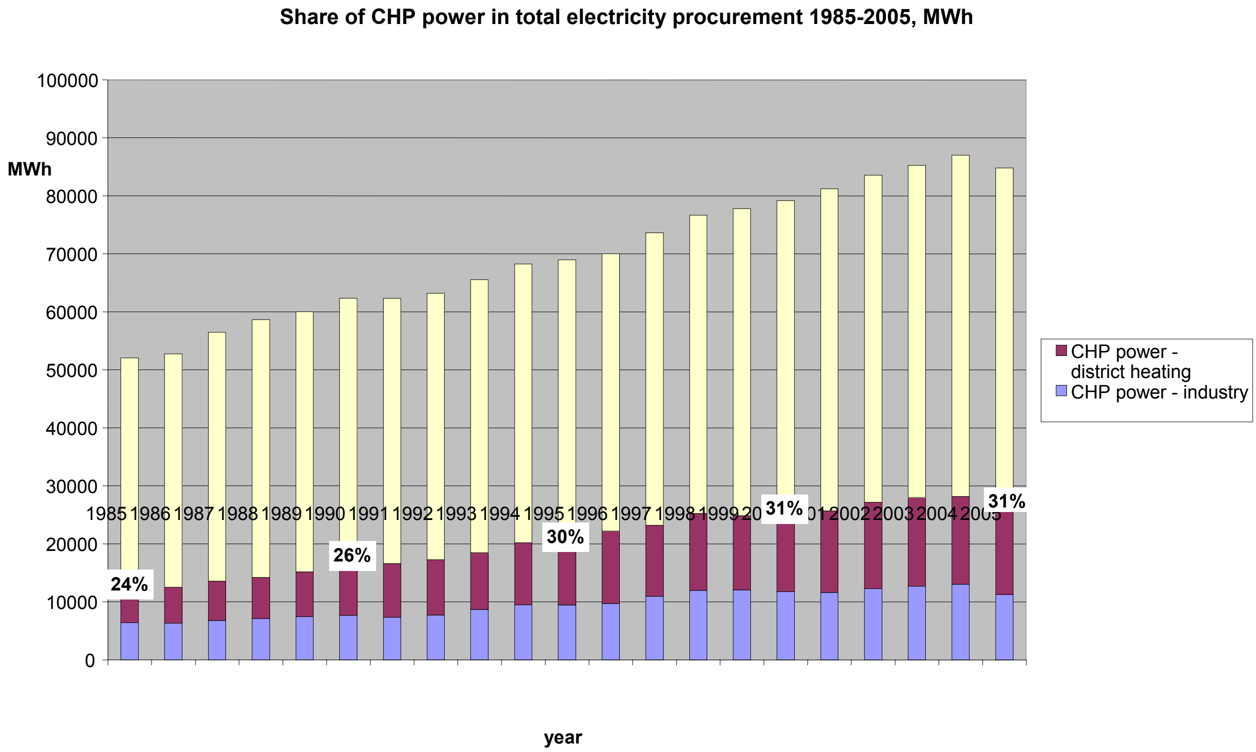


Figure 16. Share of CHP power in total electricity procurement 1985-2005. (Source: Statistics Finland, 2006)

In 2006, the cogeneration of heat and power was connected to the district heating network in 61 towns in Finland. The total capacity of cogeneration of heat and power was 4 180 MW for electricity and 7 050 MW for heat. With regard to district heating power, cogeneration units of over 100 MW account for approximately half the cogeneration capacity for district heating.

The small size category for power plants is also significant for Finland's cogeneration in the district heating sector. In Finland, 40 of the units for the cogeneration of heat and power below 20 MW are connected to the district heating network. Ten of these use oil or coal as their fuel, and the rest use natural gas, biomass or peat. The new units built over the last ten years all use either biomass or natural gas as their fuel. The majority of units that use biomass also use peat. (OPET Report 12: Small-scale biomass CHP technologies, Situation in Finland, Denmark and Sweden.)

Figure 17 presents the trend for the production of district heating in Finland and the share of cogeneration in total district heating production for the years 1985–2005. The share of cogeneration in district heating production has grown continuously. In 2006, as much as 74% of net district heating production was cogeneration of heat and power.

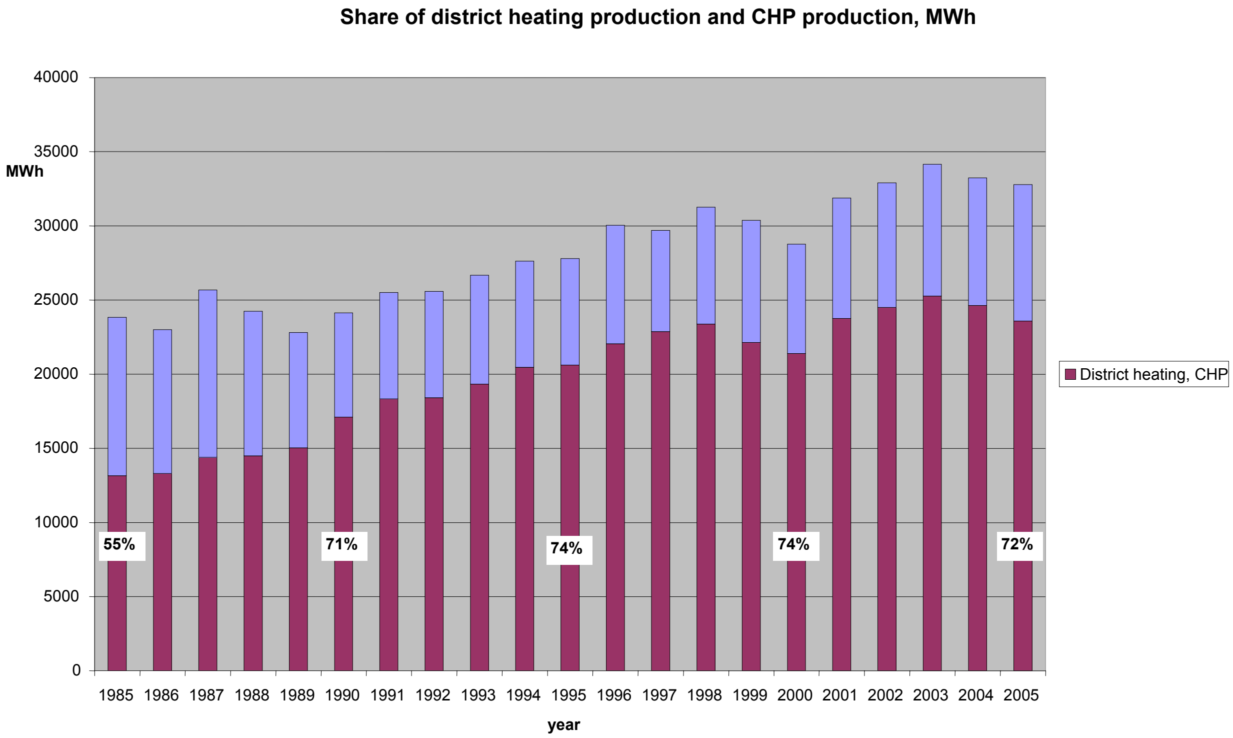
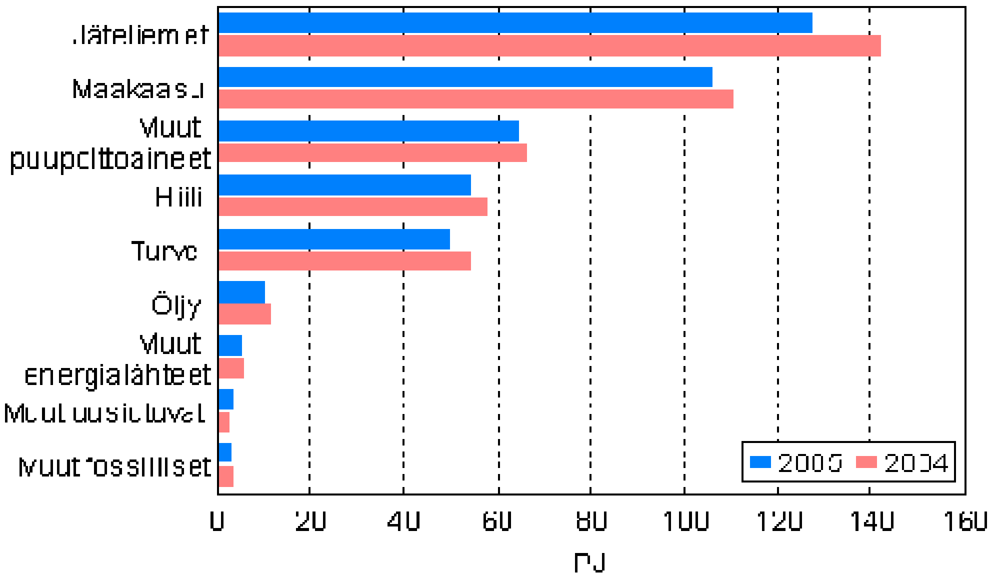


Figure 17. Share of district heating production and CHP production, 1985-2005. (Source: Statistics Finland 2006)

Figure 18 presents the distribution of fuel use for the whole area of the cogeneration of heat and power when both the industrial and the district heating sector are taken into account. The most significant fuel for the whole area of the cogeneration of heat and power is waste liquids originating from industrial production. Waste liquids are used as a fuel in industrial cogeneration, and they are formed as a by-product of the cellulose boiling process in the paper industry. In 2005, waste liquids from the forestry industry were used to produce nearly 51% of the heat generated by industrial cogeneration. By-products from the forestry industry are also currently the largest domestic energy source.



Jäteliemet = Waste liquids

Maakaasu = Natural gas

Muut puupolttoaineet = Other wood-based fuels

Hiili = Coal

Turve = Peat

Öljy = Oil

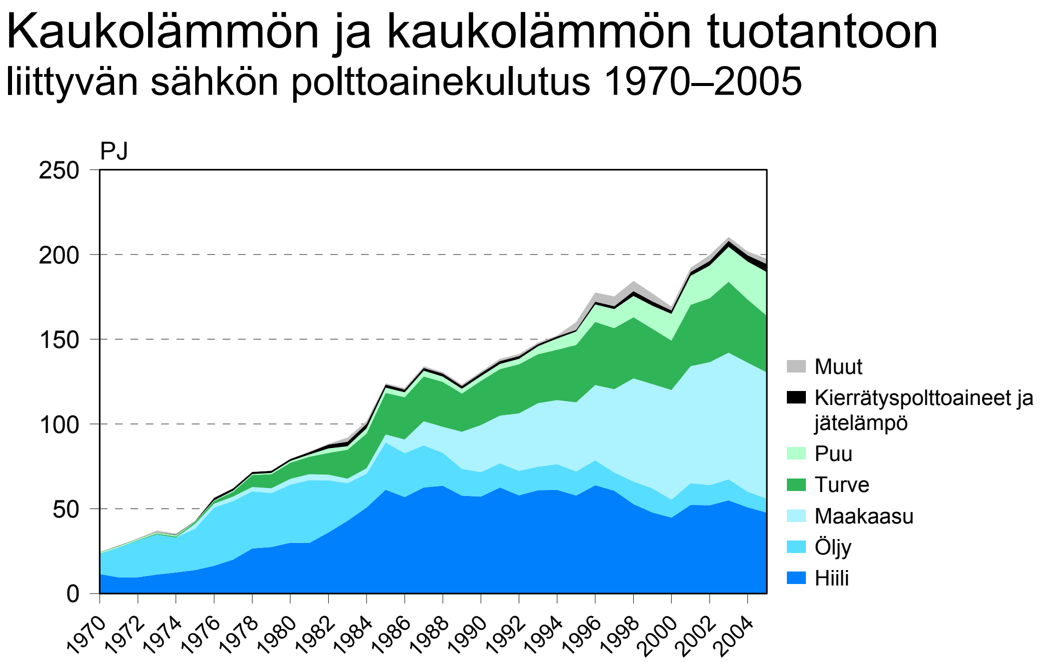
Muut energialähteet = Other energy sources

Muut uusiutuvat = Other renewables

Muut fossiiliset = Other fossil fuels

Figure 18. Fuel use in the cogeneration of heat and power, 2004 and 2005. (Source: Statistics Finland)

The most significant fuels in the production of district heating and power related to district heating are natural gas (39% in 2005), coal (25%), peat (19%) and wood waste and forest chips (total 11%). The most important fuels, natural gas and coal, are imported fossil fuels. The share of natural gas has been growing, and it has been the most significant fuel since the end of the last decade. A significant proportion of the fuels used, totalling 32%, also comprises the domestic fuels of peat, waste wood, forest chips, recycled fuels and industrial waste heat. The share of peat has stayed at approximately 20% for a long time, and instead there has been growth in the consumption of wood waste and forest chips. Figure 19 illustrates the distribution of fuel consumption for district heating and power related to district heating for different fuels in the 1970–2005 period.



Kaukolämmön ja kaukolämmön tuotantoon liittyvän sähkön polttoainekulutus 1970-2005 = Fuel consumption for district heating and power related to the production of district heating, 1970-2005
Muut = Other
Kierrätyspolttoaineet ja jätelämpö = Recycled fuels and waste heat
Puu = Wood
Turve = Peat
Maakaasu = Natural gas
Öljy = Oil
Hiili = Coal

Figure 19. Fuel consumption for district heating and power related to the production of district heating, 1970–2005. (Source: Statistics Finland)

There is regional fluctuation in Finland regarding the fuel used for district heating and power related to the production of district heating. In the area of the natural gas network, natural gas is the main fuel for district heating, coal is used in large coastal towns, and peat is mainly used in large areas of peat.

The capacity of industrial cogeneration units to produce power was 3 380 MW in 2005. Almost 80% of industrial heat production is based on heat produced at cogeneration units. The production of industrial cogenerated heat is primarily based on waste liquids from the forestry industry, the share of which is half of all fuels used (Table 7). Other wood-based fuels are the next most important source of energy. For cogeneration, natural gas is the most commonly used fossil fuel, and its share also exceeds that of peat use.

Table 7. Production of industrial heat, 2004 and 2005[4].

Production of industrial heat per production type and fuel in the period 2004–2005		Cogeneration of heat and power[a]		Separate production of heat[b]	
		TWh	TWh	TWh	TWh
		2004	2005	2004	2005
Cogeneration of heat and power					
	Coal[c]	1.7	1.6	0.3	0.3
	Oil	1.6	1.4	4.8	4.7
	Natural gas	6.2	5.7	1.9	1.6
	Other fossil fuels[d,e]	0.4	0.3	0.2	0.0
	Peat	3.8	3.5	0.6	0.7
	Waste liquids from the forestry industry	24.9	22.4	0.2	0.0
	Other wood-based fuels	9	8	2	2
	Other renewables[d,f]	0.3	0.4	0.1	0.1
	Other energy sources[g]	1.0	0.8	3.6	4.6
	Total	**48.8**	**44.2**	**13.5**	**13.9**

a) Cogeneration of heat and power includes pure cogeneration

b) Reduction heat produced during condensate production and cogeneration are included in separate production of heat.

c) In addition to coal, coal includes blast furnace and coke gases, as well as coke.

d) Hybrid fuels (such as recycled fuels) are classified as renewables and fossil fuels in relation to the fossil and biodegradable coal that they contain.

e) Other fossil fuels includes, among other things, artificial fuels, other waste fuels and the fossil-fuel proportion of hybrid fuels.

f) Other renewable fuels includes, among other things, wood-based fuels, the biodegradable proportion of hybrid fuels, and biogas.

g) Other energy sources includes hydrogen, electricity and reaction and secondary heat from industry.

The pulp and paper industry is the most significant producer and consumer of industrial heat. In 2004, the pulp and paper industry used a total of 79.7 TWh in fuel and its need for process heat was 52.0 TWh, so its share of process heat was more than 80% of the total production of industrial heat (62.3 TWh). Similarly, the production of electricity by the pulp and paper industry in 2004 was 12 TWh, which was 92.3% (13.0 TWh[5]) of all electricity cogenerated by industry.

5 Assumptions of the analysis

The evaluation of the potential for cogeneration in Finland presented in this report is based on the calculations set out in the consultancy report by Gaia Oy (Gaia Oy 2007). The background scenario for Finland's energy future was used as the basis for the calculations. The background scenario will be presented and justified in this chapter, so that it is possible to examine the background assumptions to the analysis.

The report compares the most recent evaluations of the potential for cogeneration, including the evaluation presented in the WM scenario of the National Energy and Climate Strategy (ECS 2005). The assumptions made when preparing the strategy are discussed in the background memorandum to the strategy. The analysis also uses statistics about the current structure of Finland's energy production and consumption, and its development, as discussed in Chapter 4.

[4] Source: Statistics Finland

[5] Source: Statistics Finland

5.1 Social premises

In the background to the evaluation of the future of cogeneration and of district heating and cooling, there is a scenario in which Finland's energy policy is strongly guided by the following basic political assumptions in accordance with the available or predicted guidelines.

With regard to greenhouse gas emissions, a 20% reduction in emissions by 2020 from the 1990 level has been agreed at EU level[6]. The reduction in emissions is assumed to continue such that greenhouse gas emissions in 2050 in the EU are 50% of the 1990 level[7]. Finland is assumed to have a 10% reduction in emissions by 2020 and a further 40% by 2050 when the 1990 level is used as the basis for comparison.

A second key theme within the framework of political decision-making is seeking to increase self-sufficiency in energy and to keep security of supply at the current level. In order to meet the target, it is assumed that the share of domestic fuels (peat, wood, field biomass, recycled fuels) in energy production will increase significantly from the current level.

The third theme of the energy policy is the availability of fairly priced energy in order to preserve national competitiveness. It is consequently assumed that no sources of energy that are emission-free, low on emissions or emission-neutral, including nuclear power, will be excluded from the energy production options.

Economic growth is also assumed to remain moderate, even if the growth rate is assumed to slow down. Annual growth in 2030 will be at a level of approximately 2.3%, and it will be approximately 1.7% in 2050.[8]

5.2 Changes in energy consumption

5.2.1 Slowing growth of energy consumption

The growth in energy consumption is assumed to be tempered by fiscal means. Fuel tax and electricity tax are assumed to increase and to be one and a half times the 2000 level by 2030.[9] Electricity consumption is assumed to increase at a calmer rate than previously, owing to the targets for reducing greenhouse gas emissions, work to temper the growth in energy consumption and an increase in energy efficiency. On the other hand, the need for cooling is expected to increase. For example, previous reports assumed district cooling to grow potentially to 2.6 TWh by 2030.[10]

5.2.2 Improving the energy efficiency of buildings

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[6] EU decision at the summit of 8–9 March 2007.
[7] The decisions by the Presidency at the summit of the European Council of 8/9 March 2007 state that developed countries should collectively reduce their emissions by 60-80% from the 1990 level. For example, Great Britain has reported a target reduction of 60% and Norway will have a neutral situation for CO_2 emissions by 2050.
[8] National climate change implementation strategy, Ministry of Agriculture and Forestry, MMM 1/2005. The estimates presented are based on the basic scenario for the estimates made in the Silmu programme (Finnish Research Programme on Climate Change).
[9] Energy Visions 2030, VTT Technical Research Centre of Finland, 2003.
[10] Energy Visions 2030, VTT Technical Research Centre of Finland, 2003.

When evaluating the potential for district heating and associated cogeneration, the heating needs of buildings play a key role. Heat consumption by buildings can be considered to comprise the following components:

- building stock expressed in cubic metres;
- typical heat consumption of building stock;
- the need for heating as a difference in temperature.

The building stock can be divided roughly into residential buildings and commercial premises, which are service buildings as well as production and other buildings. Population trends, changes to the population structure and family size, and changes in living space will have an impact on the number of cubic metres necessary for residential building stock.

Finland's population is estimated to increase up to 2028, when the population will be 5.45 million, and after that point it will fall.[11] Living space is assumed to increase from 36.6 m² per capita in 2005 to 44 m² per capita in 2025[12] and from then on at the same rate. The annual loss of residential buildings is assumed to be 0.4%. Other net growth in the amount of building stock is assumed to be on average 0.6% a year. The values thus obtained for changes to building stock up to 2050 are presented in the figure (Figure 20).

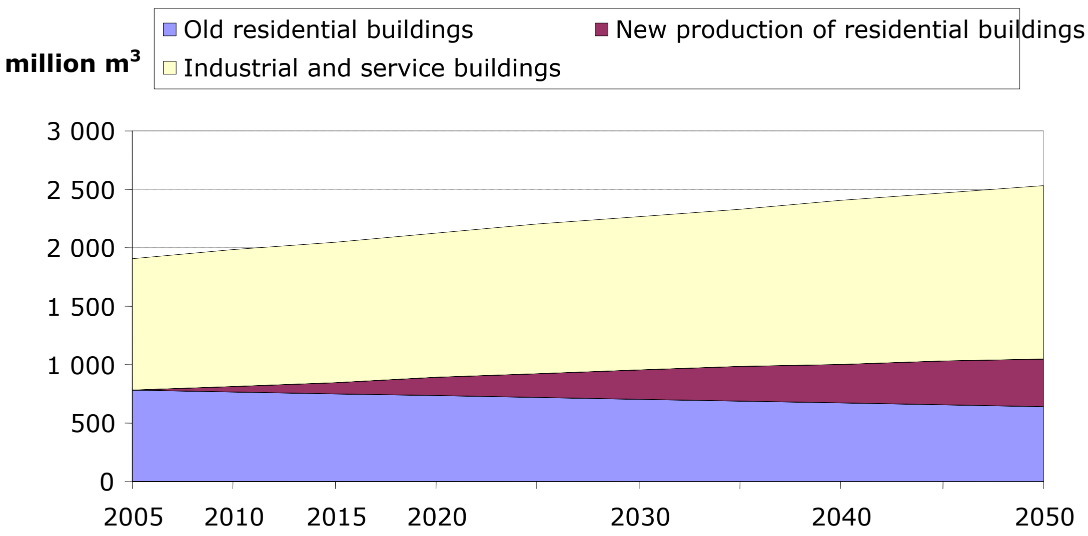

Figure 20. Trend in the building stock for residential buildings, divided into new production and old residential buildings, and trend in the building stock for industrial and service buildings.

The typical heat consumption of building stock might fall significantly thanks to the more stringent standards and renovations of new buildings. The trend in the typical heat consumption of building stock is affected by renovations to and the loss of existing building stock, the development of new building stock and changes to the typical heat consumption of renovated and new buildings.

[11] Population forecast, Statistics Finland, 2004.
[12] House building for 2025 and 2005, VTT Technical Research Centre of Finland.

The typical heat consumption of buildings can be reported, assuming that there are normal climatic conditions, as an energy need for the capacity. In so-called low-energy houses, the share of energy necessary for heating the buildings has fallen considerably, in addition to other energy consumption. For example, using current solutions, there may even be a fall of approximately 70% from the normal current level[13]. The share of low-energy houses is assumed to grow, so that by 2030 more than 50% of new homes built will be low-energy houses[14] and this share will grow to 70% by 2050. The energy efficiency requirements are also assumed to lead to technological development, thanks to which the typical heat consumption of both low-energy houses and other new production might fall at an annual rate of slightly more than one percentage point, and this is assumed also to include improvements brought about by renovations. On the basis of these assumptions, the typical heat consumption of the entire building stock might fall by an average annual rate of approximately one percentage point, which corresponds to the historical trend. Figure 21 presents the trend in typical heat consumption.

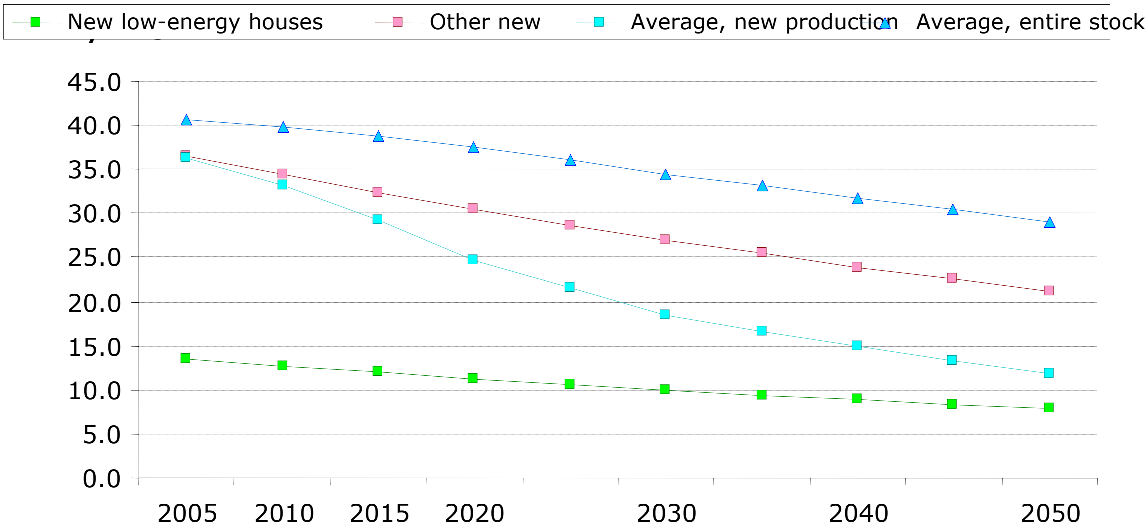

Figure 21. Predicted trend in the typical heat consumption for new production and the entire building stock.

5.2.3 Climatic warming

Thanks to climate change, the average temperature in Finland is assumed to increase by 2.3 degrees by 2030 and by 3.2 degrees by 2050 in relation to the average value for the years 1961–1990. The change will be greater in winter than in summer, as is indicated by the values in the figure (Figure 22).[15]

[13] Energy Use, Visions and Technology Opportunities in Finland, VTT Technical Research Centre of Finland, 2007.
[14] Environmental technology forecast, Sitra, 2006.
[15] National Strategy for Adaptation to Climate Change, Ministry of Agriculture and Forestry, MMM 1/2005. The values presented are based on the average values in the scenarios set out by the Intergovernmental Panel on Climate Change (IPCC) and on monthly changes calculated on the basis of quarterly changes.

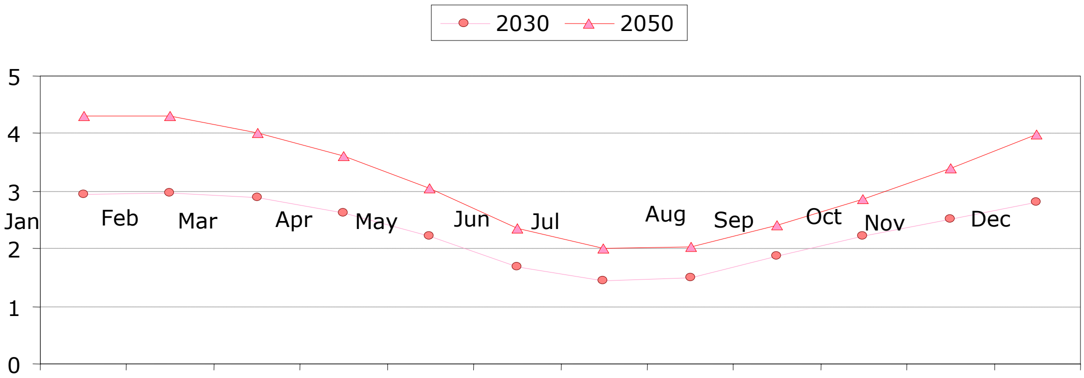

Figure 22. The impact of climatic warming predicted by the IPCC on the monthly average temperatures for the years 1971–2000.

The need for heating is generally measured using heating need figures that describe the difference between the outside temperature and the target inside temperature. The need for heating does not include heat generated from waste heat produced by humans and devices. The figure below presents the change in the heating need figures when the climatic warming predicted by the IPCC's scenarios is taken into account (Figure 23). On the basis of the calculations from the scenarios, the need for heating might fall by approximately 12% by 2030 and by approximately 16% by 2050 in comparison with the average need for heating in the years 1961–1999[16].

[16] The share for hot water is assumed to be 30% of total heating energy. Earlier calculations resulted in forecasts in a similar direction. According to the Finnish Meteorological Institute, the reduction in the need for heating would be 10–14% over the next 50 years. Website of the Finnish Meteorological Institute, read on 15 June 2007.

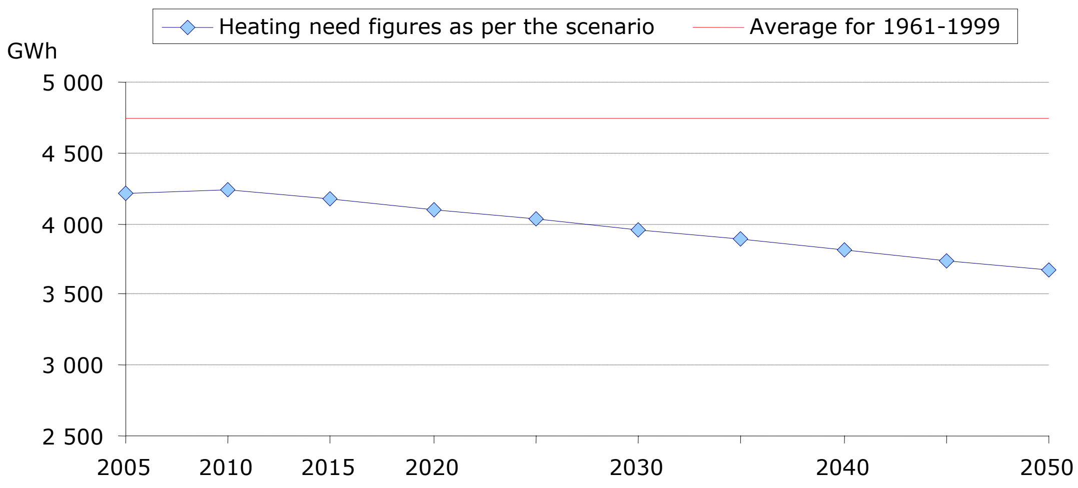

Figure 23. Calculated change in the heating need figures based on the IPCC's climate change scenarios, averaged for the whole country. The average values for the years 1961–2000 are the basis for comparing the change in average temperature[17]. The figures for 2005 are actual, and the others are predictions.

5.3 Energy sources

The real growth in fossil fuel prices is assumed to be moderate. There are not assumed to be any significant changes in the price relationships of different fuels by 2030. The availability of fossil fuels is assumed to remain good[18].

The price of electricity in Finland is approaching the price level in the rest of Europe, where the price of electricity will rise from the current level as a result of the targets to reduce emissions and a rise in the price of fossil fuels. The average values for changes in the costs of producing electricity based on natural gas and coal by 2030 will fluctuate by 20 – 50%[19].

Renewable energy sources and cogeneration will be encouraged and their competitiveness will be ensured by means of different support mechanisms, so that the set targets for reducing emissions are met. The EU has set a binding target according to which the share of renewable energy in the EU's total energy consumption would be 20% by 2020.[20] Separate oil-fired boilers will ordinarily be replaced by biofuel power plants or by woodchip and biofuel oil boilers when the old units reach the end of their working life[21].

[17] In some cases for 1961–1999, for technical reasons.
[18] World Energy Outlook, IEA, 2006.
[19] Energy Policy Data, EU, 2007. Information on the cost structure based on the IEA's report Energy Technology Perspectives, 2006, which takes into consideration changes in technology, a moderate rise in the cost of fuels and a CO_2 emissions charge of EUR 20 – 30/tonne.
[20] EU decision at the summit of 8–9 March 2007.
[21] Government programme, 19 April 2007.

5.4 Technological options

5.4.1 Choices of heating methods

It is assumed that the fact that fossil fuels are becoming more expensive and the action being taken to limit emissions caused by the use of fossil fuels for heating will serve to weaken their relative competitiveness. However, the same cost pressures will also target the production of electricity and district heating. The cheapest of the current heating methods would appear to be increasing the small-scale combustion of biofuels, for example in the form of wood or pellets, and an increase in different heat pumps. In the light of the current guidance mechanisms, however, demand for biomass must also be assumed for different industrial sectors and different intended purposes, and also for exports to guide the different support mechanisms to be implemented by other countries. This may increase the domestic price of biomass significantly, which could check the spread of its use.

The number of heat pumps has grown powerfully – from 300 heat pumps sold in 1994 to approximately 37 000 sold in 2006. The total number of heat pumps at the end of 2006 was estimated to be roughly 110 000[22]. However, the proportion of heat pumps in Finland is still small in comparison with Sweden, where there were estimated to be a total of 265 000 heat pumps at the end of 2003, and 444 000 different heat pumps at the end of 2005[23].

Reducing the typical heat consumption of new buildings will also have an impact on the grounds for the choice of heating method. Because the need for heating energy early on in a building's life cycle is relatively lower than previously, it is not worth investing large amounts in the heating infrastructure for low-energy houses. In the near future, the increase in low-energy construction and heat pumps will probably cause the position of electric heating to rise, at the expense of other forms of heating. For this reason, support for low-energy construction in future may be restricted by energy efficiency that is weaker from the perspective of primary energy costs[24].

The competitiveness of district heating implemented by large units as a choice of heating method for detached, semi-detached and terraced houses is basically affected by the location of the place of residence. The assumed increasing density of the community structure achieved by migration from north to south and from small settlements to large ones might keep the position of district heating stable throughout the country, irrespective of any other changes in the competition field. District heating is assumed to be chosen for on average 47% of building space for new buildings[25].

5.4.2 Cogeneration technology

[22] The Finnish Heat Pump Organisation, Numbers of heat pumps in Finland 1973 – 2004.
[23] Energy statistics for detached houses, SCB Statistics Sweden, 2005.
[24] See for example "How to build an energy-efficient house – Energy use and supply for buildings from a system perspective", Swedish District Heating Association, 2006.
[25] This value is based on the assumption that district heating is selected as the heating method in new buildings for 20% of private homes (average value of 15% for 2005 and 2006), 60% of terraced and other conjoined or semi-detached houses (55%) and 97% of blocks of flats (97%). The choices of heating methods are weighted in accordance with the number of new buildings forecast in the report by the Tampere University of Technology, "Energy Consumption of Buildings and CO_2-Equivalent Emissions in Finland, 2005. According to the estimates, nearly 60% of new buildings will be detached houses, which explains the relatively small overall share of district heating.

Traditional forms of energy production technology, such as combined cycle gas turbines, steam backpressure turbines, steam condensing extraction turbines, gas turbines and internal combustion engines, are developing at the current rate. Thanks to this trend and to new forms of technology, such as the Integrated Gasification Combined Cycle (IGCC) and the Natural Gas Combined Cycle (NGCC)[26], the power to heat ratio might improve, so that[27] the power to heat ratio for power plants with fuel efficiency of more than 100 MW reaches a value of 1.0 by 2020 and 1.2 by 2030 in new power plants. The power to heat ratio for power plants with fuel efficiency of less than 100 MW will reach a value of 0.9 by 2020 and 1.0 by 2030 in new power plants. The trend in the power to heat ratio may be restricted by a change in the range of fuels available when waste and wood combustion is increased, for example. It is also assumed that small generators with fuel efficiency of less than 1 MW, such as microturbines, fuel cells and Stirling engines, will come onto the market in the 2010–2020 period.

[26] IGCC = combined power plant based on solid biomass gasification, NGCC = combined natural gas power plant
[27] Energy Visions 2030, VTT Technical Research Centre of Finland, 2003.

6 Potential for increasing cogeneration

6.1 Cogeneration, district heating and cooling for towns

6.1.1 Potential for district heating

In this project, the potential for district heating has been clarified by means of a questionnaire sent to all the district heating companies in Finland[28]. 42 companies responded to the questionnaire and they represented approximately three-quarters of national district heating consumption and approximately 85% of cogeneration. The results of the questionnaire were presented by scaling the responses to match the national figures from the 2005 production or consumption data, unless otherwise stated. Where necessary, the incomplete answers of individual respondents were completed by assuming them to be in a continuing growth trend.

The table (Table 8) presents the value of growth in the national demand for district heating until 2050, obtained on the basis of the district heating companies' views. This is also illustrated by the figure (Figure 24). The players' views have also been compared with the trend in demand for district heating obtained using calculations on the basis of the background scenario and with certain other scenarios that have recently been presented elsewhere. The growth in demand for district heating according to the views of the players in the sector is more powerful than in the previous scenarios.

The values for the consumption of district heating obtained using calculations on the assumption of the background scenario deviate even more clearly from the views of players in the sector, irrespective of the fact that, when they responded to the questionnaire, the players did in practice have the key assumptions of the background scenario. In the view of the players in the sector, the consumption of district heating will continue to grow in the future until 2050, when consumption will start to fall after 2020 in the background scenario[29]. The significant differences between the views of the players in the sector and the background scenario may therefore be caused by differences in the assumptions relating mainly to climatic warming or the consumption of heating energy by buildings.

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[28] The questionnaire was implemented as an Internet survey for corporate district heating members of the energy industry in May 2007. The questionnaire is presented in Annex 1.

[29] Energy Visions 2030, VTT Technical Research Centre of Finland, 2003. The value presented nearly corresponds to a change to the Techno scenario in this work.

Table 8. Trend in the demand for district heating according to the background scenario, players in the district heating sector, the MTI's WM scenario and the VTT's Energy Visions 2030 report.

[TWh]	Background scenario	View of players in the sector	MTI's WM scenario	VTT Energy Visions
2005	29.8	29.8	29.8	
2010	31.6	32.6	30.1	
2015	32.1	33.8	31.2	
2020	32.3	34.9	32.3	
2030	32.0	36.5		30.5-36.3
2040	31.2	37.4		
2050	30.1	38.4		

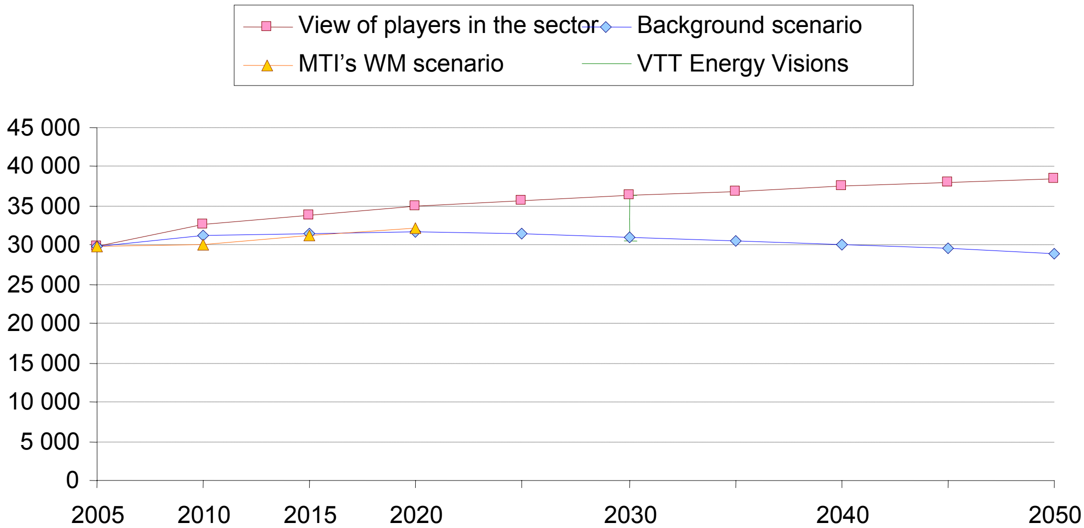

Figure 24. Trend in the demand for district heating according to the background scenario, players in the district heating sector, the MTI's WM scenario and the VTT's Energy Visions 2030 report.

6.1.2 Potential for district cooling

The factors that affect demand for district cooling include the need for cooling, the extent of district cooling networks and the relative competitiveness of district cooling in comparison with other cooling methods. The climatic warming that has been forecast will also increase the need for cooling in the Finnish climate and as people become more affluent there might be an increase in the use of cooling for comfort. The relative competitiveness of district cooling is significantly affected by the extent of network investment that it requires and of other initial investments.

Since district cooling is clearly a younger sector than district heating, it is challenging to perform long-term forecasts or estimates. The growth potential of district cooling has even been assessed by previous reports to be 2.6 TWh by 2030[30] and the size of the whole market to be approximately 3.5 TWh in 2030[31]. The view of players in the sector on the development of district cooling is presented in Figure 25. The value presented is scaled for the whole country in accordance with the relative share of district heating production that the respondent companies have. On the basis of this estimate, the quantity of district cooling in 2030 would be approximately 1 TWh, which would correspond to approximately a quarter of the total market for cooling.

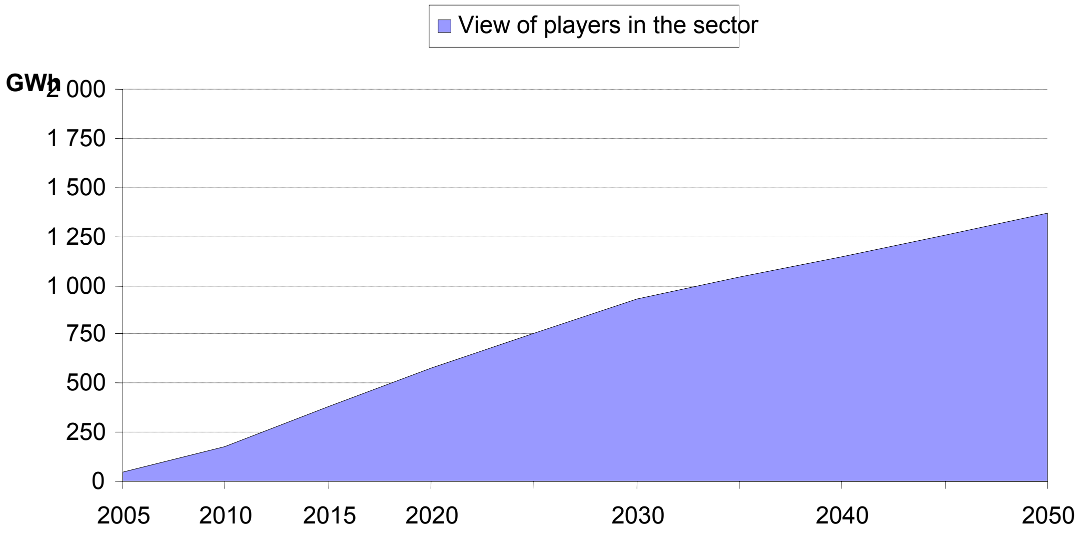

Figure 25. View of players in the sector concerning the trend in the demand for district cooling.

6.1.3 Potential for cogeneration for towns

Figure 26 presents the addition of new investments in heat and power production on the basis of the questionnaire sent to the district heating companies, as well as the net value added to heat and power production produced by cogeneration by 2020 obtained from the questionnaire. Both new investments and the net increase have been scaled in proportion to the share in heat and power production that the respondents to the questionnaire have. The difference between the new investments and the net increase should be described by the proportion of cogeneration losses. Approximately 1.5 TWh of electricity production and 2.5 TWh of heat production will be lost, which clearly remains below the estimates made on the basis of the working life of the former power plant stock[32].

[30] Energy Visions 2030, VTT Technical Research Centre of Finland, 2003.

[31] Technical measures for reducing HFC and PFC compounds and SF_6 emissions and their costs in Finland, VTT Technical Research Centre of Finland, 2001.

[32] Energy Use, Visions and Technology Opportunities in Finland, VTT Technical Research Centre of Finland, 2007.

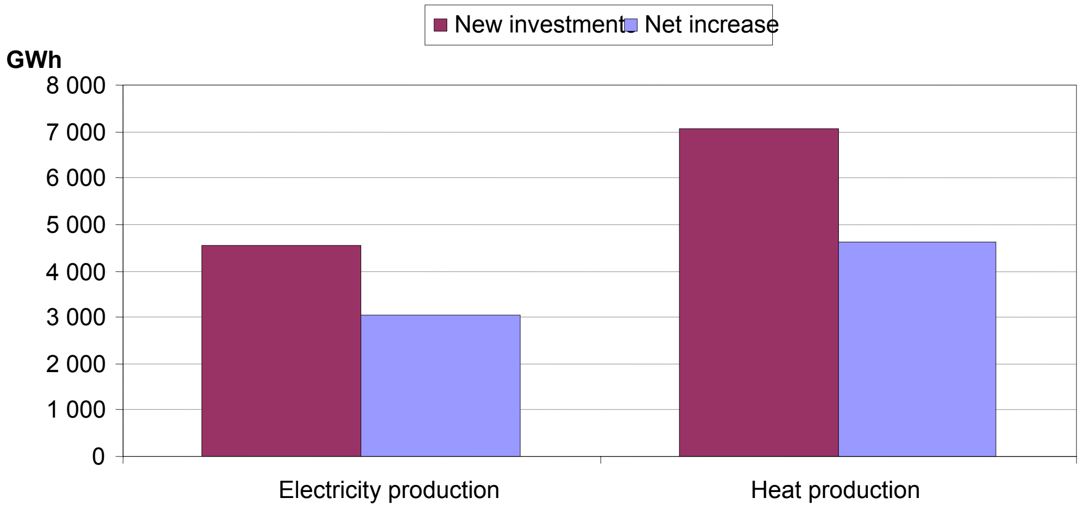

Figure 26. New investments and net increase for electricity and heat produced by cogeneration for the quantities of energy produced annually in 2020.

The view of the district heating companies concerning the potential for heat and power cogeneration in connection with the production of district heating for towns is presented below (Table 9 and Figure 27). The share of cogeneration in total district heating production will increase slightly is from approximately 72% in 2005 to approximately 73–74%. The quantity of heat produced by cogeneration is estimated to increase powerfully until 2030, after which point it is estimated that the growth will slow down. Similarly, the quantity of electricity produced by cogeneration is estimated to increase annually in a similarly powerful way until 2030, but only by 0.4 TWh from 2030 to 2050.

Table 9. Estimate of the quantities of heat and power produced by cogeneration, and the growth percentages, in the view of the district heating companies.

	Cogenerated power		**Cogenerated heat**	
	TWh	**growth %**	**TWh**	**growth %**
2005	23.6	-	13.9	-
2010	25.8	10%	16.0	15%
2015	27.1	15%	16.4	18%
2020	28.3	20%	16.9	22%
2030	29.7	26%	17.7	27%
2040	30.3	29%	17.9	29%
2050	30.9	31%	18.1	30%

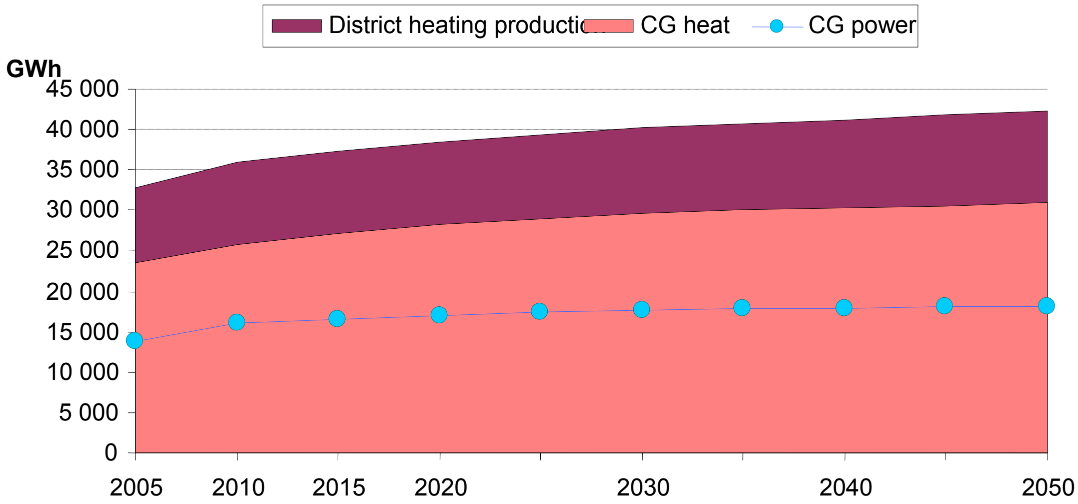

Figure 27. Scenario for the quantities of heat and power produced by cogeneration in comparison with total district heating production, based on the views of the district heating companies[33].

The predicted growth scenario for cogenerated power, produced on the basis of the views of the district heating companies, is compared below (Figure 28, Table 10) with the trend in demand for district heating obtained using calculations based on the background scenario and on certain scenarios that have recently been presented elsewhere[34]. It must be emphasised that although demand for district heating grew significantly more powerfully than the background scenario in the view of the players in the district heating sector, the quantity of electricity produced by cogeneration will clearly grow more slowly than the background scenario in the sector's view. According to both the district heating companies and the background scenario, the share of electricity produced by cogeneration will clearly remain below that of previous reports.

Table 10. Trend in electricity produced by cogeneration in accordance with the background scenario, players in the district heating sector, the MTI's WM scenario and the VTT's Energy Visions 2030 report.

[TWh]	Background scenario	View of players in the sector	MTI's WM scenario	VTT Energy Visions
2005	13.9	13.9	-	-
2010	15.3	16.0	18.0	-
2015	16.3	16.4	19.5	-
2020	17.2	16.9	20.9	-
2030	18.9	17.7	-	16.0 – 27.7
2040	20.6	17.9	-	-

33 District heating production is calculated on the basis of cost estimates for district heating, assuming that the net cost corresponds to approximately 91% of production when network and measurement losses have been deducted.

34 For calculating the background scenario, it has been assumed that the share of cogeneration will increase by approximately 79% by 2050 and renewables from cogeneration units will increase at an average annual rate of 2%. The average power to heat ratio of new units is also assumed to increase in accordance with the background scenario to 1.0 by 2020 and to 1.2 by 2030.

2050	22.1	18.1	-	-

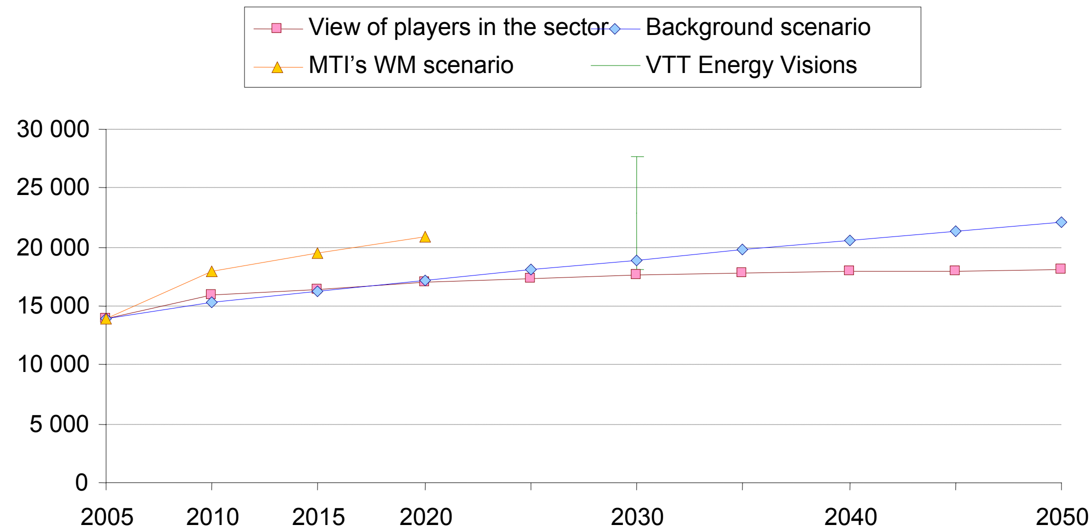

Figure 28. Trend in electricity produced by cogeneration in accordance with the background scenario, players in the district heating sector, the MTI's WM scenario and the VTT's Energy Visions 2030 report.

6.2 Industrial cogeneration

It is challenging to estimate the trend in cogeneration used for industrial process heat production because of the uncertainties caused by changes to industrial buildings. In an increasingly globalised operating environment, companies ideally aim their investments at low costs on the one hand and low risk on the other. However, the decisions made by each company are based on their subjective assessment of the situation, which makes it more difficult to estimate the trend in relation to the predicted cost of district heating for towns. For energy-intensive sectors, the investments are long-term when the existing structures change slowly under normal conditions.

The estimated trend in industrial cogeneration and the corresponding figures and growth percentages are presented below (Table 11, Figure 29). Most industrial cogeneration is connected to processes in the pulp and paper industry, which account for approximately 80% of all industrial cogeneration. When estimating the trend, it has been assumed that the availability of raw materials will not restrict production and associated energy production. The value presented for industrial cogeneration is based on the outlooks presented previously for up to 2020[35], after which the trend is assumed to continue in relation to the predicted economic growth and the assumed improvement in energy efficiency.

[35] Scenarios used in the preparation of the national energy and climate strategy, Ministry of Trade and Industry, 2005. The calculations for the WM scenario are used as the basis for comparison.

Table 11. Trend in the heat and power produced by industrial cogeneration, in accordance with the background scenario.[36]

	Cogenerated heat		Cogenerated power	
	TWh	**growth %**	**TWh**	**growth %**
2005	44.2		13.0	
2010	47.7	8%	14.3	3%
2015	48.7	10%	15.1	9%
2020	49.7	12%	15.9	15%
2030	48.8	10%	16.6	20%
2040	47.6	8%	17.1	23%
2050	45.7	3%	17.4	25%

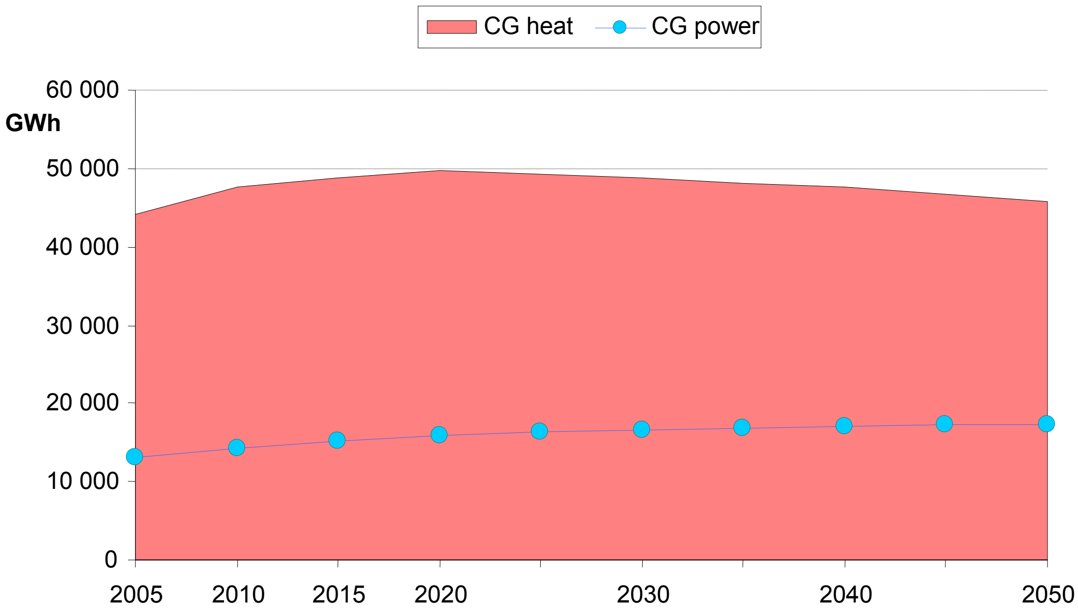

Figure 29. Estimated trend in the heat and power produced by industrial cogeneration.

The quantity of heat produced by industrial cogeneration is estimated to grow until 2020, after which point the assumed increase in energy efficiency and slowing of the economic trend will even out consumption at largely the same level, irrespective of any increased growth in production. Instead, the assumed improvement in the power to heat ratio of production units achieved by technological development when power plant stock is renovated will still increase the quantity of electricity produced by cogeneration even after 2030.

[36] 2004 is used as the basis for comparison, owing to the industrial conflict in the forestry industry in 2005.

6.3 Sources of energy for cogeneration

The distribution of energy sources for the new investments reported by the district heating companies up to 2020 is presented in the figure (Figure 30). The share of natural gas is estimated to be greater in the new investments, corresponding to approximately 37% of all new heat production. The share of peat will be slightly less than one third in the new objects of investment, and that of wood and other solid biomass will be approximately one quarter. On the basis of the responses, the final share will be intended to be covered mostly by waste and recycled fuels; biogas and biofuel oils will also have a marginal share.

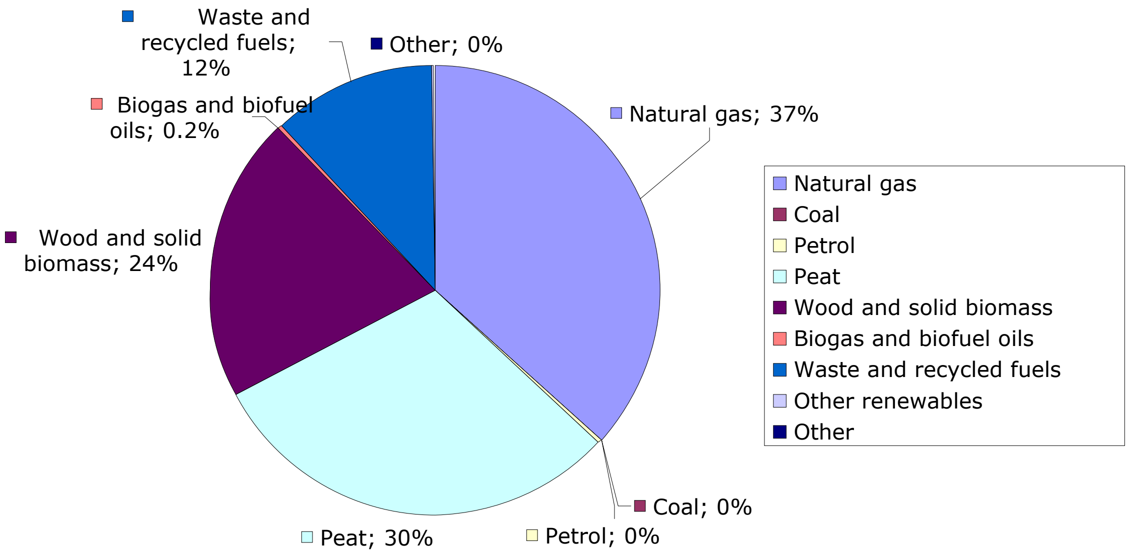

Figure 30. Estimate by the district heating companies of the shares of energy sources used for the production of heat energy at new units up to 2020[37].

The shares of new investments do not seem to reflect directly the estimates by the district heating companies relating to the trend in the relative shares of energy sources, which are presented below (Figure 31). Of the fossil fuels, the relative share of coal appears to clearly fall, but the share of natural gas is also slightly lower. Instead, the relative share of wood and other solid biomass is estimated to grow significantly, as will waste and recycled fuels. Some of the growth in renewable energy sources appears to be at the expense of fossil fuels and natural gas. The relative share of peat is expected to grow moderately. The share of other renewable energy sources, such as geothermal heat, heat from seawater, solar heat and hydrogen, in cogeneration energy sources is also estimated to be small in 2050.

[37] With regard to new investments, the results of the questionnaire have been completed using other material from the questionnaire and other information available from sources that are available to the public.

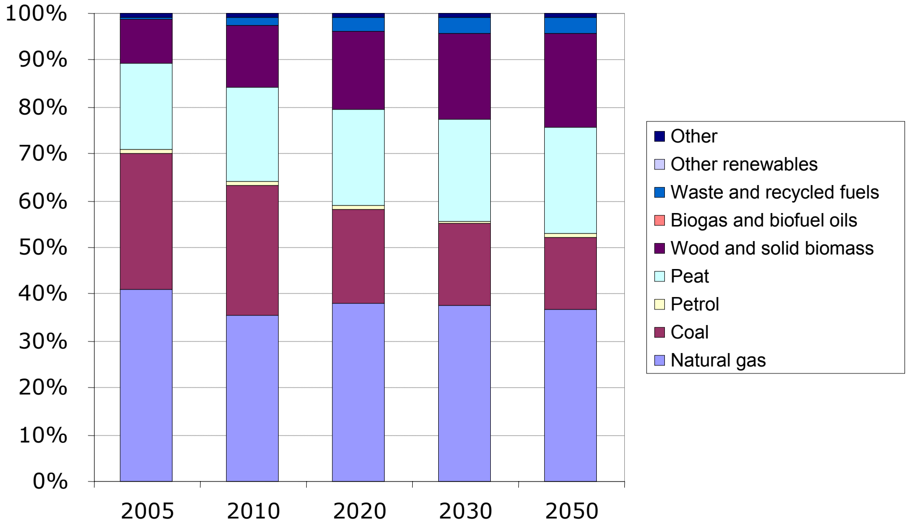

Figure 31. View of the district heating companies on the changes in the shares of cogeneration energy sources in connection with the production of district heating for towns up until 2050, percentage of heat production scaled in relation to the respondents' heat production.

The consumption of primary energy, estimated using the relative distribution trend for energy sources formed on the basis of the responses from the district heating companies (Figure 31), the estimated production quantities for cogeneration, and a moderate trend in efficiency, are presented below (Figure 32). The average efficiency of cogeneration for the entire cogeneration unit stock is estimated to increase from approximately 85% in 2005 to approximately 90% by 2050. The need for primary energy used in cogeneration will increase from approximately 150 PJ to slightly more than 180 PJ. The total consumption of fossil fuels is estimated to fall by approximately 8%, that of peat is estimated to grow by approximately one and a half times and the share of renewable energy sources is estimated to treble.

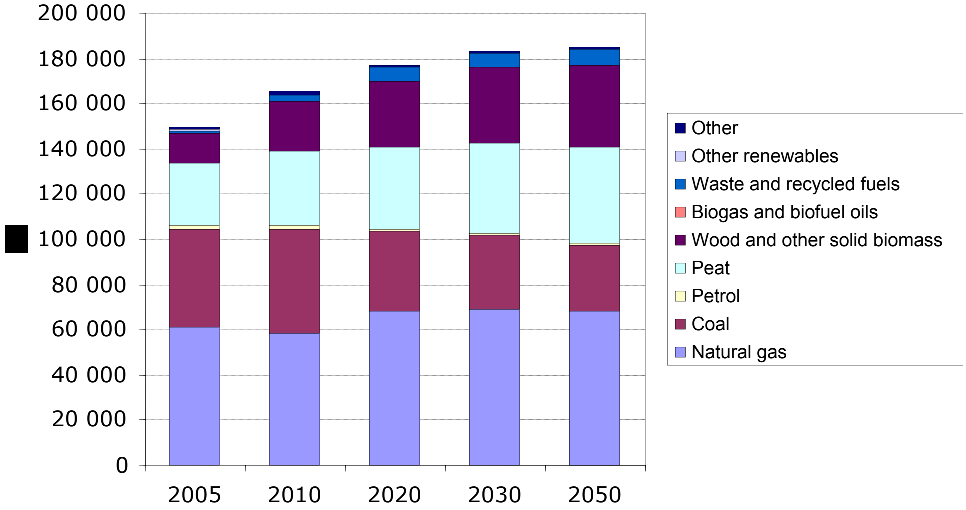

Figure 32. Estimated consumption (TJ) of primary energy fuels used in cogeneration on the basis of the responses from the district heating companies, scaled to national level. [38]

The quantity of renewable energy sources used in cogeneration, as estimated by the district heating companies, will increase to approximately 44 PJ by 2050. The majority of this, approximately 37 PJ, would be based on the use of wood and other solid biomass. Also, on the assumption that half the coal and petrol from separate production will be replaced by renewable energy sources and that the share of renewables otherwise remains stable, this will result in primary energy production of approximately 60 PJ for total district heating production using renewable energy sources. For example, this may be compared with the estimate according to the National Energy and Climate Strategy of 2005, where district heating production would use approximately 46 PJ of renewable fuels in 2025[39]. On the basis of the responses from the district heating companies, the estimate would then be at a level slightly above 50 PJ.

In the responses of the district heating companies relating to renewable energy sources, the use of waste and recycled fuels in cogeneration is estimated to increase to approximately 5.7 PJ by 2020 and from there it will increase moderately to 6.5 PJ by 2050. The national biofuel waste strategy sets a target of exploiting approximately 6 PJ of town waste for energy production in 2010[40] and the programme to promote renewable energy also estimates the total quantity of recycled fuels to be approximately 10 PJ in the years 2010 and 2025. District heating cogeneration should therefore have a significant amount of all waste flows, so that the share estimated by the district heating companies can be achieved.

Figure 33 presents an estimate of the trend in energy sources for industrial cogeneration. The estimate is based on the assumption that the quantity of fuels used in industrial cogeneration

[38]The figures are calculated on the basis of the trend in the relative share of energy sources at the district heating companies' own production units, and estimated by them, and on the basis of consumption data for 2005.
[39] Scenarios used in the preparation of the national energy and climate strategy, Ministry of Trade and Industry, 2005. The calculations for the WAM scenario are used as the basis for comparison.
[40] National strategy to reduce amounts of biodegradable waste going to landfill, Ministry of the Environment, 2004.

corresponds to the distribution of fuels in the pulp and paper industry and also exploits the views presented previously[41] up to 2020. The trend after 2020 is estimated by assuming the trend within industry to be relatively similar to that of the district heating companies. The need for primary energy will even out at a level of approximately 300 PJ thanks to the assumed efficiency and improvement in energy efficiency.

The share of biomass of wood origin in energy sources for industrial cogeneration was historically significant owing to its key role in the forestry industry, and this is estimated to continue. On the whole, the share of renewable energy sources in industrial cogeneration is estimated to grow to approximately 75%, partly at the expense of natural gas and petrol.

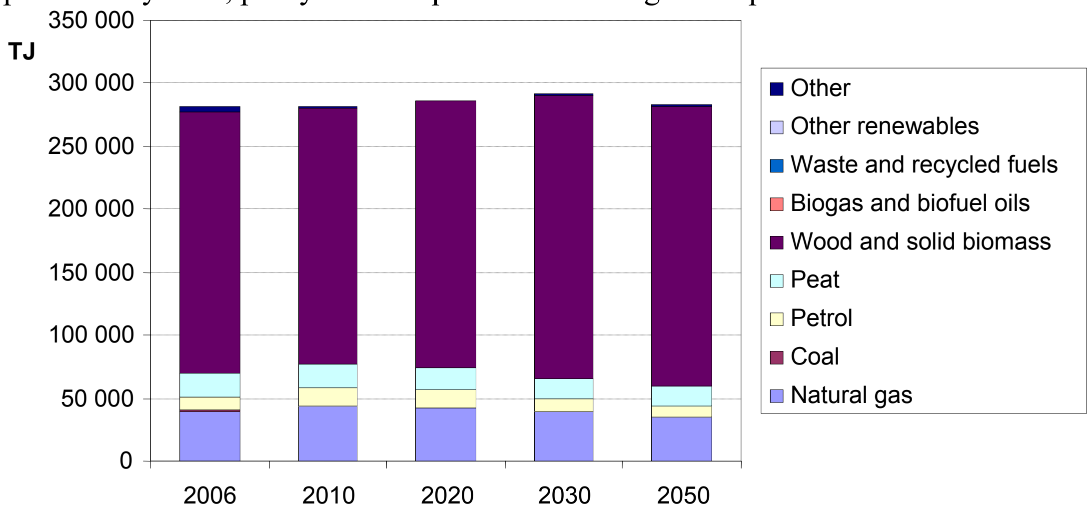

Figure 33. Estimated quantities of fuels used in industrial cogeneration.[42]

6.4 Production technology for cogeneration

The estimates of the respondents to the questionnaire that was sent to the district heating companies concerning the distribution of production technology for new investments are presented in Figure 34. When natural gas is used as an energy source, it is judged that a combined cycle gas turbine is selected as the production technology. Of the other unit investments, steam condensing extraction turbines are mainly concentrated in large units and most investments are considered to be achieved using steam backpressure turbines. Of the other forms of technology, internal combustion engines have a marginal share.

[41] Decision on awarding emissions rights 2005-2007, Annex 1, Ministry of Trade and Industry, 2004. The distribution of fuels for all industrial cogeneration has been assumed to be consistent with the total fuel consumption of the pulp and paper industry, even if in practice some natural gas, etc. is used to generate process heat. However, on the whole there are no significant differences.
[42] Data for 2006, Finnish Forest Industries Federation.

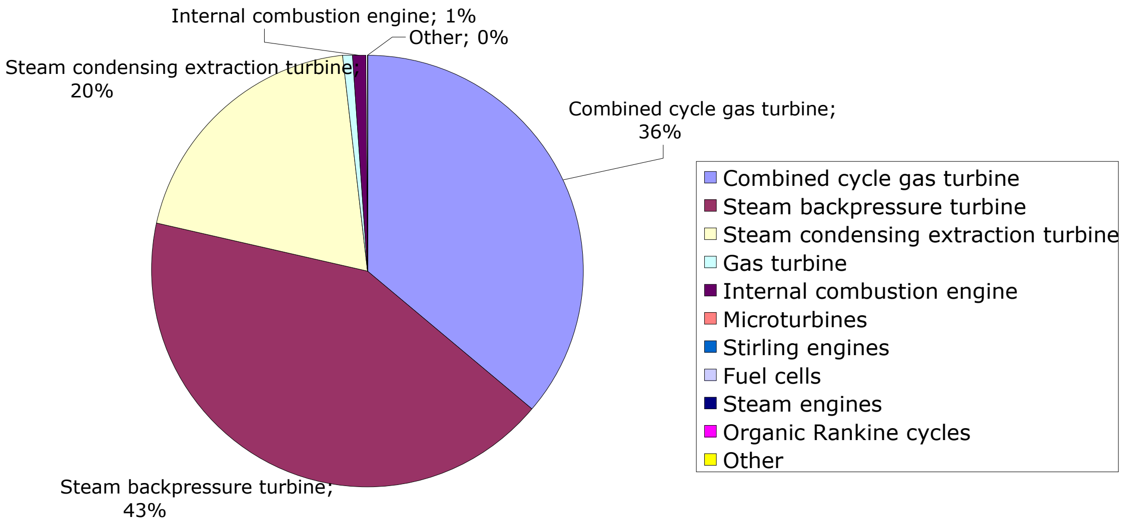

Figure 34. Estimate of the district heating companies concerning the share of the forms of production technology used for the production of heat energy at new units up to 2020[43].

According to the district heating companies, traditional forms of production technology, combined cycle gas turbines, steam backpressure turbines and steam condensing extraction turbines look as though they will retain their relative shares pretty much as is presented in Figure 35. Since production capacity as a whole will increase, the capacity of such kinds of technology will also increase in absolute terms (Figure 36). The marginal share of internal combustion engines is estimated to increase moderately up to 2050. It is estimated that new kinds of technology, such as microturbines, fuel cells and organic Rankine cycles, will be introduced with small shares between 2030 and 2050. For fuel cells, the dissemination potential in relation to other European countries, for example, might be restricted by the relative lack of development of the distribution network for natural gas as a suitable fuel.

[43] With regard to new investments, the results of the questionnaire have been completed using other material from the questionnaire and other information available from sources that are available to the public.

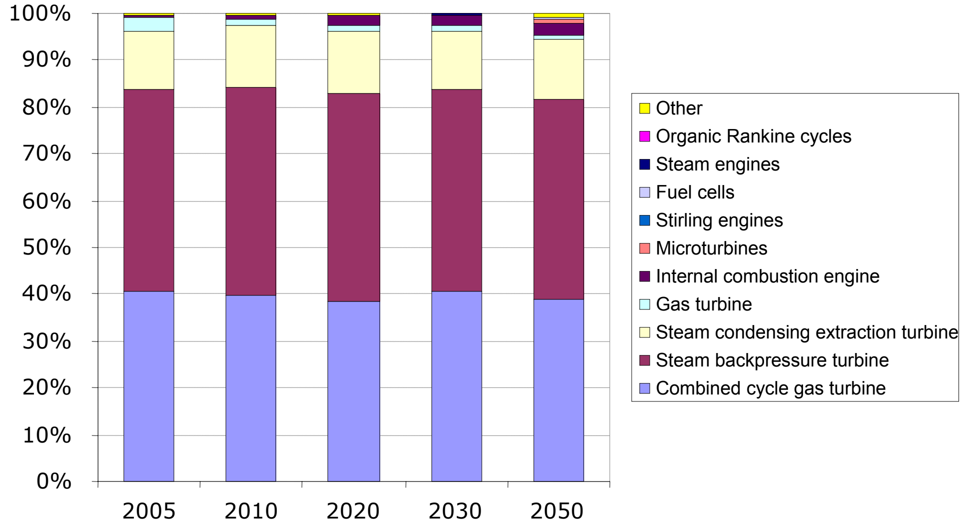

Figure 35. Combination of the trend in the relative nationwide shares calculated on the basis of the relative shares of the district heating companies' own forms of production technology, in accordance with the EU's CHP Directive[44]

[44] EU's CHP Directive 2004/8/EC, Annex 1.

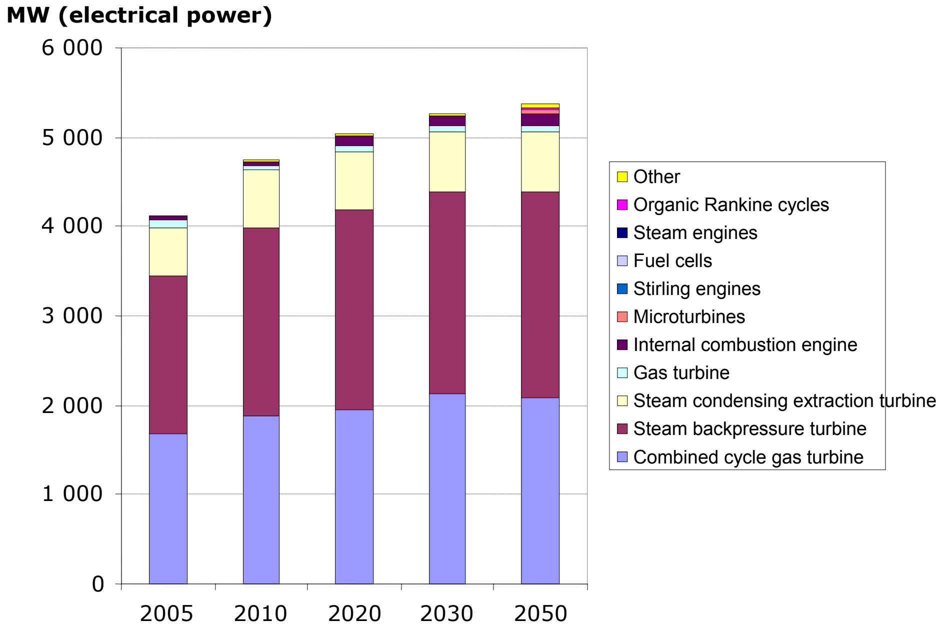

Figure 36. Calculated trend for electricity production capacity for cogeneration by district heating companies, divided up into forms of production technology, and calculated on the basis of the relative shares of forms of production technology reported by the district heating companies[45].

Of the forms of industrial production technology, those that are in a dominant position according to the classification in the EU's CHP Directive are clearly steam backpressure turbines, and in practice soda boilers have an important role owing to their relatively large share in the pulp and paper industry. According to the estimates, most industrial CHP production capacity requires basic improvements or needs to be completely replaced by 2030. It must be assumed that the forms of production technology that have a higher power to heat ratio, such as combined cycle gas units and later units based on IGCC technology will increase their relative share.

6.5 Efficiency classes for cogeneration units

Figure 37 presents the view of the district heating companies concerning the trend in the relative shares of efficiency classes in cogeneration for power plants up to 2050, and Figure 38 presents changes to the estimated capacity. The relative share of small efficiency classes will grow at the expense of large units and the overall capacity of large plants of more than 100 MW cannot be estimated to increase. This is natural, since places with electrical power having potential of more than 100 MW have largely been exploited already.

[45] The figures are calculated on the basis of the trend in the relative share of forms of production technology at the district heating companies' own production units, and estimated by them, and on the basis of the actual total capacity for 2005.

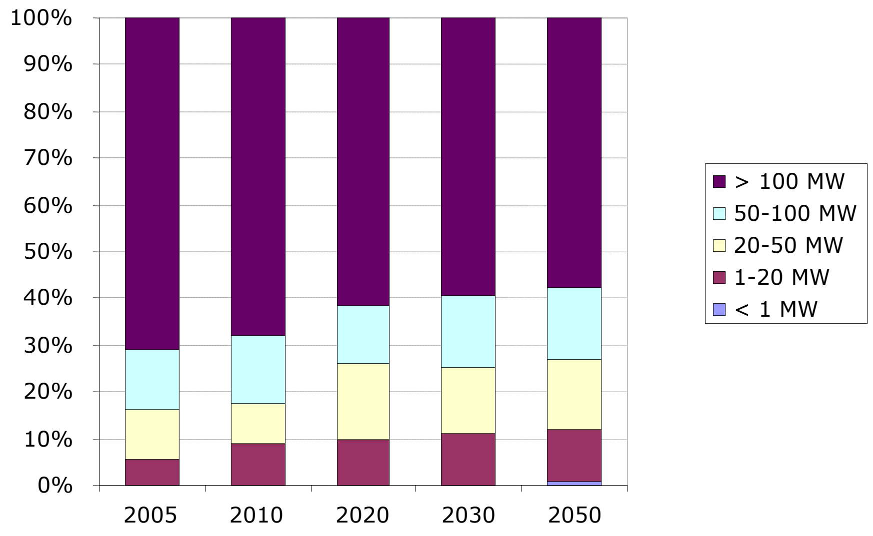

Figure 37. Trend in the relative nationwide share of electrical power classes for cogeneration units of the district heating companies, based on their own assessments.

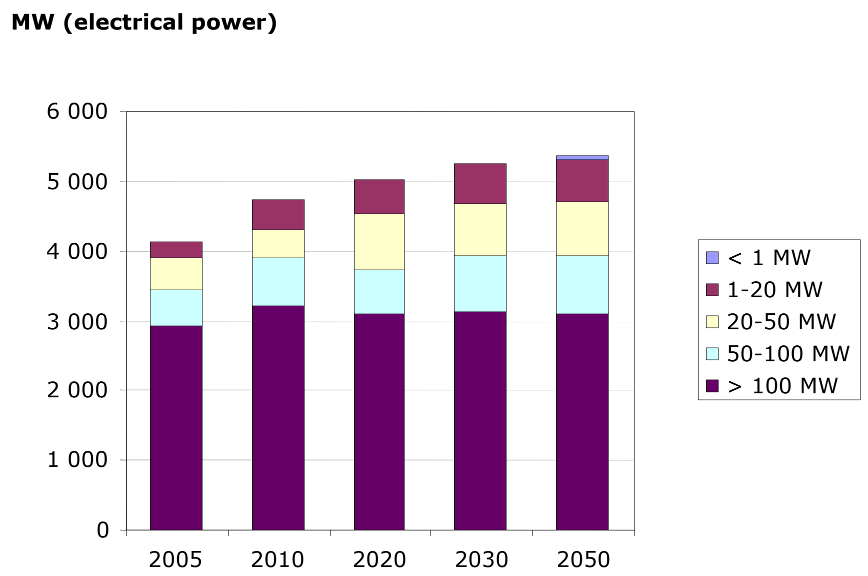

Figure 38. Calculated trend in the electricity production capacity for cogeneration by district heating companies, divided up into efficiency classes, and calculated on the basis of the relative efficiency classes assessed by the district heating companies[46].

[46] The figures are calculated on the basis of the trend in the relative share of efficiency classes at the district heating companies' own production units, and estimated by them, and on the basis of the actual total capacity for 2005.

6.6 *Key impact of district heating and cogeneration*

6.6.1 Probable replacement of separate production

It is predicted that cogeneration will increase in towns, especially at small plants. Some of the increase might aim to match the heating needs of new production, but part of it might also be the replacement of old boilers when they reach the end of their working life. However, on the basis of the questionnaire sent to players in the district heating sector, the relative share of cogeneration in the production of district heating will not grow significantly. The players estimate that the percentage growth in the share of cogeneration will correspond to approximately 0.5 TWh of the replacement of separate heat production.

The following figure presents the quantities of cogeneration that will replace the separate production of electricity, obtained by means of a calculation on the basis of the views of the district heating companies and of the estimates made by the industry (Figure 39). The potential is nearly as great in cogeneration for industry and district heating, where the increase in production combined with the assumed improvement in the power to heat ratio may produce nearly 10 TWh more electricity than at present. According to the estimate, the share of district cooling will increase nearly as significantly to replace separate production by 2050.

The increase in district cooling from the current level of a few tens of GWh to nearly 1.5 TWh by 2050 will affect the replacement of separate production in two different ways. The efficiency of compression cooling is weaker than the cooling power produced using the absorption technique of cogeneration, and cogeneration can also be used to produce electrical power roughly corresponding to the cooling power, depending on the power to heat ratio of the plant[47].

The electricity production generated by increased cogeneration is assumed largely to replace the production of electricity by means of condensation, the main fuels for which are coal, peat and wood-based fuels.

[47] Application of the latest absorption cooling technology in district cooling, VTT Technical Research Centre of Finland, 1998. The calculation assumes that the efficiency of the district cooling is twice as good as that of other forms of cooling technology.

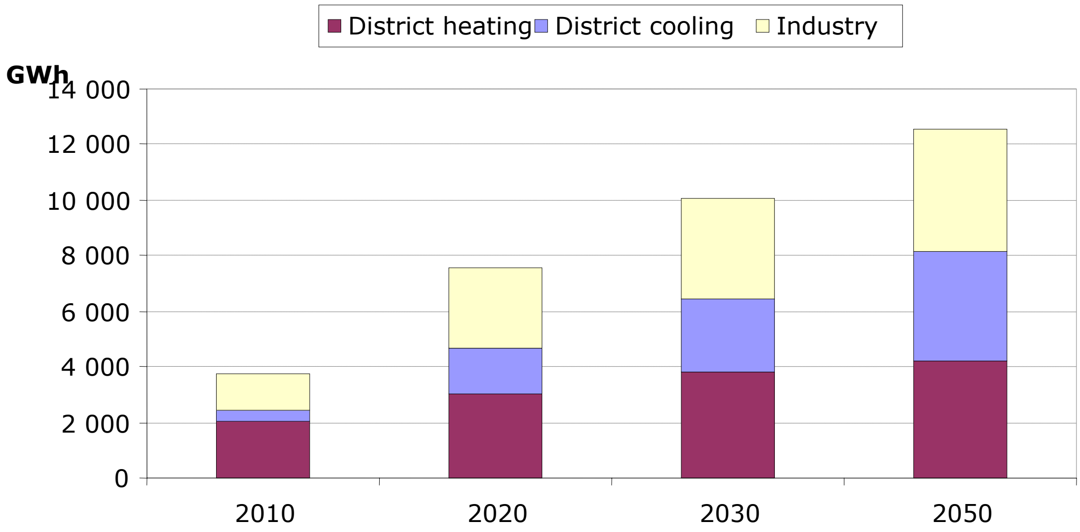

Figure 39. The impact of cogeneration on the replacement of the separate production of electricity, assuming that the estimated increase in energy needs would otherwise by produced at separate plants.

6.6.2 Primary energy savings

The cogeneration of heat or cooling and electricity achieves greater efficiency than their separate production. The primary energy saving produced by replacing the quantities produced separately, as presented in the previous section, may be estimated on average for the period examined, assuming most probably that the electricity that replaces separate production by condensation power has an average efficiency of 40% in 2005 and efficiency is assumed to improve gradually to 48% in 2050. This figure presents the estimated reduction in the need for primary energy thus calculated (Figure 40). District cooling takes into account the better efficiency of producing district cooling, which emphasises its significance alongside district heating in 2050.

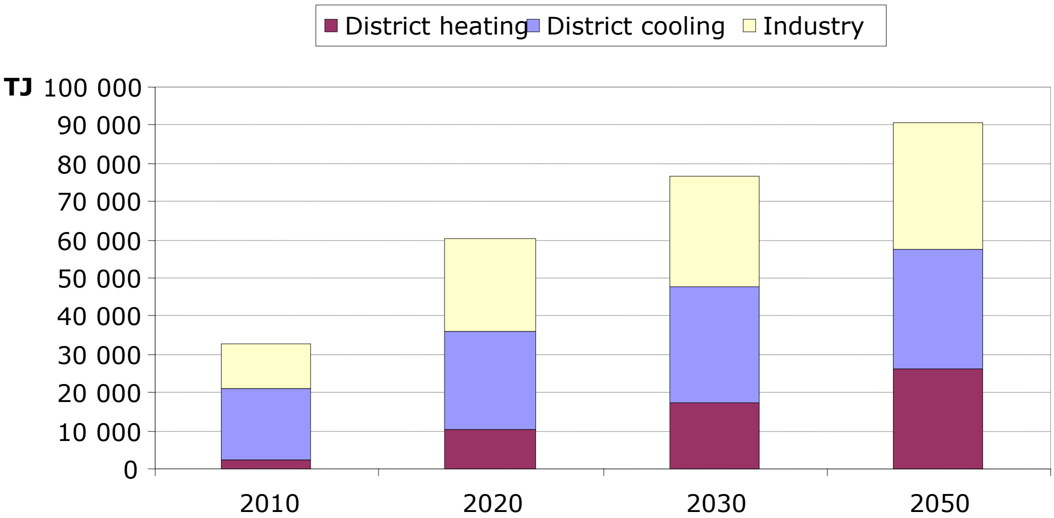

Figure 40. Primary energy savings achieved using cogeneration, based on the replacement of separate production.

6.6.3 Reducing greenhouse gas emissions

The primary energy savings achieved will also have an impact on greenhouse gas emissions from heat and power production. The reduction in greenhouse gas emissions has been calculated on the assumption that the greenhouse gas emissions from new separate production would correspond to the average actual greenhouse gas emissions from current electricity procurement in Finland. Figure 41 presents the estimated reduction in emissions thus obtained which can be achieved by cogeneration. In relation to the average procurement of electricity, the reduction in greenhouse gas emissions would be slightly more than 4 million tonnes in 2030 and approximately 5 million tonnes in 2050.

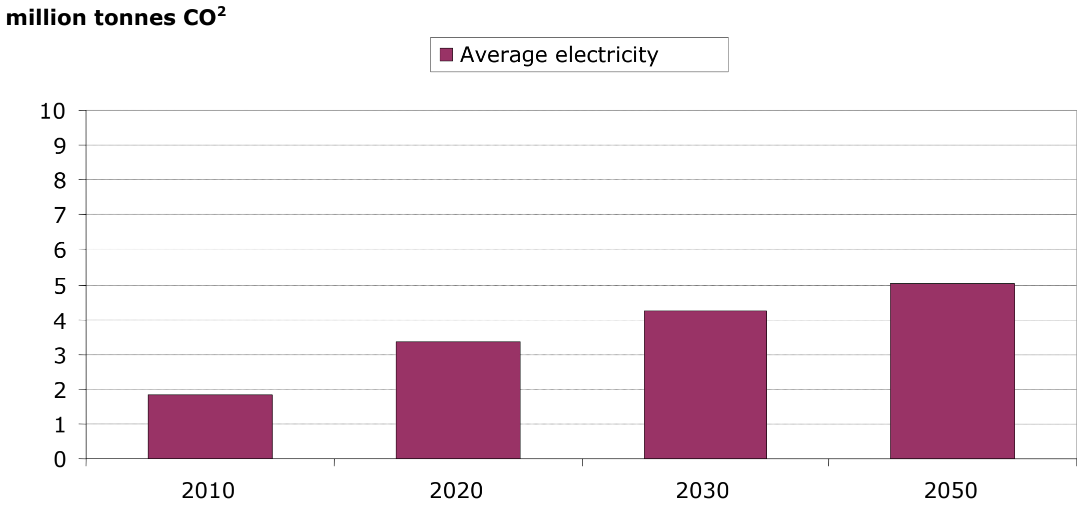

Figure 41. The reduction in greenhouse gas emissions that can be achieved by cogeneration in relation to a situation where the emissions from the separate production of electricity correspond to the actual emissions from average electricity procurement in Finland[48].

6.6.4 Cost-effectiveness

The cost-effectiveness of cogeneration can be assessed by examining the investment costs necessary for increasing cogeneration in relation to the savings that it can achieve both in the amount produced separately and in greenhouse gas emissions. The average investment cost for a CHP plant in the period examined (2005 – 2050) is assumed to be approximately 1200 EUR/kW[49]. The average need for investment is approximately 360 MW a year and the annual average need for investment is approximately EUR 440 million. The amount of CO_2 emission reductions achieved by cogeneration in the period examined is on average 3.7 million tonnes a year in relation to the average emissions from electricity procurement in Finland. Similarly, the savings from the separate production of electricity in the period examined are on average 14 TWh a year. Assuming that the average price of CO_2 emissions is EUR 20/tonne and the market price for electricity is EUR 50/MWh, the total annual saving can be calculated as approximately EUR 770 million. Figure 42 illustrates the average annual costs and savings.

[48] The emissions factor for Finland's average electricity procurement is 200 kg/MWh (source: Motiva 2004).
[49] World Energy Outlook, IEA, 2006. The investment cost for a medium-sized CHP plant in 2030 is approximately 1600 USD/kW (electrical power). The exchange rate is assumed to be 1.3 USD/EUR.

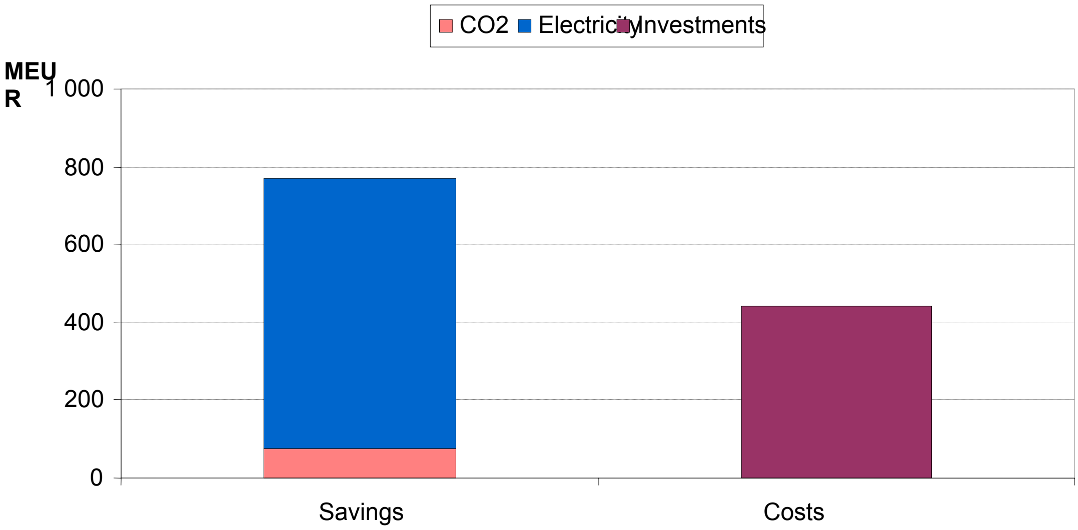

Figure 42. Average savings achieved annually by cogeneration in relation to the average investment costs.

7 Barriers to cogeneration

7.1 General

Finland has done some long-term work to promote combined heat and power production (CHP). Modern CHP is competitive on the market in relation to the separate production of heat and power. The heat loads that are enabled by the profitable cogeneration of heat and power are exploited quite effectively regardless of the fact that energy tax has not necessarily been conducive to cogeneration in all respects.

However, for small size classes, the separate production of heat is still relatively more competitive than CHP production. Investment aid has therefore particularly been used to promote the use of renewable energy sources by small power plants, and joining the small-scale production network has been made easier by legislation starting in 2007.

The emissions trading that started in 2005 has highlighted the fact that small-scale emissions trading creates a barrier to CHP production, so that it is more economical merely to build up heat production, for example, and not fall under emissions trading, than to build a cogeneration unit and fall under emissions trading. This is particularly highlighted when fuels that are not emission-free, such as peat, natural gas and coal, are used. It is very difficult to find methods for solving this issue.

The quantities of emission rights awarded to each plant do not take into consideration any changes to district heating consumption. This weakens the viability of district heating and cogeneration for towns at the same time, since an increase in production and fuels caused by new customers also increases emissions. In particular, the emissions trading scheme is not capable of recognising a situation that is positive for the environment, where a new district heating customer changes his form of heating, typically from oil-fired heating to district heating, and thus moves from the non-emissions-trading sector to the emissions-trading sector.

The use of cogeneration for industry and its suitability depend on the needs of industrial processes to have electricity, heat and steam. Structural change in the forestry industry will affect the industrial cogeneration capacity in the years ahead, but at the same time it is difficult to assess the temporary impact. The industry mainly defines its needs itself, and promotional measures do not have much of an impact on the choices. The biggest impact of promotional measures is visible in the sawmill and timber goods industry, where it is mainly only heat that is generated at present, but combined production could also be promoted.

Agricultural biomass and different kinds of biodegradable waste from the food industry, among other things, will enable small-scale CHP production, for example, engine uses that generate heat and power using biogas. In relation to this, Finland has prepared promotional measures, including at the Ministry of Agriculture and Forestry. The main barrier at present is the competitiveness of the projects in question.

7.2 Perspective of players in the sector

Despite the political consensus in favour of cogeneration in principle, companies in the sector may regard Community support measures to be inadequate or that regulation is too restrictive from their own perspective when specific investment decisions are being considered.

The assessment of barriers to cogeneration based on the questionnaire sent to the district heating companies is presented in the figure (Figure 43). More than one-third of respondents considered it to be a particularly significant barrier that there was unfavourable policy guidance. Barriers relating to the price and availability of fuels were regarded as particularly great by slightly more than one in five respondents. Slightly fewer than one in five felt that making environmental standards more stringent was a particularly significant barrier. All the barriers mentioned above were regarded to be at least significant by more than half the respondents.

Barriers relating to licensing practices were also regarded as significant or moderate in the majority of responses. Barriers relating to investment funding and land-use planning were few on average and they were only problematic in a small proportion of the responses. Restrictions on the electricity grid were regarded as minor barriers, and two out of three respondents considered it to be a minor or small barrier.

In the space for open responses, comments were also made concerning barriers to cogeneration. In the environment and energy sector, there was a wish for long-term investment in the sector, in accordance with its demanding nature. Policy guidance was also viewed as having a significant role in performing feasibility calculations to support investment decisions. This is not necessarily about the unfavourable nature of the policy guidance itself, but rather about uncertainties surrounding guidance during the lifetime of power plant investments.

On the basis of the open responses, barriers relating to the availability of fuels might concern the treatment of peat. Treating peat as a fossil fuel is regarded as unfair, and there is support for changing its classification to a biofuel.

Of the problems related to investment funding, it was highlighted that plants falling under emissions trading cannot be awarded investment aid, and this might lead to the construction of small additional boiler houses. Furthermore, it was stated in relation to regional heating solutions for small settlements that improving competitiveness in comparison with solutions for each property would require support for network investment and the cost of initial losses. On the other hand, it was regarded as an operational condition for small regional networks in the distant future that they be connected to decentralised energy production solutions.

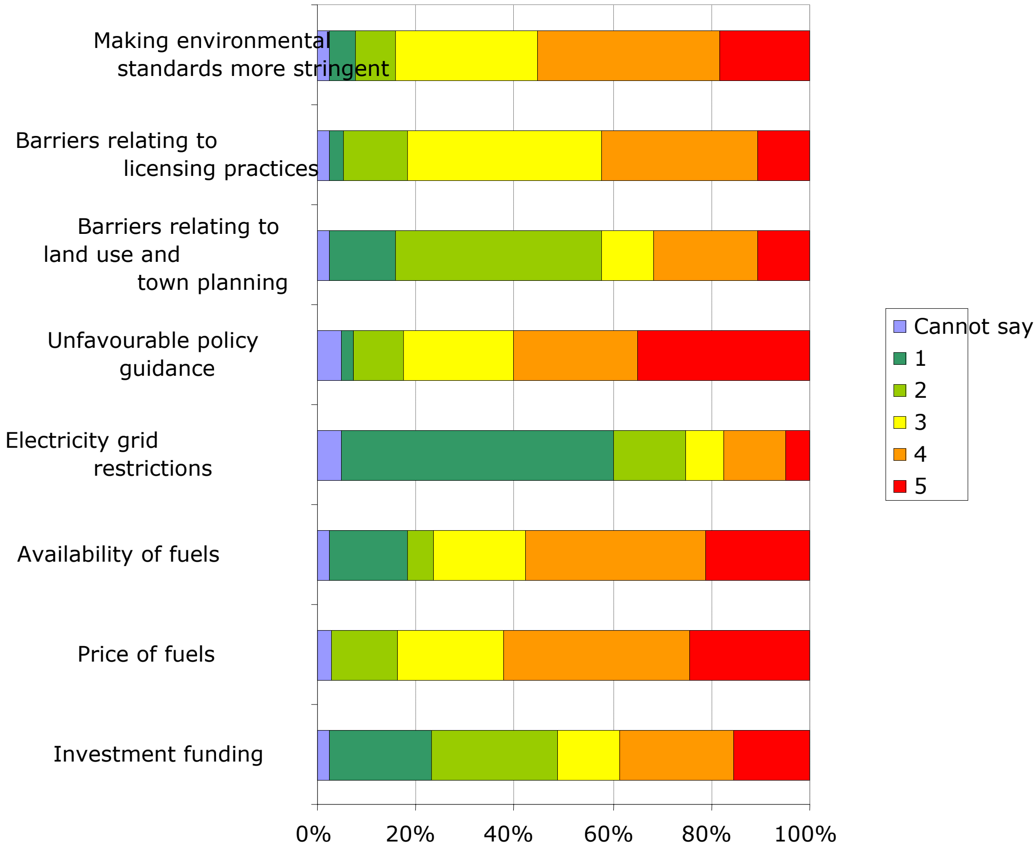

Figure 43. View of district heating companies regarding barriers to the maximum implementation of cogeneration (1 = very small barrier, 5 = very large barrier).

8 National development strategy

Finland has done some long-term work to promote combined heat and power production (CHP). Modern CHP is competitive on the market in relation to the separate production of heat and power. This is mainly due to the structure of our industry and the climatic conditions. CHP production is not particularly supported in Finland, with the exception of small-scale CHP production based on renewable energy sources, since small-scale separate production is still relatively more competitive than CHP production.

The aid scheme targeting the production of electricity is based on investment aid for power plants in Finland and on tax assistance that is regarded as operational support through the energy tax scheme. Aid for the production of wood-based fuels may also be regarded as indirect aid for the production of electricity based on wood-based fuels. Energy aid particularly aims to promote renewable energy sources and energy efficiency.

Investment aid is particularly used to promote small power plants that use renewable energy sources, and joining the small-scale production network has also been made easier by legislation that started in 2007.

Finland has studied and clarified the suitability of different forms of aid within the emissions trading scenario and on the free electricity markets a great deal. Emissions trading might increase the price of electricity and thus improve the competitiveness of electricity production in combined production of heat and power. This appears most clearly in the work on constructing power plants that use renewable energy sources and changing old power plants. Support for new technology also continues to be important in the emissions trading sector. Aid is still regarded as an important means of control in the non-emissions-trading sector.

Aid for the cogeneration of heat and power in Finland is only justified for small-scale production when renewable fuels are used. Aid is no longer awarded to larger CHP plants (bioenergy), since the projects mainly fall under emissions trading and the control impact that this has is considered sufficient for the use of bioenergy to be increased in this class. CHP projects are not considered to be energy saving or energy efficiency projects in themselves in Finland, but CHP will mainly be selected for suitability reasons and competition requirements.

There are no large, free useful heat loads in Finland. Instead, there are small useful heat loads. When promoting the combined production of heat and power, there is a particular focus on increasing the number of small power plants by making it easier for them to join the network. Renewable energy sources constitute a significant proportion of the fuel use of such plants. It is also possible to combine old heat networks and build new ones, for example in newly-built settlements.

9 References

The following list contains the sources cited in the report. The sources are also cited in footnotes, especially for Chapters 5 and 6.

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