

Comprehensive assessment of the potential for exploiting high-efficiency cogeneration, district heating and district cooling.

*Promotion of efficiency in
heating and cooling in
accordance with the
provisions of
Article 14(1) of the
Energy-Efficiency
Directive.*

ER 2013:24

Books and reports published by the Swedish
Energy Agency may be ordered via
www.energimyndigheten.se
Fax number for orders: +46 (0)8 505 933 99
E-mail: energimyndigheten@cm.se

© Swedish Energy Agency

ER 2013:24

ISSN 1403-1892

Foreword

On 29 November 2012, the Swedish Government decided to give the Swedish Energy Agency a mandate to carry out a comprehensive assessment of the potential for exploiting high-efficiency cogeneration, district heating and district cooling in accordance with the provisions of Article 14(1) of and Annex VIII to Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

In its work on the comprehensive assessment, the Swedish Energy Agency has made great use of the report *Potential for cogeneration, district heating and district cooling (2013:15)* by the consultancy firm Profu. The report was produced as part of the 'Fjärrsyn' research programme on district heating and cooling, which was co-financed by the Swedish Energy Agency. The Swedish Energy Agency participated in the work of the project reference group.

The reference group met twice during this mandate. The members of the reference group were: Anders Ydstedt of the Industry Group for Re-Use of Energy, Erik Thornström of the Swedish District Heating Association, Håkan Sköldberg of Profu, Katarina Abrahamsson and Johan Nilsson of the Swedish Energy Markets Inspectorate, and Erik Dotzauer of Fortum Heating.

Daniel Friberg has been the investigator-in-charge. The project group has also included Sara Björkroth and Sofia Andersson. Quality assurance was carried out by Kristina Holmgren.

[signed]

Erik Brandsma

Director-General

[signed]

Daniel Friberg

Project Manager

Abbreviations and definitions

Alpha value: The relationship (ratio) between the electricity and heat produced at a cogeneration plant.

EED/Energy-Efficiency Directive: Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

Efficient district heating and cooling¹: A district heating or cooling system using at least 50 % renewable energy, 50 % waste heat, 75 % cogenerated heat or 50 % of a combination of such energy and heat.

Efficient heating and cooling²: A heating and cooling option that, compared to a baseline scenario reflecting a business-as-usual situation, measurably reduces the input of primary energy needed to supply one unit of delivered energy within a relevant system boundary in a cost-effective way, as assessed in the cost-benefit analysis referred to in this Directive, taking into account the energy required for extraction, conversion, transport and distribution.

BATT: Branches and treetops.

High-efficiency cogeneration³: Cogeneration production from cogeneration units shall provide primary energy savings of at least 10 % compared with the references for separate production of heat and electricity (please see Annex 3 for calculation principles according to the EED).

Industrial back pressure: Electricity generation from cogeneration in industry.

Nordic electricity mix⁴: 97.3 CO_{2eq}/kWh and 1.74 of primary energy.

Primary energy factor (PEF): How much primary energy is used considering losses in both final and indirect energy consumption.

Primary energy: Primary energy is energy that has not undergone any conversion.

Swedish electricity mix⁵: 36 g CO_{2eq}/kWh and 2.1 of primary energy.

¹ Definition in Article 2(41) of the EED.

² Definition in Article 2(42) of the EED.

³ Definition in Article 2(34) of the EED.

⁴ Calculations for 2008 from the Environmental Fact Book (2011).

⁵ Ibid.

Contents

1 Summary	5
2 Introduction	7
2.1 Potential for efficiency in heating and cooling in accordance with the Directive	7
2.2 District heating and cogeneration in Sweden	9
3 Potential for efficient heating and cooling	14
3.1 Potential for efficient district heating	14
3.2 Potential for high-efficiency cogeneration in the district-heating system	18
3.3 Potential for industrial cogeneration	24
3.4 Potential for district cooling	27
3.5 Identification of the energy-efficiency potential of district heating and cooling infrastructure	29
4 Technical Potential	32
5 Cost-benefit analysis	35
5.1 Profitable measures and external factors	35
5.2 Profitability calculation models	37
5.3 System and geographical boundaries	39
5.4 Choice of baseline and alternative scenarios	39
6 Proportion of high-efficiency cogeneration	42
7 Estimated primary-energy saving	43
7.1 The Swedish definition of primary energy	43
7.2 Primary-energy savings according to the 'change impact' principle	45
7.3 Conclusion	51
8 Map of the national territory	53
8.1 Explanations of the maps	53
8.2 Existing and planned heating and cooling infrastructure	64
9 Strategies, policies and measures that may be adopted up to 2020 and up to 2030	67
9.1 Measure 1: Principles for reporting the potential for residual heat when designing new district-heating production	67
9.2 Measure 2: Testing of price changes and principle of equal treatment	68
9.3 Measure 3: Regulated access to the district-heating network	70
9.4 Measure 4: Review of the National Board of Housing, Building and Planning Building Regulations to achieve competitive and technical neutrality	71
9.5 Measure 5: Review of tax rules that cause distortion	71

10 An estimate of public support measures for heating and cooling	73
11 Bibliography	74
Annex 1: Article 14(1)–(4) of the EED, 2012/27/EU	77
Annex 2: Cost-benefit analysis in accordance with ANNEX IX to the EED	78
Annex 3: Methodology for determining the efficiency of the cogeneration process	81
Annex 4: An investigation into three different primary-energy weighting principles	84
Annex 5: EED, Annex VIII g)(i)–(vi)	87
Annex 6: Input data for the cost-benefit analysis	88

1 Summary

This report provides an assessment of the potential for high-efficiency cogeneration and efficient district heating and cooling, on the basis of the EU Directive on energy efficiency (2012/27/EU), which was decided upon in October 2012. The focus is on identifying the potential that can be realised by 2020 and by 2030. The report also explains how the potential for high-efficiency cogeneration, district heating and district cooling can help to achieve the energy-efficiency targets that have been set. As part of this mandate, the potential for profitable district heating, district cooling and cogeneration has been identified on the basis of analyses that have already been performed. Accordingly, the potential for improving energy efficiency is expressed in terms of estimated primary-energy savings.

In the context of implementing the Directive, it should be pointed out that the district-heating market in Sweden is already largely developed, and all existing cogeneration is highly efficient. The report analyses the impact of the *expansion* in district heating, district cooling and cogeneration on increasing energy efficiency. Although it has been estimated that supplies of district heating as a whole will fall in Sweden in the future, as a result of efficiency improvements in energy consumption and competition with other heating options, the focus is on those areas where district heating is expanding. It is the consequences of that very expansion, i.e. the choice of district heating instead of something else, that are to be elucidated. Falling heating supplies to existing district-heating customers as a result of improvements in energy efficiency and conversion to other heating options, for example, are therefore not included in the energy-efficiency calculations.

Some 55 TWh of district heating was produced in 2011. The analysis shows that there is still some potential for expanding district heating, district cooling and cogeneration. This potential is limited by the fact that there has already been great expansion other than in district cooling. The potential for district heating in the future has been estimated at 4 TWh by 2020 and 8 TWh by 2030.

District-cooling production currently amounts to nearly 1 TWh. The potential for district cooling in the future is estimated as an additional 1 TWh by 2020 and 2 TWh by 2030. Electricity produced from cogeneration amounted to 10.5 TWh in the district-heating network and 6 TWh in industry in 2011. The potential for cogeneration consists of both cogeneration in the district-heating system and cogeneration in industry, which is known as industrial back pressure. The potential for electricity production from cogeneration in the future will amount to 5 TWh by 2020. After that, it is estimated that there will only be a marginal increase by 2030. Raised expectations in the electricity-certificate scheme after 2020 should, however, be able to increase the proportion of cogeneration; this has not been considered for the purposes of this report. Just over half of this potential can be attributed to district heating, and half to industry. Most cogeneration in the future will be based on biofuels.

Article 14(1) of the Directive requires a primary-energy saving to be calculated as the potential resulting from district heating, district cooling and cogeneration in comparison with other energy options. The Swedish Energy Agency has based these calculations on the energy content of the fuel as prescribed in Annex IV to the Directive. The Swedish Energy Agency

is of the view that the factors used in these calculations should not be used for any other purpose.

The total primary-energy savings from the potential expansion of cogeneration, district heating and district cooling are estimated to be 9.75 TWh by 2015, 14 TWh by 2020, 15.5 TWh by 2025, and no more than 16 TWh by 2030 (Table 2).

2 Introduction

The aim of this report is to provide a comprehensive assessment of the potential for high-efficiency cogeneration and efficient district heating and cooling, on the basis of the EU Directive on energy efficiency (2012/27/EU), which was decided upon in October 2012. The potential must be assessed on the basis of the detailed requirements laid down in Article 14(1) (please see Annex 1 to this report and Annex VIII to the Energy-Efficiency Directive (please see section 2.1)). The focus must be on identifying the potential that can be realised by 2020 and by 2030. Another of the report's aims is to show how the potential for high-efficiency cogeneration, district heating and district cooling can help to achieve the energy-efficiency targets that have been set.

Article 14(3) states that a cost-benefit analysis must be carried out in order to assess the potential (please see Annex 2 to this report). Finally, Article 14(4) states that if the assessment that is carried out yields a profitable result, adequate measures must be taken to develop the markets.

This report is structured so that **Chapter 3** discusses demand and supply now and in the future, with a focus on 2020 and 2030. The assessment of anticipated expansion in turn relies upon the assumptions concerning various costs and benefits, which are discussed in **Chapter 5**. **Chapter 4** discusses the technical potential that the interpretative note on the Directive proposes should precede the economic potential, but which is discussed separately here.⁶ **Chapter 6** discusses the fact that all cogeneration in Sweden is highly efficient. **Chapter 7** discusses the estimated primary-energy saving to be achieved through the expansion of district heating, cogeneration and district cooling, given the primary-energy weighting principle that has been selected. **Chapter 8** includes maps of Swedish territory showing the heating demand points, industries with waste heat, and various energy-production facilities, as required by the Directive. Finally, **Chapter 9** proposes measures to promote the district-heating market. Since the market is already developed, possible measures for improving the market are discussed.

2.1 Potential for efficiency in heating and cooling in accordance with the Directive

The requirements that must be satisfied according to Annex VIII to the Directive, and around which this report revolves, are given below. The place in this report where each point is fulfilled is indicated in brackets after each point.

1. The comprehensive assessment of national heating and cooling potentials referred to in Article 14(1) shall include:

- a) A description of heating and cooling demand; (*Chapter 3*)

⁶ The technical potential is not essential according to the Directive, but it is discussed in any case, since it could be of interest.

- b) A forecast of how this demand will change in the next 10 years, taking into account in particular the evolution of demand in buildings and the different sectors of industry; (*Chapter 3*)
- c) A map of the national territory, identifying, while preserving commercially sensitive information: (*Chapter 8*)
 - i) heating and cooling demand points, including:
 - municipalities and conurbations with a plot ratio of at least 0.3; and
 - industrial zones with a total annual heating and cooling consumption of more than 20 GWh;
 - ii) existing and planned district heating and cooling infrastructure;
 - iii) potential heating and cooling supply points, including:
 - electricity generation installations with a total annual electricity production of more than 20 GWh; and
 - waste incineration plants;
 - existing and planned cogeneration installations using technologies referred to in Part II of Annex I, and district heating installations;
- d) Identification of the heating and cooling demand that could be satisfied by high-efficiency cogeneration, including residential micro-cogeneration, and by district heating and cooling; (*Chapter 3*)
- e) Identification of the potential for additional high-efficiency cogeneration, including from the refurbishment of existing and the construction of new generation and industrial installations or other facilities generating waste heat; (*Chapter 3*)
- f) Identification of energy efficiency potentials of district heating and cooling infrastructure; (*Chapter 3*)
- g) Strategies, policies and measures that may be adopted up to 2020 and up to 2030 to realise the potential in point (e) in order to meet the demand in point (d), including, where appropriate, proposals to: (*Chapter 9*)
 - i) increase the share of cogeneration in heating and cooling production and in electricity production;
 - ii) develop efficient district heating and cooling infrastructure to accommodate the development of high-efficiency cogeneration and the use of heating and cooling from waste heat and renewable energy sources;

- iii) encourage new thermal electricity generation installations and industrial plants producing waste heat to be located in sites where a maximum amount of the available waste heat will be recovered to meet existing or forecast heat and cooling demand;
- iv) encourage new residential zones or new industrial plants which consume heat in their production processes to be located where available waste heat, as identified in the comprehensive assessment, can contribute to meeting their heat and cooling demands. This could include proposals that support the clustering of a number of individual installations in the same location with a view to ensuring an optimal matching between demand and supply for heat and cooling;
- v) encourage thermal electricity generating installations, industrial plants producing waste heat, waste incineration plants and other waste-to-energy plants to be connected to the local district heating or cooling network;
- vi) encourage residential zones and industrial plants which consume heat in their production processes to be connected to the local district heating or cooling network;
- h) The share of high-efficiency cogeneration and the potential established and progress achieved under Directive 2004/8/EC; (*Chapter 6*)
- i) An estimate of the primary energy to be saved; (*Chapter 7*)
- j) An estimate of public support measures to heating and cooling, if any, with the annual budget and identification of the potential aid element. This does not prejudice a separate notification of the public support schemes for a State aid assessment. (*Chapter 10*)

2. To the extent appropriate, the comprehensive assessment may be made up of an assembly of regional or local plans and strategies. (*not applicable*)

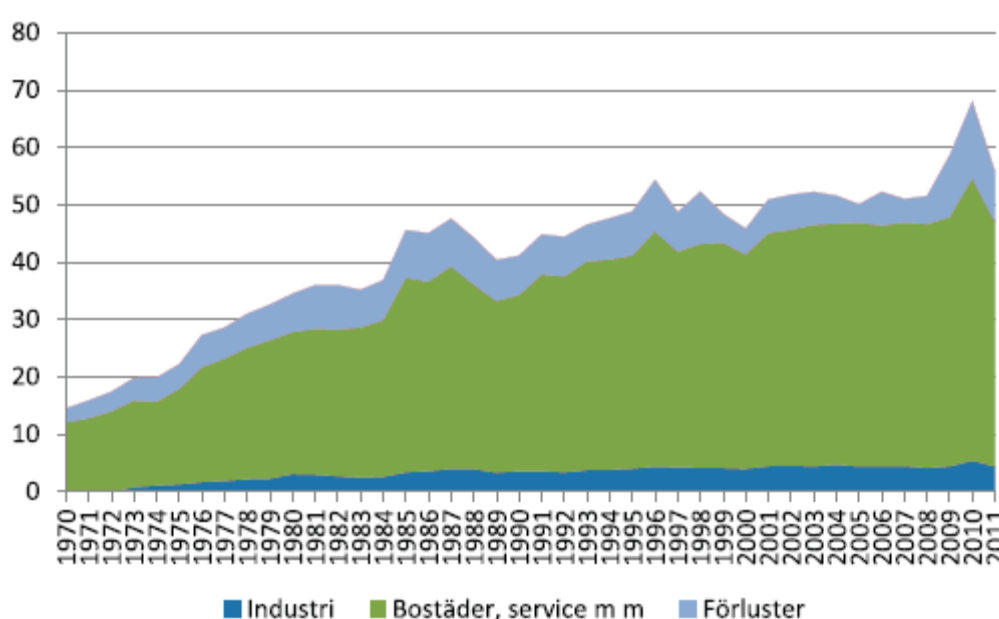
2.2 District heating and cogeneration in Sweden

In order to gain an understanding of the Swedish situation and the choice of methods for implementing the Directive in Sweden, this section will describe the development of the market up until today.

There has been district heating in Sweden since the 1940s, and previously it was predominantly produced at heating plants. Figure 1 shows consumption of district heating between 1970 and 2011. District heating accounted for 56 % of total energy consumption by homes and commercial premises in 2011. Half of this district heating was used in multi-dwelling buildings, 36 % was used on commercial premises, and the remaining 14 % was used in detached houses. A small proportion was also supplied to industries for process heat and for heating their premises. District cooling was introduced in the 1990s, but it is still a small market.

In principle, district heating represents the entire market segment for multi-dwelling buildings and the majority of heating for commercial premises, and there is little room for expansion. With regard to the distribution across buildings in 2011, some 86 % of the area accounted for by multi-dwelling houses and 72 % of the area accounted for by commercial premises was heated exclusively by means of district heating.⁷ The need for heating in buildings will fall on the whole, even if new connections and new uses for district heating emerge. Measures to improve efficiency and heat-pump installations owned by existing customers are the factors that have the greatest impact on supplies.⁸ District heating has for the most part been fully developed in Sweden, so a more pertinent matter for district-heating undertakings is that of maintaining market share in the heating market and finding new uses.

Figure 1 Consumption of district heating, 1970–2011, TWh.



Swedish	English
Industri	Industry
Bostäder, service m m	Homes, services, etc.
Förluster	Losses

Source: Energy in Sweden 2013

According to Article 2(41) of the EED, the definition of *efficient district heating and cooling* is that it is a district heating or cooling system using at least 50 % renewable energy, 50 % waste heat, 75 % cogenerated heat or 50 % of a combination of such energy and heat. There are only a few individual systems that do not have to satisfy this criterion.⁹ Figure 2 below shows that, on the whole, Sweden already satisfies the efficiency criterion, with 58 % renewables in district-heating production in 2011. Waste heat accounted for approximately 8 % at the same time, and the proportion of heat from cogeneration production in the district-

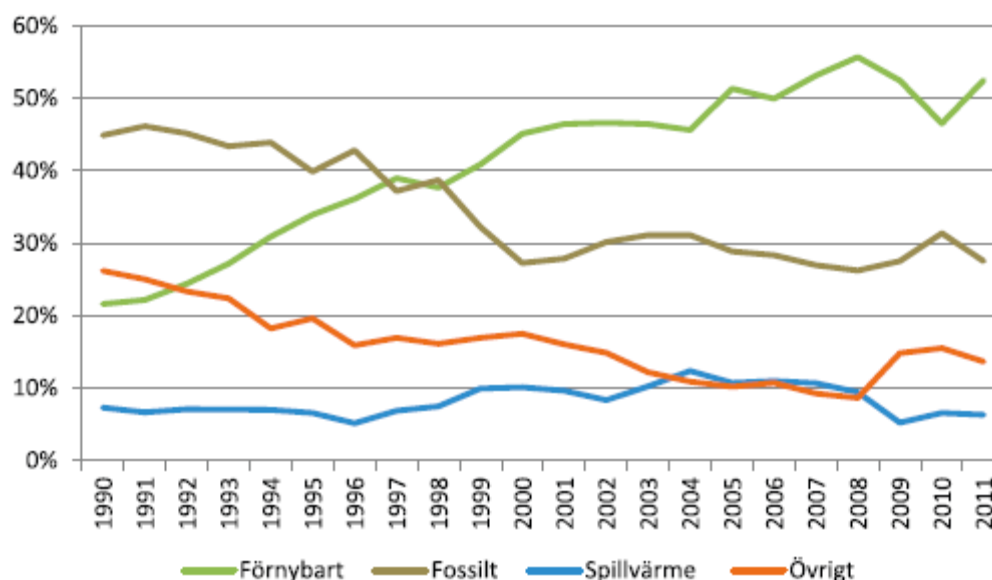
⁷ Energy statistics for detached houses, multi-dwelling houses, and commercial premises 2011 (ES 2012:07).

⁸ District heating in the future – Needs (2009:21).

⁹ Source: According to estimates from the Swedish District Heating Association.

heating system has grown since then. In 2011, cogeneration met 45 % of heat needs in the district-heating system, a threefold increase compared with 1990.

Figure 2 Fuel consumption in the district-heating sector, broken down into renewables and other fuels, percentage share, 1990–2011.



Swedish	English
Förnybart	Renewable
Fossilt	Fossil
Spillvärme	Waste heat
Övrigt	Other

Source: Energy indicators 2013

With regard to the proportion of electricity consumption accounted for by cogeneration in 2011, cogeneration produced 10 % of the electricity consumed,¹⁰ in comparison with only 3.4 % in 1990 (Figure 3).

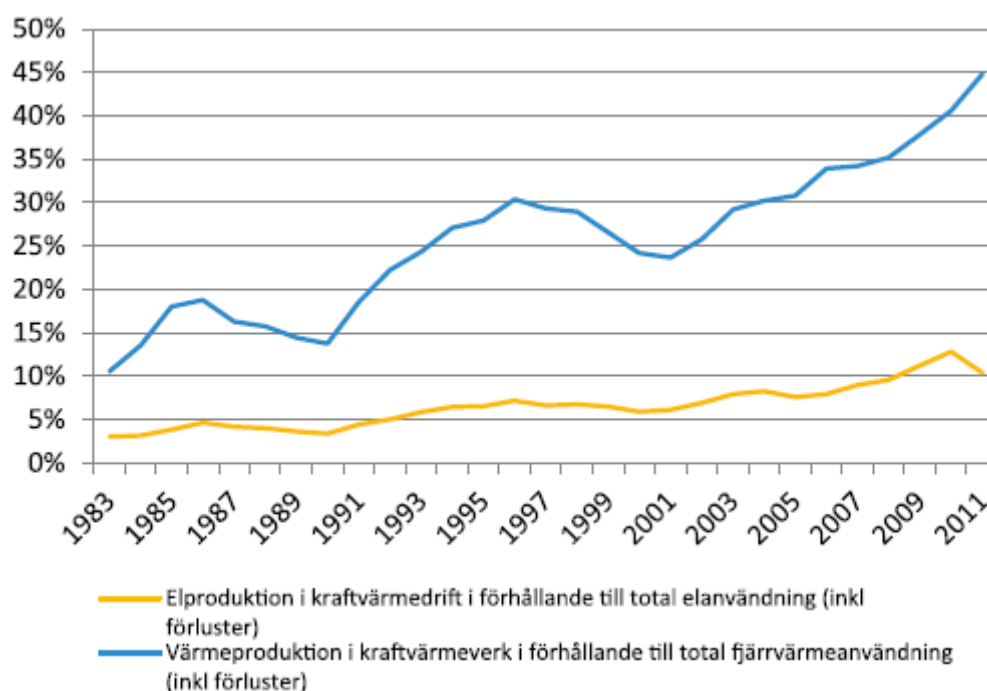
There are various instruments that have had a substantial impact on this trend, such as a gradually lower level of carbon-dioxide tax on heat production from cogeneration plants in the EU ETS¹¹, to stimulate increased cogeneration production as a whole, with rising electricity prices. Not least the electricity-certificate scheme has had a clear impact on the cogeneration trend and has helped to increase the proportion of renewable fuels in this sector. The waste-landfill ban, which was introduced in 2002 and updated in 2005, has been favourable to waste-based cogeneration.

¹⁰ Including transmission losses.

¹¹ In 2008, CO₂ tax fell from 21 % to 15 %, and in 2011 it fell from 15 % to 7 % (from a basic amount of 105 öre per kg of CO₂). The tax was abolished in 2013. The reason for this was that the EU ETS must be the main instrument for reducing CO₂ emissions. CO₂ tax was abolished for industrial back-pressure facilities as early as 2011, and this has in some ways resulted in a distortion to the detriment of cogeneration in the district-heating system.

In line with the heating basis and the predicted fall in district-heating supply, there is a limit to how much cogeneration in Sweden can be developed, even if there is some scope to replace super-heated water boilers/heating plants.

Figure 3 Proportion of electricity and district heating produced from cogeneration.

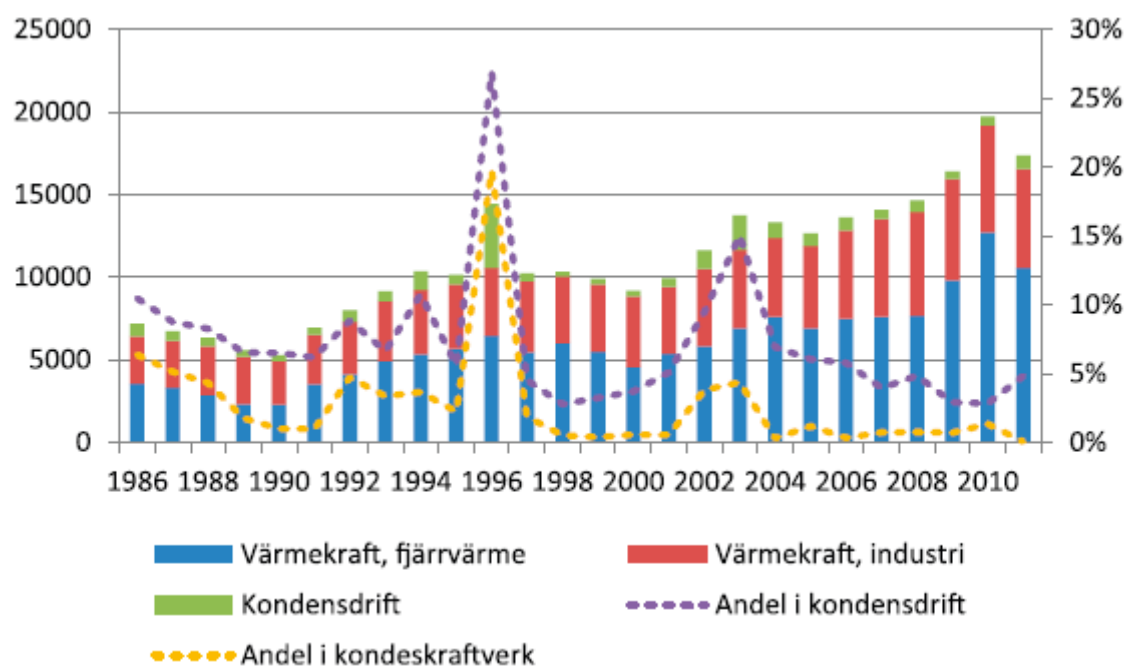


Swedish	English
Elproduktion i kraftvärmedrift i förhållande till total elanvändning (inkl förluster)	Electricity production from cogeneration operations in relation to total electricity consumption (including losses)
Värmeproduktion i kraftvärmeverk i förhållande till total fjärrvärmeanvändning (inkl förluster)	Heating production at cogeneration plants in relation to total district-heating consumption (including losses)

Source: Energy indicators 2013

With regard to the upgrading of condensing power plants to cogeneration plants, which Article 14(5) of the Energy-Efficiency Directive is intended to promote, there is negligible scope for this in Sweden. Figure 4 shows the proportion of thermal power in condensing operations, which indicates that there is extremely limited potential for replacing condensing power production with cogeneration in Sweden. Furthermore, condensing operations are used primarily when there are real peaks in electricity consumption, and it would therefore be unrealistic to eliminate them.

Figure 4 Electricity produced from cogeneration, and proportion of condensing power from conventional thermal power, expressed in GWh, 1986–2011.



Swedish	English
Värmekraft, fjärrvärme	Thermal power, district heating
Kondensdrift	Condensing operations
Andel i kondeskraftverk	Proportion at condensing power plants
Värmekraft, industri	Thermal power, industry
Andel i kondensdrift	Proportion in condensing operations

Note: The peak in 1996 indicates a cold year, and 2010 was also unusually cold.

Source: Energy indicators 2013

3 Potential for efficient heating and cooling

The estimates of the potential for high-efficiency cogeneration, and of efficient district heating and cooling in accordance with Article 14(1) of the Energy-Efficiency Directive, are based on a number of studies that are also summarised in this section. As part of these studies, technical¹² and economic assessments have been performed in relation to forecasts and potential. The various studies are partly based on various calculation assumptions, for example in relation to investment costs, energy prices, and the trend in and performance of the heat basis. The assumptions forming the basis for the assessments of potential, which are intended to ensure that a proper cost-benefit analysis of the national territory is carried out, are presented in more detail in Chapter 5.

3.1 Potential for efficient district heating

The 'Fjärrsyn' report 'District heating in the future – Needs' (2009:21) found that the trend of increased energy efficiency on the consumer side and greater competition from heat pumps mean that total supplies of district heating in Sweden will fall by 2025. On the basis of the methodology and underlying analyses, the report has been updated by the consultancy firm Profu, partly by moving the base year to 2011, and partly by extending the time frame to 2030. The estimated future trend in total district-heating supplies in Sweden is shown in Figure 5. For a more detailed description of the methodology for the assessment of future district-heating needs, please see 'Fjärrsyn' report 2009:21.

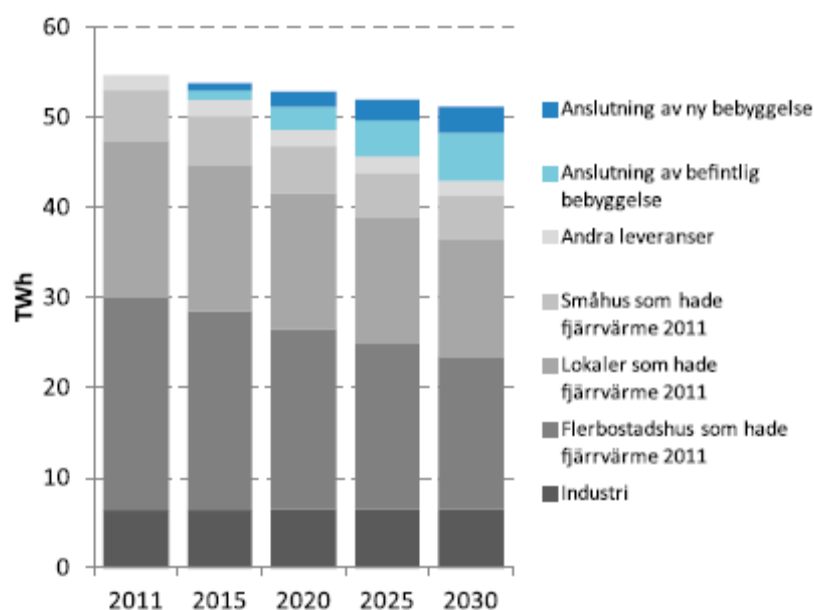
New district-heating connections for both existing and new buildings are not offsetting the fall that is simultaneously taking place in buildings that are already connected, resulting from increased efficiency and conversion to heat pumps. Some 54.7 TWh of district heating¹³ was produced in 2011, and it is estimated to fall to 51 TWh by 2030, despite the fact that new connections to existing buildings (5.3 TWh) and new buildings (2.7 TWh) together are estimated to amount to 8 TWh by 2030. The net fall is thus estimated to be approximately 4 TWh, which would be 12 TWh if there were no new connections.

As mentioned above, the focus is on those cases where district heating is expanding, in other words on new connections, since it is the potential for improving efficiency in relation to this expansion that is discussed in the report (Chapter 7). The estimated new connections for different types of building appear in Figure 6. There will be a total of approximately 8 TWh up to and including 2030. Increased supply levels for industry are not given in the figure, but they are included in the calculations and are assumed to amount to only 0.2 TWh more in 2030 than is supplied now.

¹² The district-heating systems adopted for the purpose of the models impose some technical restrictions, for example.

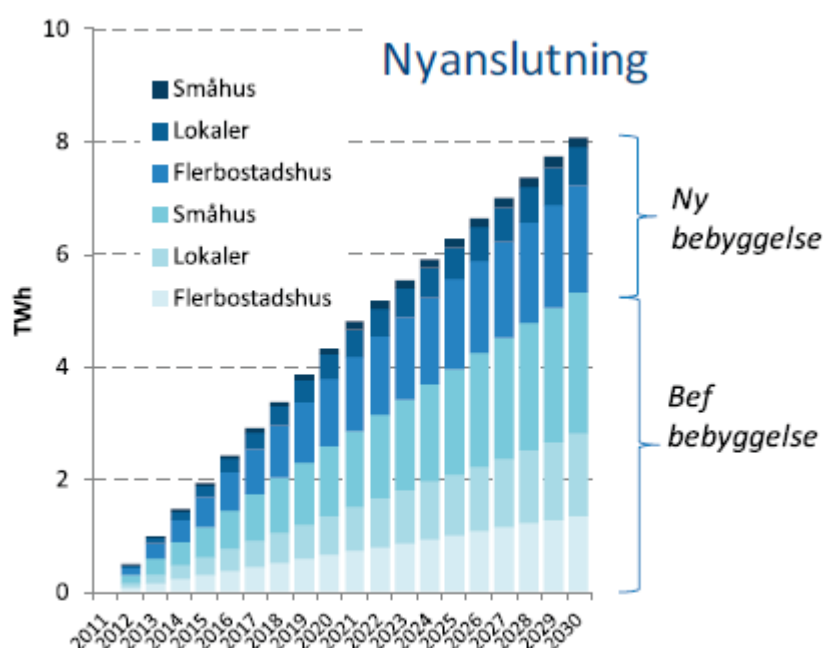
¹³ Updated/corrected figures from the Swedish Energy Agency Energy Indicators report, 2013, give 55.8 TWh.

Figure 5 Estimated trend in total district-heating supplies in Sweden up to and including 2030 (Source: updated calculations for the ‘District heating in the future – Needs’ project, ‘Fjärrsyn’ report 2009:21).



Swedish	English
Anslutning av ny bebyggelse	Connection of new buildings
Anslutning av befintlig bebyggelse	Connection of existing buildings
Andra leveranser	Other supplies
Småhus som hade fjärrvärme 2011	Detached houses that had district heating in 2011
Lokaler som hade fjärrvärme 2011	Commercial premises that had district heating in 2011
Flerbostadshus som hade fjärrvärme 2011	Multi-dwelling buildings that had district heating in 2011
Industri	Industry

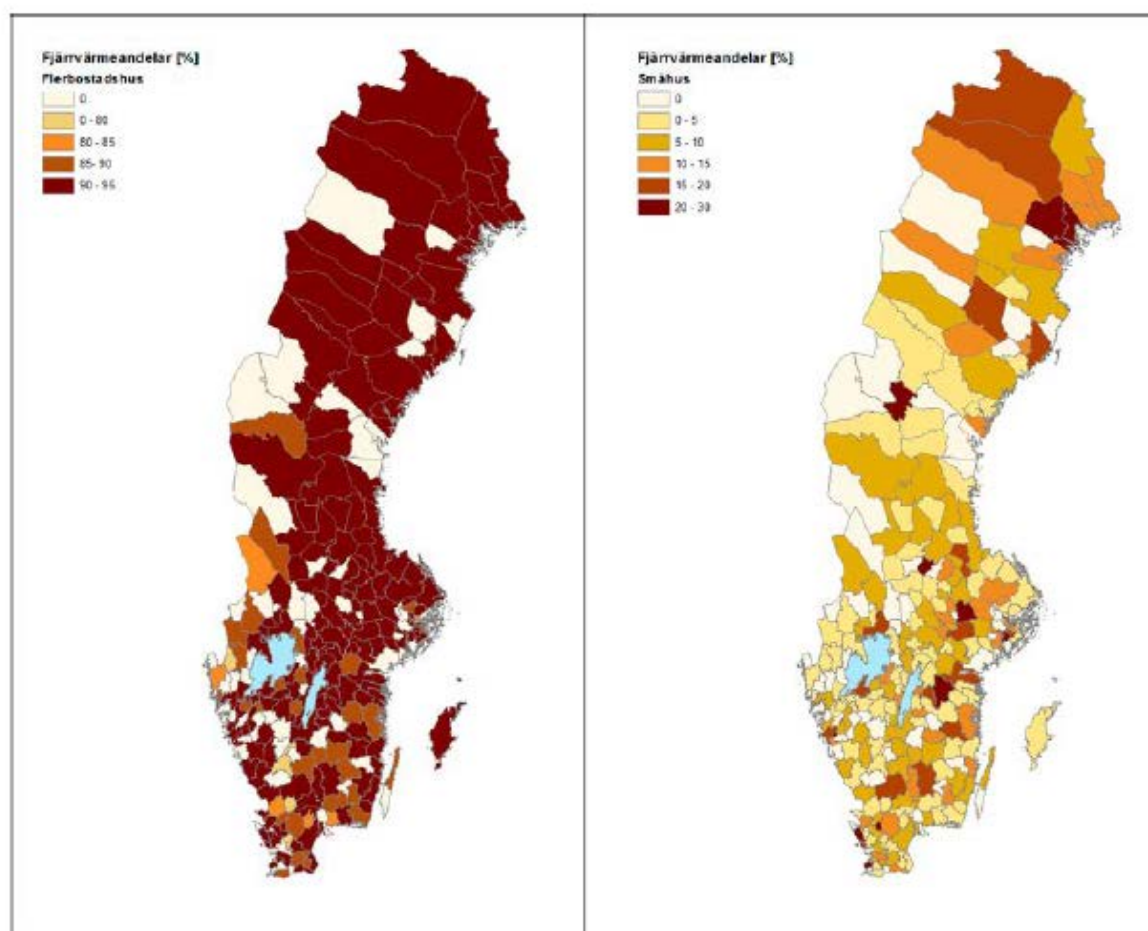
Figure 6 New district-heating connections, broken down according to building type (excluding industry). Source: updated calculations for the 'District heating in the future – Needs' project, 'Fjärrsyn' report 2009:21.



Swedish	English
Nyanslutning	New connections
Småhus	Detached houses
Lokaler	Commercial premises
Flerbostadshus	Multi-dwelling buildings
Ny bebyggelse	New buildings
Bef bebyggelse	Existing buildings

A supplementary description of the current extent of district heating may be found in map form in Figure 7. The two maps show the market share of district heating in Swedish municipalities. The figure on the left shows the market share of district heating for the heating of multi-dwelling houses, while that on the right shows the same share for detached houses.

Figure 7 Market share of district heating for multi-dwelling houses (left) and detached houses (right). (The colour code '0' means that there is no data available.)



Swedish	English
Fjärrvärmeandelar [%]	Share of district heating [%]
Flerbostadshus	Multi-dwelling buildings
Småhus	Detached houses

The information given in the maps, and the estimates of changes in the district-heating base ('Fjärrsyn' report 2009:21), form the basis for estimating the potential for further district-heating connections. This includes interviews and the collection of data from district-heating undertakings, as well as estimates of the impact of improving energy efficiency and conversion to heat pumps. The calculations show that measures to improve efficiency have the greatest impact, with a fall of approximately 10 TWh by 2025 among houses that had district heating in 2007. At the same time, partial conversion to heat pumps is estimated to involve a fall in district-heating supplies of approximately 3 TWh.¹⁴ The basis used for this report (please see Figures 5 and 6) has updated the start year to 2011 and extended the time frame to 2030.¹⁵

¹⁴ These assumptions relate to the 'baseline scenario' and have been updated somewhat (please see Figure 5).

¹⁵ The approach to this analysis is described in depth in *District heating in the future* (2009:21).

3.1.1 Conclusion on the potential for district heating

The total estimated potential for district heating is 4 TWh by 2020 and 8 TWh by 2030 for new connections for new and existing buildings. On the whole, however, there will be a fall in this basis as a result of existing customers implementing measures to improve energy efficiency and converting to heat pumps.

3.2 Potential for high-efficiency cogeneration in the district-heating system

The estimates of electricity production from cogeneration plants in the district-heating system are discussed here. The information has been obtained from seven different sources.

3.2.1 District heating and cogeneration in the future, Official State Report 2005:33 ('the district-heating report')

The first study that has been used is the district-heating report entitled 'District heating and cogeneration in the future', Official State Report 2005:33, from 2005. Annex 4 to that report discusses an 'Estimate of the potential for high-efficiency cogeneration in Sweden', produced by Öhrlings PriceWaterhouseCoopers. They performed the calculations using a 'heat-spot' model all of the district-heating systems in Sweden. The cogeneration that was profitable was calculated for every single system on the basis of the calculation assumptions. These included an assumption that the heating base would grow. The potential was reported for 2010, 2015 and 2020. The results appear in Figure 8 and the values in the figure entitled 'Official State Report 2005:33'. The assumed costs were low from today's viewpoint.

The aim of the report was to calculate the potential for cogeneration over 10-15 years, which means 2015-2020. The analysis is based on model calculations using two tools, Martes and MARKAL. The Martes analysis is based on calculations for district-heating production in respect of 15 actual systems. The calculations have identified options for expanding production, including various cogeneration options. The 15 systems operate as model systems, and all other Swedish district-heating systems have been assigned to one of the 15 model systems as part of the 'Swedish up-scaling'. The total profitable potential for cogeneration has thus been identified by means of a decidedly 'bottom-up initiative'. Forecasts of heat demand have been obtained for every single model system. The forecasts vary between unchanged and + 30 % district-heating needs over 10-15 years, with a mean of + 14 %.

The baseline scenario for the Martes analysis gives total electricity production from cogeneration plants of 14.7 TWh. Biofuel cogeneration is clearly dominant. The result appears in Figure 8 and the value in the figure entitled 'Swedish Electricity Research Centre 05:37'. The sensitivity analysis that was carried out indicates a range of 11.8-18.6 TWh of electricity. The lowest level is obtained in the event that there is no electricity certificate, while the highest level occurs when there is a very low price for natural gas, resulting in large quantities of electricity from natural-gas cogeneration.

3.2.2 Swedish District Heating Association, 'District heating 2015 – sector forecast', 2009

In 2009, the Swedish District Heating Association produced forecasts for several areas, including future cogeneration. The forecasts were based on questionnaires sent to member undertakings and related to the situation in 2015. The questionnaire had a high response rate, and it predicted a strong trend in electricity production at cogeneration plants. From the 2007 level of 7 TWh, the forecast showed that a level of 13 TWh should be reached by 2015, which means that it would nearly double. The result appears in Figure 8 and the value in the figure entitled 'Sector 2009'. The document also explains the trend in district-heating supplies up to 2015. They were expected to increase by 4 TWh (8 %) between 2007 and 2015.

3.2.3 Swedish District Heating Association, Swedenergy, the Swedish Forest Industries Federation, and the Swedish Bioenergy Association (Svebio), 'Expansion of cogeneration in Sweden up to 2020', November 2011

In 2011, the Swedish District Heating Association, Swedenergy, the Swedish Forest Industries Federation, and the Swedish Bioenergy Association (Svebio) administered a questionnaire to describe the trend in cogeneration and back pressure until 2020. There was a particular focus on the facilities that were being phased out of the electricity-certificate scheme. The studies show that electricity production from cogeneration in the Swedish district-heating system is expected to increase from the 2010 level of 12.2 TWh to 13.2 TWh in 2015 and 13.6 TWh in 2020. The net increase comprises an increase of approximately 4.5 TWh and a fall of approximately 3 TWh at existing facilities. As with all the other studies, the increase in cogeneration is dominated by facilities that are fired by biofuels or waste. The results appear in Figure 8 and the values in the figure entitled 'Sectors 2011'.

The stagnation in expansion revealed by the studies is explained in the report with reference to the fact that the heating base is saturated (in other words that there is no scope for any more), that the undertakings are not planning to continue until 2020, and that few facilities will be phased out of the electricity-certificate scheme between 2016 and 2020, so there will be less pressure for new construction.

3.2.4 Profu, 'District heating in the future', 'Fjärrsyn' report 2011:2

The 2011 Profu report 'District heating in the future' contains MARKAL calculations. Several different scenarios were produced. The variable parameters were the trend in district-heating needs, the price of emission allowances, and the scope of the electricity-certificate scheme. Of these parameters, future cogeneration production is predominantly affected by the trend in heating needs. The baseline scenario is based on a slight increase in district-heating supplies (+ 4 % by 2030), while the increased-efficiency scenario assumes that there will be a fall in district-heating supplies (- 13 % by 2030). The results appear in Figure 8 and the values in the figure entitled 'Fjärrsyn 2011:2' (Two lines are given, namely the baseline scenario with a slight increase in district-heating supplies, and the increased-efficiency scenario with a fall in district-heating supplies).

These two scenarios give the following trend in electricity production at cogeneration plants:

[TWh]	2010	2015	2020	2025	2030
Electricity prod. baseline scenario	9.5	16.5	16.3	16.1	15.9
Electricity prod. increased-efficiency scenario	9.5	13.8	12.6	11.3	10.9

The table shows that electricity production at cogeneration plants in the increased-efficiency scenario increases to begin with and then falls away again. The reason for this is not only the fall in the heat base for cogeneration, but also the expansion of waste cogeneration, which has a low electricity yield. This limits the scope for other forms of cogeneration with a higher electricity yield. The consequences of waste-cogeneration expansion are also felt in the baseline scenario. Supplementary calculations have been performed for six real Swedish district-heating systems, using the Martes model. These calculations confirm the trends from the MARKAL calculations.

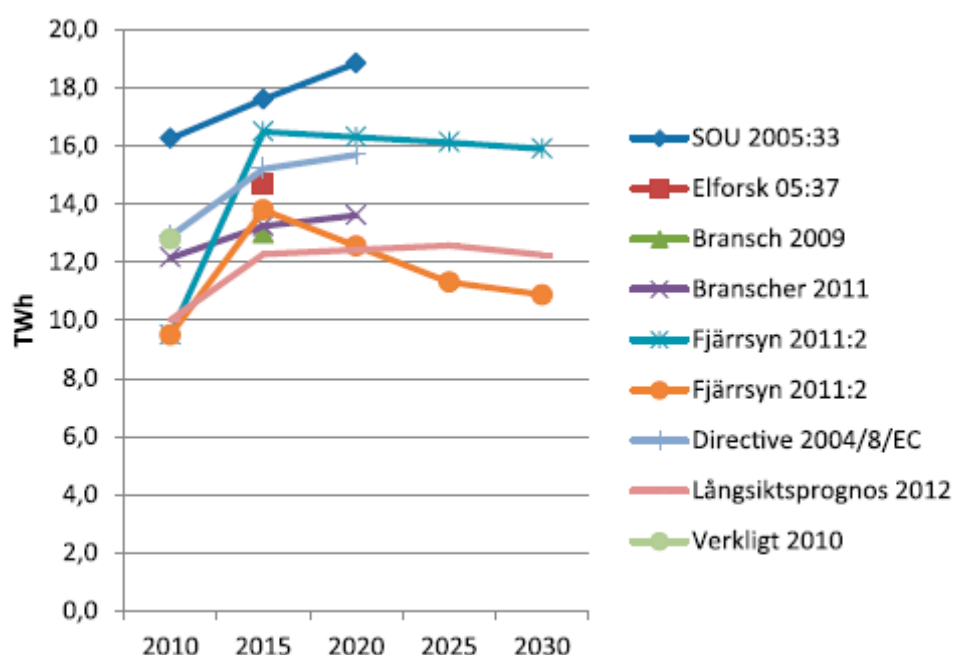
3.2.5 Data/information on national potential for the application of high-efficiency cogeneration following Article 6 of and Annex IV to the Cogeneration Directive 2004/8/EC, 15-15-15 scenario, Profu, commissioned by the Swedish Energy Agency, 2010

The Swedish Energy Agency commissioned Profu to review the economic and technical potential for cogeneration in accordance with a questionnaire from the EU. The historical data were based on sector-specific statistics, while the future forecasts were based on calculations using the MARKAL model. The focus of this mandate was on the economic potential. The calculations suggest a trend whereby electricity production will increase from the 2007 level of 7.2 TWh to 15.2 TWh in 2015 and 15.7 TWh in 2020. The results appear in Figure 8 and the values in the figure entitled ‘Directive 2004/8/EC’.

3.2.6 Profu, Basis for the Swedish Energy Agency’s Long-Term Forecast, 2012

In the context of the Swedish Energy Agency’s long-term forecasts, baseline calculations were performed using the MARKAL model to support the assessment of how electricity and district-heating production were likely to develop. A similar baseline was also produced in conjunction with the Long-Term Forecast 2012. Calculations were performed for a couple of different scenarios, but the differences between them in relation to cogeneration are so small that only the results for the baseline scenario are given. The MARKAL calculations suggest that electricity production at cogeneration plants will reach 12.3 TWh in 2015, 12.4 TWh in 2020 and 12.3 TWh in 2030. The results appear in Figure 10 and the values in the figure entitled ‘Long-term forecast 2012’. The calculations are based on a fall in district-heating supplies of - 5 % by 2030.

Figure 8 Electricity production at district-heating cogeneration plants.



Swedish	English
SOU 2005:33	Official State Report 2005:33
Elforsk 05:37	Swedish Electricity Research Centre 05:37
Bransch 2009	Sector 2009
Bransch 2011	Sectors 2011
Fjärrsyn 2011:2	'Fjärrsyn' 2011:2
Långsiktsprogno 2012	Long-term forecast 2012
Verkligt 2010	Actual 2010

3.2.7 Conclusion on the potential for cogeneration

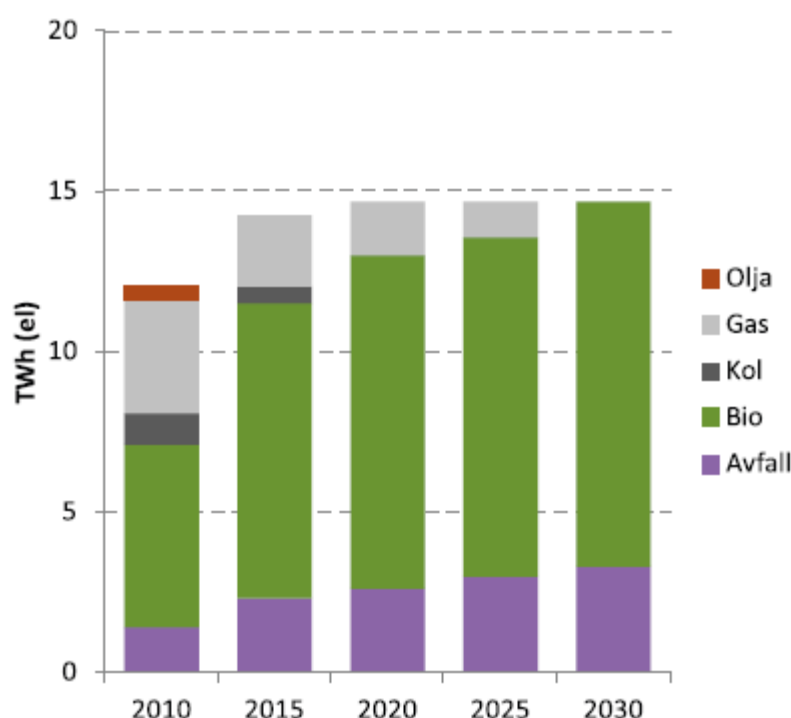
Cogeneration production in the district-heating network amounted to 10.5 TWh in 2011. The overall estimate of cogeneration potential, based on the sources discussed above, is 14.7 TWh of electricity for both 2020 and 2030. This is based on the assumption that district-heating supplies will fall somewhat in the longer term.

The conclusion for cogeneration potential in 2020 is a mean of the levels for 'Sectors 2011' and 'Directive 2004/8/EC'. It is also approximately the mean of both the 'Fjärrsyn 2011:2' values, which is considered to be reasonable. For the purposes of estimating the trend until 2030, it has been assumed that there will be a slight fall in district-heating needs, and that the potential for cogeneration will therefore not continue to grow but will remain constant. 'Fjärrsyn 2011:2' indicates a slight fall in electricity production at cogeneration plants. It is assumed that the expansion of waste-based cogeneration will be somewhat less than in these scenarios, which will enable higher levels of electricity production from other technologies. In the longer term, there will be certain contributions from micro-cogeneration and small-scale cogeneration. Small-scale cogeneration is partly included in the form of baselines on which the potential is based, but the potential may have been underestimated on this point.

Technology is being developed with the aim of reducing costs, and actual facilities are being constructed.

The trend in cogeneration production for each type of fuel, as assumed for the purposes of this report, is shown in Figure 9 and explained in greater detail in section 3.2.8. It is this trend that forms the basis for the estimated potential for improving energy efficiency later on in the report. Nonetheless, it is reasonable to assume that there will still be some fossil fuels in the form of reserves and peak-load boilers. This is not illustrated in the figure. With regard to the actual result for electricity production at cogeneration plants of 12.8 TWh in 2010, it should be considered that 2010 was a cold year and that the heat base for cogeneration was therefore extensive and the price of electricity was high, which made cogeneration particularly attractive from the economic perspective. The cogeneration potential for 2020 and 2030 assumes the conditions in a normal year.

Figure 9 Electricity production from cogeneration in the district-heating network, for each type of fuel (the bar for 2010 has been corrected for a normal year, and is therefore somewhat lower than the actual result).



Swedish	English
TWh (el)	TWh (electricity)
Olja	Oil
Kol	Coal
Bio	Biofuel
Avfall	Waste

The account above relates to cogeneration in the district-heating network. The Directive also pays attention to private micro-cogeneration. The expectations for the expansion of micro-cogeneration are considered to be very limited. An indication of future potential may be

found in the Profu report for the Swedish Energy Agency in relation to Directive 2004/8/EC (Profu 2010a). It states that there will be an increase of 0.3 TWh in electricity production from micro-cogeneration between 2010 and 2020. The rest of the analysis disregards the role that micro-cogeneration has to play.

3.2.8 Sensitivity analysis

The potential illustrated in Figure 9 is based on the assumptions concerning the world around us that are considered most likely to come to fruition. Many of these assumptions are uncertain and could have a significant impact on the resulting cogeneration potential. A couple of these assumptions are the scope of the electricity-certificate scheme and the trend in the price of emission allowances. The impact of these assumptions has been studied in a relatively detailed manner in the 'Fjärrsyn' report entitled 'District heating in the future' (Profu 2011). It states that the influence of variations in these parameters has a very limited impact. In principle, a higher price for carbon-dioxide emission allowances will not have any impact on the cogeneration potential. The higher CO₂ price will itself result in a higher electricity price, which will increase the incentives for cogeneration. At the same time, however, the calculations show that the price of electricity certificates will fall, which means that the driving force of cogeneration will remain approximately unchanged. According to the report, the increased scope of the electricity-certificate scheme will also not have any impact on the cogeneration potential. This is explained by the fact that the heat base does not provide any scope for more cogeneration despite the higher price of electricity certificates. Instead, wind power will meet the increased need for electricity production eligible for electricity certificates.

According to the aforementioned 'Fjärrsyn' study, among others, this is a parameter that will have a substantial impact on the trend in the district-heating base. A difference of approximately 20 % in the heat base by 2030 will result in a difference of as much as 5 TWh in electricity production from cogeneration, equivalent to a difference of approximately 35 %. The calculations therefore suggest that electricity production from cogeneration will fall more rapidly than the district-heating base. An important reason for this is that the resources available from base-load production with very low variable costs, such as industrial waste heat and waste incineration (with no or low electricity yield), will maintain their heat production and cover a larger share of the total heat base. Consequently, the scope for cogeneration with a higher electricity yield will have a yet smaller heat base. This means that a fall of 10 % in the heat base by 2030, which is a very rough estimate, would mean that electricity production from cogeneration would hardly increase at all in comparison with the current level. An instrument that has a direct impact on the need for heating is the building regulations, in other words the rules that specify the energy-related properties that buildings must have. This applies both to the new-build rules and conversion rules. The factor with the greatest impact on the overall trend in district-heating needs, at least for the period up to 2030, is thus the trend in the heating needs of existing buildings.

A parameter that could potentially give clearly greater potential for cogeneration is a combination of very low prices for natural gas and a greatly expanded natural-gas system in Sweden. In that case, combined-cycle gas facilities that are fired by natural gas and have a very high electricity yield could increase electricity production significantly on the basis of a limited district-heating base. The price of natural gas would, however, need to be extremely

low, since we have an electricity-certificate scheme that compels us to produce specific volumes of renewable electricity. Such a trend therefore appears to be very remote.

3.3 Potential for industrial cogeneration

The assessments of electricity production from industrial cogeneration plants, i.e. industrial back pressure, are discussed below. The information has been obtained from five different sources.

3.3.1 District heating and cogeneration in the future, Official State Report 2005:33 ('the district-heating report')

The first study that has been used is the district-heating report entitled 'District heating and cogeneration in the future', Official State Report 2005:33, from 2005. Annex 4 to that report discusses an 'Estimate of the potential for high-efficiency cogeneration in Sweden', produced by Öhrlings PriceWaterhouseCoopers. In order to identify the potential for industrial back pressure, electricity production has been examined in relation to the use of fuels for various industrial sectors in the EU15. On this basis, if Swedish industry were to have the same electricity yield as the rest of Europe, back-pressure production would have been 10-15 TWh in 2003 in comparison with the actual production level of 5 TWh. The results appear in Figure 10 and the values in the figure entitled 'Official State Report 2005:33'. The method that has been used does not take account of trends in the industrial sectors, nor to the composition of the paper and pulp industry, for example, in relation to manufacturing processes (e.g. an entirely different electricity yield for chemical and mechanical pulp manufacturing). The results also deviate greatly from the other sources that have been used.

3.3.2 Swedish District Heating Association, Swedenergy, the Swedish Forest Industries Federation, and the Swedish Bioenergy Association (Svebio), 'Expansion of cogeneration in Sweden up to 2020', November 2011

The Swedish Forest Industries Association and the Swedish Bioenergy Association were responsible for the part of the report that dealt with the development of back pressure. The study only discussed back pressure in the forestry industry. It does, however, account for the majority of back pressure in Swedish industry, currently accounting for 93 % of total back pressure.

The studies show that electricity production from industrial cogeneration in the Swedish forestry industry is expected to increase from the 2010 level of 5.9 TWh to 6.8 TWh in 2015 and 7.3 TWh in 2020. The net increase comprises an increase of approximately 1.5 TWh and a fall of approximately 0.1 TWh at existing facilities. The distribution of fuels for electricity production in back-pressure operations is largely unchanged from 2010 to 2020, and is dominated by black liquor and bark. The proportion of oil will fall from 4 % to just over 1 %. The results appear in Figure 10 and the values in the figure entitled 'Sector 2011'.

3.3.3 Data/information on national potential for the application of high-efficiency cogeneration following Article 6 of and Annex IV to the Cogeneration Directive 2004/8/EC, 15-15-15 scenario, Profu, commissioned by the Swedish Energy Agency, 2010

This reference work reviews the economic and technical potential for cogeneration in accordance with a questionnaire from the EU. The historical data were based on sector-specific statistics, while the future forecasts were based on calculations using the MARKAL model. Only the economic potential is highlighted here.

The calculations suggest a trend whereby electricity production at industrial back-pressure facilities will increase from the 2007 level of 6.1 TWh to 6.5 TWh in 2015 and 6.6 TWh in 2020. The results appear in Figure 10 below and the values in the figure entitled 'Directive 2004/8/EC'.

3.3.4 Profu, Basis for the Swedish Energy Agency's Long-Term Forecast, 2012

The MARKAL calculations performed to support the Swedish Energy Agency's Long-Term Forecast 2012 show how electricity production will develop in two specific scenarios. Industrial back-pressure production of electricity is part of this. It is linked to the forecast trend in the industrial sectors. The differences between the scenarios with regard to industrial back-pressure are so small that only the results for the baseline scenario are given. The MARKAL calculations suggest that electricity production at cogeneration plants will reach 6.4 TWh in 2015, 6.8 TWh in 2020 and 7.2 TWh in 2030. The results appear in Figure 10 below and the values in the figure entitled 'Long-term forecast 2012'.

3.3.5 Profu, Analysis of biofuel consumption in the district-heating sector and industrial back pressure, linked to the MARKAL calculations, commissioned by the Swedish Energy Agency, 2010.

Among other things, this mandate studied the trend in industrial back pressure up to 2020 and 2030. Unlike the sector-specific forecast of November 2011, this forecast also includes industrial back pressure outside the forestry industry. Although the assessment from this work is also that the overwhelming majority of potential for industrial back pressure lies in the forestry industry, other sectors will also contribute total electricity production of approximately 1 TWh per annum in the long term. There has been a large amount of contact with the industry in order to produce the forecast.

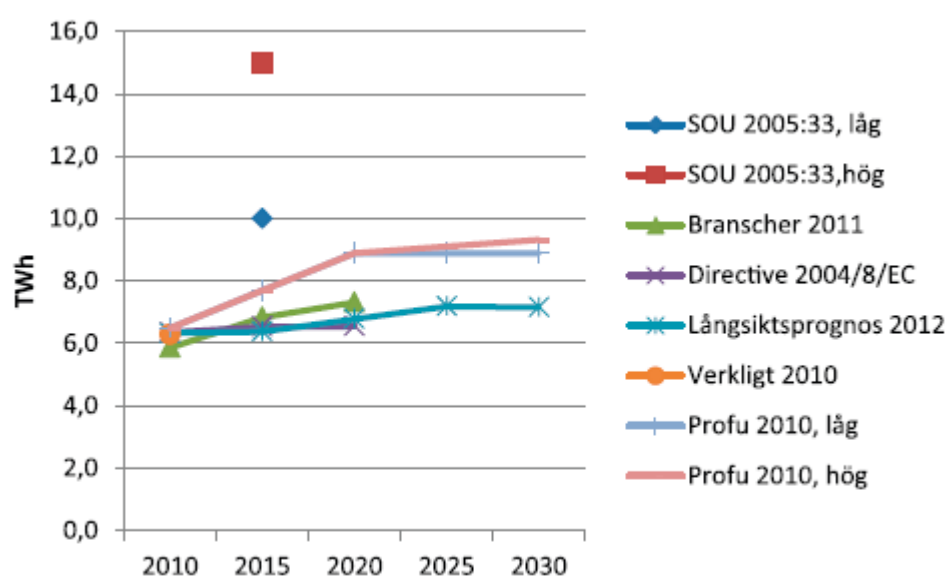
A single level of anticipated back-pressure production has been given for 2020. From this perspective, undertakings have fairly clear plans for any changes to production that may occur. On the other hand, there is greater uncertainty for 2030, so two levels have been given, namely 'low' and 'high'.

These two scenarios give the following trend in electricity production from industrial back pressure:

[TWh]	2010	2020	2030
Electricity production, low	6.5	8.9	8.9
Electricity production, high	6.5	8.9	9.3

The results appear in Figure 10 and the values in the figure entitled ‘Profu 2010, low’ and ‘Profu 2010, high’.

Figure 10 Electricity production from industrial back pressure



Swedish	English
SOU 2005:33, låg	Official State Report 2005:33, low
SOU 2005:33, hög	Official State Report 2005:33, high
Branscher 2011	Sectors 2011
Långsiktsprogno 2012	Long-term forecast 2012
Verkligt 2010	Actual 2010
Profu 2010, låg	Profu 2010, low
Profu 2010, hög	Profu 2010, high

3.3.6 Conclusion on the potential for back pressure

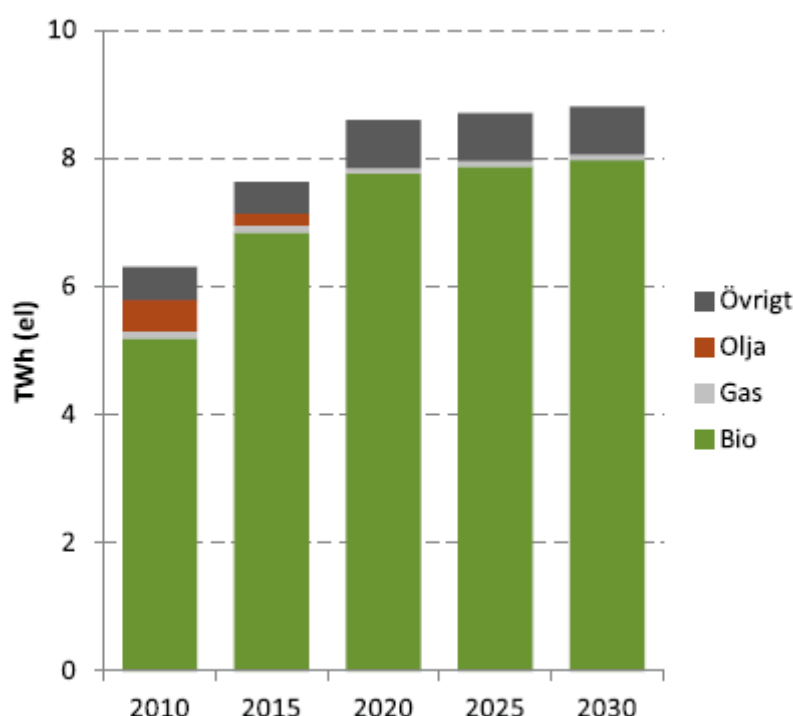
Industrial back pressure amounted to 6 TWh in 2011. The overall estimate of back-pressure potential, based on the sources discussed above, is 8.6 TWh of electricity for 2020 and 8.8 TWh for 2030. The selected potential is a mean of the levels for ‘Sectors 2011’ and ‘Profu 2010, high’. The former reference work, however, added approximately 1 TWh first, in order to perform calculations for all industrial sectors. The selected potential is higher than the economic potential given by the Long-Term Forecast 2012. The reasons for the

differences include, for example, the development of industrial sectors, the prices of electricity and fuel, the price of electricity certificates, etc.

The conclusion for the trend in back-pressure production of electricity up to 2030 is given in Figure 11 for each type of fuel. It is this trend that forms the basis for the estimated potential for improving energy efficiency later on in the report.

Electricity production from industrial back-pressure is also predominantly affected by alternative assumptions concerning the trend in the heat base. This essentially equates to the process-heat needs of the forestry industry.

Figure 11 Electricity production from cogeneration in industry (industrial back pressure), broken down according to fuel type ('other' mainly consists of blast-furnace gas, which is a residual product from the iron and steel industries).



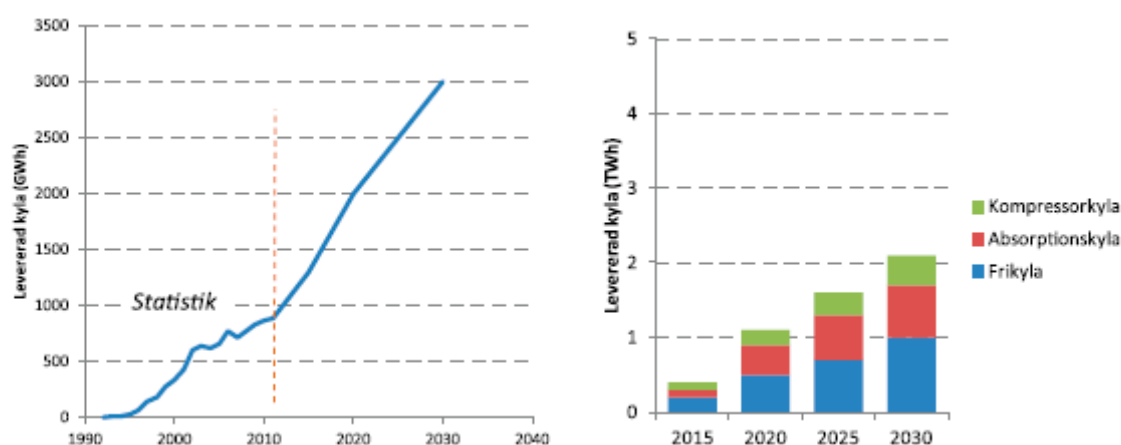
Swedish	English
TWh (el)	TWh (electricity)
Övrigt	Other
Olja	Oil
Bio	Biofuel

3.4 Potential for district cooling

Supplies of district cooling have risen rapidly and steadily since 1990 (please see Figure 12). In recent years, however, the rate of this rise has levelled off somewhat. There is only a limited basis for assessing the future trend in the Swedish market as a whole. The most recent

official forecast for this sector is from 2009, by the Swedish District Heating Association (2009), and it gives a projection up to 2015. It is assumed that district cooling may account for approximately 1.3 TWh in 2015. For the period between 2015 and 2030, there is a very rough estimate of ‘future potential’ of 2-5 TWh in a report by ÅF (ÅF/Confederation of Swedish Enterprise 2011). On the basis of these two reports, it has been assumed that total consumption of district cooling will be approximately 3 TWh in 2030, which is an increase of just over 2 TWh in comparison with 2010 (Profu 2013). For the sake of simplicity, the future expansion of district cooling has been divided up into three main technologies: compression-cooling machines with electricity as the power source, absorption-cooling machines with district heating as the main power source, and free cooling, which in principle has a negligible primary-energy input (Figure 12). The distribution between these three technologies in future expansion has been based on assumptions from the current composition of some of the largest district-cooling systems in the country. (Sorption cooling, which also uses district heating as the power source, is also included under the heading of absorption cooling. On this point, it has been assumed that its performance is equal to that of an absorption-cooling machine.)

Figure 12 Estimated trend in district cooling up to 2030, total in GWh of supplied cooling (left) and increase compared to 2010, broken down according to cooling technology, in TWh of supplied cooling (right).



Swedish	English
Statistik	Statistics
Levererad kyla (GWh)	Supplied cooling (GWh)
Levererad kyla (TWh)	Supplied cooling (TWh)
Kompressorkyla	Compression cooling
Absorptionskyla	Absorption cooling
Frikylla	Free cooling

Note: Statistical source: 1992-2011, Swedish District Heating Association and Swedish Energy Agency (Energy in figures, 2012)

3.5 Identification of the energy-efficiency potential of district heating and cooling infrastructure

The aim of this chapter is to identify the potential for improving the efficiency of district heating and cooling infrastructure as required by point f) of Annex VIII to the EED.

As a result of improved technology, more efficient network use, and a greater proportion of ‘ready heat’,¹⁶ distribution and conversion losses from the district-heating system have fallen over the years. Over the 1990–1999 period, losses amounted to 17 % on average, falling to 10 % on average between 2000 and 2009. In 2011, however, some 15.5 % of the total district-heating consumption of 56 TWh was accounted for by losses.

A challenge for the district-heating sector is to reduce heat losses from distribution pipelines. A research project was therefore launched as part of the wider ‘Fjärrsyn’ project on district heating and cooling (2012:16). It was called ‘High-performance district-heating pipes’ and it examined high-performance insulation materials consisting of aerogel felt and vacuum felt next to the service pipe, in combination with the usual polyurethane insulation. A number of district-heating pipe prototypes with this hybrid insulation have been manufactured.

The results of the first technical tests showed that both of these high-performance materials reduced heat losses from the pipe by 15-30 %, but the vacuum panel appeared to have the greatest potential and was the most economical. Accordingly, the ‘Fjärrsyn’ research report (2013:23) entitled ‘District-heating pipes with hybrid insulation’ followed this up with field measurements whereby the lifetime properties of primarily the vacuum panels were examined, and theoretical calculations were verified. The insulation properties did not deteriorate appreciably, but the technology relating to the material, application and large-scale manufacturing needs to be developed.

Losses amounted to 8.7 TWh in 2011. A reduction of 30 %, which is technically possible, would bring these losses down to 6 TWh.

3.5.1 Lower system temperatures in future district-heating systems will lead to lower primary-energy consumption¹⁷

Future district-heating systems will probably have lower system temperatures than the current ones do. In order to enable this, the temperatures in the secondary systems of connected buildings need to be lowered. There are a range of potential heating systems suitable for operation at low temperatures to choose from in the context of new builds. Examples of such systems include under-floor heating, traditional fan-convector units, and radiators that are adapted to low-temperature systems. There are considerably fewer options available for existing buildings. One option that has been studied is to increase the convective heat transfer for existing radiators by means of air blasting using small fans mounted on the radiator, known as ‘radiator fans’. Field trials and simulations with this solution show that heat output can be increased by up to 60 %. Radiator fans are not only suitable for lowering radiator temperatures in existing buildings generally, but also as a supplementary measure in

¹⁶ ‘Ready heat’ is hot water that is produced and supplied locally.

¹⁷ Combined district heating and cooling, ‘Fjärrsyn’ report (2011:8).

individual spaces where the heat output is too low. The return temperature of the district-heating water will be reduced automatically if the temperature needs of the building's heating system are lower. Lower temperature needs can also be used so that the primary flow temperature is lowered without increasing the primary flow. If, for example, the potential reduction in the flow temperature is used in a district-heating network with cogenerated power, the increased electricity production will exceed the electricity needs of the radiator fans in most operating scenarios, i.e. there will be a net gain.

There is reason to believe that demand for comfort cooling will continue to increase, and possibly not only for office buildings, etc. but also for homes. Since there are often high costs involved with installing cooling systems in existing buildings, the option of using the radiator system for combined heating and cooling has been investigated. There are two buildings in Sweden where this has already been tested and applied. The solution is primarily relevant where cooling needs are modest, such as in residential properties, but also in some types of commercial premises, such as offices incorporated into old residential properties. In this context it is worthwhile to use radiator fans, including to increase heat transfer during cooling. It is thus possible to increase the cooling power by up to 34-75 %, depending on the radiator type.

At the aggregate level, it is difficult to estimate what the result of these options would be in terms of the potential for improvements to energy efficiency, but an attempt to calculate this for an individual system is described in the next chapter.

3.5.2 Lower primary-energy consumption as a result of more efficient infrastructure¹⁸

In order to assess the benefits of lower district-heating temperatures, their impact on primary-energy factors for district heating has been estimated. The calculations apply to a district-heating system where the heat production is based on a cogeneration plant and on separate heating units for peak load and summer load. The calculations of the change in primary-energy factors for district heating have been performed by reducing the primary temperatures using two methods:

1. Implementation of optimised radiator control;
2. Implementation of radiator fans.

The results show that the primary-energy factors for district heating very much depend on the type of electricity production that the cogeneration plant is intended to replace. If the electricity that is produced is intended to replace electricity produced at a coal-fired condensing power plant, the primary-energy factors (PEFs) for district heating will be reduced by 25-40 % when radiator fans are used. This applies when both the primary flow and return-pipe temperature are reduced and the extra electricity consumption that the operation of the fans entails is not taken into consideration. If the higher electricity consumption that the fans entail is taken into consideration, the PEFs for district heating will still fall by 20-25 %, irrespective of whether the fans are only operated when required for electricity production. This operating strategy is particularly important for higher fan speeds, which use more electricity. If the substituted electricity is assumed to have been produced as

¹⁸ *Temperature-efficient district-heating systems*, 'Fjärrsyn' report (2012:2).

part of the European electricity mix, the impact on the PEFs for district heating will fall by a few percentage points. For the Nordic electricity mix, the impact on the PEFs for district heating will be even less. If the primary return-pipe temperature and primary flow are reduced while the flow temperature remains unchanged, the PEFs for district heating will not be affected to the same extent as in the preceding case. The PEFs for district heating may still, however, fall by approximately 5 % if the substituted electricity is envisaged to replace coal-fired condensing. This result can be achieved either with radiator fans or with optimised radiator control.

4 Technical Potential

The interpretative note¹⁹ accompanying the EED states that the methodology proposed to the Member States involves assessing the level of demand for heating that can technically be implemented in the form of high-efficiency cogeneration, micro-cogeneration, and efficient heating and cooling. It requires an assessment of what the maximum technical potential is. It proposes that the economic potential should then be added to it.

Sweden has a low proportion of cogeneration in the district-heating network in comparison with other EU Member States. The proportion of district heating produced at cogeneration plants has increased over time and is currently approximately 45 % in Sweden, which can be compared to proportions of approximately 80 % in other EU Member States. There are several reasons for the fact that the proportion of cogeneration is lower in Sweden. Two important reasons are the comprehensive expansion of hydro-electric power, and nuclear power. Another explanation is the historically low electricity prices, which have encouraged investment in super-heated water boilers. The previous wording of the rules on taxation and energy-policy instruments has also contributed to the lower proportion of cogeneration. From the technical perspective, it would be possible to achieve the same high proportion of cogeneration in Sweden as in other European countries. In the 'Fjärrsyn' project (2011:2) entitled 'District heating in the future', Profu took the view that cogeneration could represent at least 60 % of Swedish district-heating production after 2020, be the economic aspects would have to be taken into consideration.

Technical potential of cogeneration

The technical potential of cogeneration depends on the heat base, which is made up of the district-heating system and industrial process-heat needs. Two important parameters for the development of cogeneration are the extent to which the existing heat base is exploited and how the total size of the heat base develops. Projections suggest that the heat base will shrink as a result of measures to improve energy efficiency and a warmer climate (please see Chapter 3).

Waste and biofuel, which dominate Swedish cogeneration plants, have a relatively low electricity ratio, and this means that the electricity yield from cogeneration in Sweden will only be modest. From the technical perspective, cogeneration should be capable of considerable expansion if there were to be large-scale investment in gas-fired cogeneration. In addition to cogeneration based on natural gas, there is also the potential for cogeneration based on gasified biofuels. This would give greater electricity production from the district-heating base, since the proportions of electricity and heat at a cogeneration plant will differ across different fuels. Gaseous fuels enable the extraction of a larger proportion of energy in the form of electricity.

¹⁹ Interpretative note on Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EC, and repealing Directives 2004/8/EC and 2006/32/EC Article 14: Promotion of efficiency in heating and cooling (B 16).

Gas-engine facilities of 0.5-10 MW currently dominate cogeneration facilities that use gaseous fuels, with electrical efficiency of 25-30 % and total efficiency of 80-90 %. With technological development, facilities of these kinds may achieve a gradual improvement in efficiency through the development of processes and engines. These could also be combined with a vapour cycle or organic Rankine cycle (ORC) to make use of exhaust heat. This would enable electrical efficiency of 30-35 % with total efficiency remaining unchanged or increasing slightly.²⁰

For larger facilities, gasification would have to be capable of using gas-turbine combination cycles instead of engines, with electrical efficiency of 35-45 % and total efficiency of 85-90 %. Through gas-turbine development, this could be expected to increase somewhat, so that efficiency of 40-50 % could be achieved.

In respect of biomethane obtained from gasified biofuels, the efficiency would largely be similar to that for natural gas.

Efficiency is approximately 20 % for waste from incineration facilities. There is potential to increase this efficiency level using gasified waste, but this technology has not had a commercial breakthrough. It could increase the efficiency level to approximately 30 %. With regard to the technical potential, it will be assumed that the same quantity of waste will be used for cogeneration production as in 2011 (3.8 million tonnes).

Technical potential of electricity production from waste heat

The technology for electricity production from industrial waste heat is currently available commercially via the Organic Rankine Cycle (ORC). This technology currently has an efficiency level of 4-5 % with a heat source at 90 °C, but technological development is continuing for similar processes with an efficiency level of approximately 10 % at the same temperature. Some 4 TWh of residual industrial heat was supplied to the district-heating network in 2008. In the Third-Party Access (TPA) report (Official State Report 2011:44), the Industry Group for Re-Use of Energy (IÅE) estimates that an additional 4.4 TWh could be supplied.

Technical potential of micro-cogeneration

The potential for micro-cogeneration has been estimated as 0.3 TWh over the 2010–2020 period (Profu 2013). This technology is primarily relevant in areas where there is a natural-gas network, but it could be technically possible to use gasified biofuels and biogas in other areas too, albeit very much in the long term. The development of fuel cells in the order of 1-100 kW could have better potential.

Technical potential overall

Some 56 TWh of district heating was supplied in 2011, and the technical potential has been assessed on this basis, starting from the assumption that heating needs will fall by 10 % and

²⁰ Information from Lars Waldheim of Waldheim Consulting.

distribution losses will fall to 7 %.²¹ This should result in district-heating needs of 46 TWh. Bearing in mind the above descriptions of technical development, the potential for high-efficiency cogeneration is estimated to amount to 26 TWh_{electricity}. The table below shows the technical potential based on the aforementioned assumptions. No account has been taken of industrial cogeneration.

	Input	TWh_{heat}	TWh_{electricity}
Biofuel	42 TWh	18.8	18.8
Waste	3.8 tonnes	6.6	3.3
Natural gas*	3.5 TWh	2.2	2.7
Waste heat	8.4 TWh		0.8
Micro-cogeneration			0.3
Heating plant		18.4	
Total		46	26

* Alternative method (calculated as for 2011 in SCB EN 11 SM 1301)

In its report, ‘District heating and cogeneration in the future’ from February 2004, the Swedish District Heating Association gives a potential value for cogeneration of approximately 20 TWh_{electricity} in the existing Swedish district-heating network. According to that report, electricity production should reach higher levels than at present if there is greater access to natural gas or, in the long term, to gasified biofuel. If the natural-gas network is expanded in Central Sweden, this potential could increase to electricity production in the form of cogeneration amounting to approximately 28 TWh_{electricity}. The table above gives an estimate of 26 TWh_{electricity}.

²¹ Please see Chapter 2.

5 Cost-benefit analysis

The potential for expanding cogeneration, district heating and district cooling, as discussed in Chapter 3, relies upon cost-benefit calculations from a number of different reports and analyses, the fundamental assumptions for which are discussed separately in this chapter. The assumptions forming the basis for ascertaining where and to what extent the expansion of cogeneration, district heating and district cooling will be profitable are discussed here. According to Article 14(3), the potential discussed in Chapter 3 must be assessed on the basis of a cost-benefit analysis based on climate conditions, economic feasibility and technical suitability in accordance with Annex IX to the EED. That Annex states that ‘the purpose of preparing cost-benefit analyses in relation to measures for promoting efficiency in heating and cooling as referred to in Article 14(3) is to provide a decision base for qualified prioritisation of limited resources at society level.’

The analysis must also cover all socio-economic factors and environmental factors.

This chapter discusses the criteria upon which the cost-benefit analysis relies, such as determining the **supply and demand opportunities**, establishing the **system and/or geographical boundaries** and producing the **relevant baseline and alternative scenarios**. **The time frame must be relevant and the current net value must be used** as an assessment criterion.²²

The exchange rates, fuel and energy prices, taxes, etc. used as input data for the assumptions forming the basis for the calculations of potential for efficient district heating and high-efficiency cogeneration are discussed in Annex 6 to this report.

5.1 Profitable measures and external factors

The assessment of potential assumes, in principle, that existing instruments internalise external costs. It is thus assumed that carbon dioxide has been correctly priced through carbon-dioxide taxation and emission allowances, and that the market for electricity certificates works well and gives rise to correct prices, etc. In view of this assumption, the market will implement the projects that are profitable, and any external factors of relevance will also be taken into consideration. Stakeholders can therefore be said to act in a socio-economically efficient manner. It is, of course, open to debate whether the current instruments actually do internalise any negative effects from the environmental perspective, or whether they actually do take other socio-economic effects into consideration. It is also open to debate whether certain positive effects are properly reflected in the price. The Swedish Energy Agency, however, is of the view that the current instruments are sufficient, so for the time being no new or different instruments are needed to develop the district-heating market, since it is already fully developed in principle. In other words, there are not considered to be any direct ‘costs/barriers’ to the promotion of efficient heating and cooling that need to be priced, quantified and incorporated into an ‘enhanced’ cost-benefit analysis.

²² Please see Annex 2 to this report for a comprehensive review of Annex IX to the EED.

There are, however, some imperfections in the heating market that should be reviewed, since they could result in distortions of competition. It is uncertain whether these market imperfections affect the potential for further expansion of district heating and cogeneration and, if so, to what extent. These market imperfections are discussed in sections 5.1.1 to 5.1.4 inclusive.

5.1.1 Building regulations²³

The current building regulations could distort competition between heating options, since there are different limits for purchased energy, which in turn set the limits for how much heating energy may be used. In the coldest climate zones, the performance of buildings allows 95 kWh/m² per annum of electricity to be purchased, but 130 kWh/m² per annum of district heating. The installation of heat pumps therefore means that the heat actually used amounts to 285 kWh/m² per annum, provided that the heat pump has an efficiency level of 3. A house that is heated by means of a heat pump may therefore consume 155 kWh/m² per annum more than a house that is heated by means of district heating. This in turn means that less stringent construction requirements can be imposed on buildings that are constructed with the use of heat pumps in mind. The warmer the climate, the smaller the difference, with 115 kWh/m² per annum in Central Sweden and 75 kWh/m² per annum in South Sweden. This poses the risk of distorting competition in the heating market, since it is cheaper to construct buildings with the use of heat pumps in mind. At the same time, however, there are requirements relating to rated power, which means that there is no risk of the distortion becoming quite as great as that.

Since the potential of new builds only represents part of the potential for expanding district heating, any amendments to the building regulations are not considered to have such a great impact on the potential itself. The assessment of potential (Chapter 3) is based on the fact that 90 % of new-build multi-dwelling homes will be connect to the district-heating network. Parenthetically, however, the potential may be affected negatively if the wording of the energy requirements in the building regulations remains unchanged.

With regard to measures, please see section 9.4.

5.1.2 Energy taxation

District-heating undertakings pay the full rate of electrical-energy tax on their own consumption of electricity (29.3 öre/kWh), while industry has a lower rate of tax (0.5 öre/kWh).²⁴ This could result in a distortion of competition and an economic barrier to replacing oil consumption for heat production.

There is also the design of the CO₂ tax for heat supplies to industry, whereby industries operating within the EU ETS are exempt from CO₂ tax but district-heating undertakings are only exempt if the industry in question is covered by Annex 1 to the Emissions Trading

²³ Please see the National Board of Housing, Building and Planning Building Regulations, BBR 20.

²⁴ Source: Swedish District Heating Association.

Directive. This means, for example, that heat supplies from district-heating undertakings to the food industry or sawmills are still subject to CO₂ tax.

With regard to measures, please see section 9.5.

5.1.3 Tax exemption for self-generated electricity

The current tax exemption for self-generated electricity distorts competition both within the electricity-certificate scheme and in the heating market, since heating by means of heat pumps, for example, is encouraged through the use of tax-exempt, self-produced electricity from wind power to operate the pumps. This means that the tax rules are not stakeholder-neutral.

With regard to measures, please see section 9.5.

5.1.4 Examples of other socio-economic effects

Examples of relevant socio-economic effects that are difficult to quantify and incorporate into the calculations for an analysis like this include the fact that district heating provides great benefits through its ability to recover waste heat from industry, and the opportunities for exploiting waste incineration for heating purposes.²⁵ These positive socio-economic effects cannot, however, be quantified in terms of their value as part of this investigation. These advantages do, however, also benefit society in the form of lower prices for district heating, which are for the time being covered by the models used. There may also be opportunity costs for the use of biofuels at cogeneration plants and in super-heated water boilers that are not covered by this report.

5.2 Profitability calculation models

The MARKAL model has been used for several of the studies drawn upon to assess the potential for improving the efficiency of cogeneration, district heating and district cooling (please see Chapter 3, Potential for efficient heating and cooling).

MARKAL is an optimisation model that is based on linear programming, i.e. a mathematical algorithm for solving optimisation problems where the target function (that is to be optimised) and boundary conditions are expressed as linear equations. The target function is generally the discounted total system costs, and must be minimised. Boundary conditions could, for example, include the efficiency levels for a certain type of facility, environmental requirements, power-transmission links between countries, energy consumption in a given sector, etc. In other words, the solution to a MARKAL calculation is the combination of technologies in the entire chain from fuel extraction or imports to end use, via conversion into

²⁵ Swedish District Heating Association, as part of the 'Fjärrsyn' project, Socio-economic analysis of district heating. The benefits to society of district heating in the energy system now and in the future, report 2013:5.

electricity and district heating, for example, that achieves the lowest total cost expressed as the discounted current value.²⁶

MARKAL NORDIC²⁷ is the name of a MARKAL model that includes a description of the stationary energy systems in four of the Nordic countries, namely Sweden, Norway, Finland and Denmark. ‘Stationary energy system’ means the production of electricity, district heating and process steam and final energy consumption in homes, services and industry. It also includes a rather simplified description of electricity production in Germany and Poland. In this model, all of the countries are linked to each other via electricity-transmission links that can be enhanced by means of repeated investment.²⁸

MARKAL NORDIC includes approximately 80 consumer sectors (such as heating for single-family houses in Finland, energy consumption in the iron and steel sectors in Norway, operational electricity in the service sectors in Sweden, and energy consumption in the Danish agricultural sector). Each sector is described with an energy need for final or useful energy and an approximate load curve for that need.

MARKAL NORDIC has been used because it describes the trends in the energy systems from now up to 2050, given a large number of boundary conditions and assumptions. Particular emphasis has been placed on the description of existing energy and carbon-dioxide taxes, the European Emissions Trading Scheme for emission allowances, and support schemes for renewable energy such as the Swedish electricity-certificate scheme.

The model uses the net current value as an assessment criterion. The actual calculated interest is set at 7 %. In the socio-economic analysis, the calculated interest is generally lower than that (at approximately 4 %), while it can be considerably higher for private-sector stakeholders. A calculated interest rate of 7 % may be said to lie somewhere between a business-economic and a socio-economic calculated interest rate. This has been deemed appropriate for estimates of potential where market players are assumed to be the main agents for fulfilling that potential but the State can have a certain role to play in introducing various measures to improve a market that is already developed.

An economic lifetime of 21 years has been assumed for most of the technologies involved in electricity and district-heating production. The exceptions to this are new hydro-electric power (economic lifetime of 42 years) and new nuclear power in Finland (economic lifetime of 35 years). On the whole, the lifetimes are to be treated as economic lifetimes and as an overall assessment for a turnkey facility.²⁹ The assumptions are based on the study by the Swedish Electricity Research Centre entitled *Electricity from new and future facilities 2011*.³⁰ The model only permits intervals of seven years. This does not have a decisive impact on the results, but it does explain the precise choice of year.

²⁶ 3.2.4 Profu, ‘District heating in the future’, Annex 2.

²⁷ The MARKAL NORDIC model tool is managed and updated by the consultancy firm Profu AB (a Swedish acronym for Project-Related Research and Development in Gothenburg).

²⁸ Profu, Calculations using MARKAL NORDIC in the Long-Term Forecast 2012.

²⁹ District heating in the future, Annex 1.

³⁰ Swedish Electricity Research Centre Report 11:26.

5.3 System and geographical boundaries

The heating and cooling needs are divided up according to sector (multi-dwelling houses and commercial premises, detached houses, industry, and other), but not geographically. The calculations, however, are based on Sweden as a geographically demarcated area, although they also take account of imports and exports. For a more detailed explanation, please see the description of the MARKAL NORDIC model in the preceding section.

5.4 Choice of baseline and alternative scenarios

5.4.1 Definition of the alternative to cogeneration

The text of the Directive states that the alternative to cogeneration must consist of the separate production of district heating (in super-heated water boilers) and electricity (at condensing power plants) with the *same* fuel. The efficiency gain from the cogeneration itself can thus be evaluated for a given fuel. It does, however, say relatively little about the efficiency gain from an actual system. In reality, such an attempt would mean, for example, that the alternative to a biofuel-fired cogeneration plant would consist partly of a biofuel-fired super-heated water boiler, which is perfectly reasonable in itself, and a biofuel-fired condensing power plant, which in contrast appears to be rather unreasonable. From the perspective of an actual system, the alternative is completely different in terms of electricity at the plant itself. Instead, the alternative is determined by the design of the energy system in question. Calculations have been performed both on the basis of the criterion laid down in the text of the Directive and on the basis of an assumption concerning the system perspective (please see Chapter 7).

With regard to the alternative for process-heat production in the case of industrial back pressure, on the other hand, it is assumed that this is specific to each fuel. In that case, it is reasonable to assume that the alternative to producing process heat at a back-pressure plant is a process-heat plant (with no electricity production) using the same fuel. If this is the case, there is no 'alternative system' in the same way as there is for district-heating production and probably for electricity production.

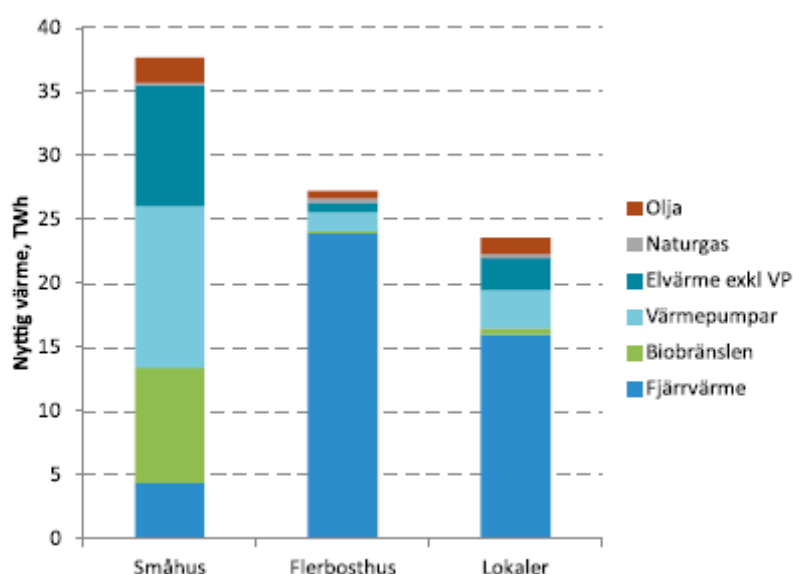
With regard to fuels for electricity or district heating at a cogeneration plant, the allocation principle does not play any part in the analysis. Specifically, the analysis is based on a quantity of electricity and district heating that is produced, which is compared to the same quantities produced using the alternative determined by applying a selected primary-energy weighting principle.

5.4.2 Definition of the alternative to district heating

District heating is partly expanded through new connections in existing buildings and partly through new connections in new buildings. The prerequisites for district heating (and the alternatives to district heating) differ depending on whether it is existing buildings or new ones that are being considered. In addition to this, both existing and new buildings are subdivided into detached houses, multi-dwelling houses, and commercial premises. New

connections (expansion) for district heating must be weighed up against an alternative heating method. For existing buildings, the initial assumption is that the alternative to a district-heating connection is a weighted mean of the current heating scenario, excluding district heating. In other words, if a new district-heating connection is made and is equivalent to 1 TWh, for example, it is assumed that this will replace 1 TWh of alternative heating. This comprises a mix where the proportion of the various heating options is the same as their relative share of total heating (excluding district heating) in the given building type (detached houses, multi-dwelling houses, or commercial premises). The exception to this is heat pumps. It is thus assumed that district-heating connections are not made to new customers in existing buildings where there is currently some kind of heat-pump solution. For detached houses, therefore, the predominant alternatives are electrical heating (excluding heat pumps), biofuels, oil and gas, while for multi-dwelling houses and commercial premises the main alternative is electrical heating. Figure 13 shows the added useful heat for each type of energy in the three types of building in the existing building stock.

Figure 13 Heating needs (useful energy) in detached houses, multi-dwelling houses and commercial premises in 2007 (Source: Swedish Energy Agency).



Swedish	English
Nyttig värme, TWh	Useful heat, TWh
Småhus	Detached houses
Flerbosthus	Multi-dwelling houses
Lokaler	Commercial premises
Olja	Oil
Naturgas	Natural gas
Elvärme exkl VP	Electrical heating, excluding heat pumps
Värmepumpar	Heat pumps
Biobränslen	Biofuels
Fjärrvärme	District heating

For new buildings, however, it is assumed that heat pumps are the only alternative, with the exception of small houses, where it is assumed that, in addition to heat pumps, a small

proportion (20 %) also consists of pellet-fired heating. On the whole, this means that the alternative to district heating in new buildings, irrespective of the type of building, consists of relatively energy-efficient heating options. In terms of improving energy efficiency, therefore, it could be difficult to maintain the rate of new connections to district heating, not least if the choice of primary-energy factors ‘disadvantages’ district heating and the efficiency levels (heating factors) of heat pumps continue to improve. Finally, with regard to supplies of district heating to industry, electricity has consistently been assumed to be the alternative (Profu 2013). There is also no difference between the different types of building. In the case of industry, this involves buildings such as offices that are located on an industrial estate or at an industrial facility. There are still some that use oil heating, which could potentially be replaced by district heating. Oil has not, however, been included as an alternative in this case. There is also potential for district heating to be used in processes too, and not only to heat industrial premises (Trygg *et al* 2009). This could include drying and heating processes, for example. Such process-specific considerations are not, however, taken into account here.

5.4.3 Definition of the alternative to district cooling

The alternative to district cooling is consistently assumed to comprise individual compressor-driven cooling machines. In other words, this is the same technology as the compression-cooling machines that make up one of the technologies for producing district cooling. What distinguishes it is its size and thus its cold factor. The cold factor for individual compression-cooling machines is assumed to be 2.5, and 4 for similar technologies in district-cooling production. These assumptions are based on the Swedish District Heating Association’s reports (2012 and 2009c). The current figures from the industry suggest that the cold factors could be higher than those stated above. The relationship between the performance of large and small cooling machines, however, is the same.

6 Proportion of high-efficiency cogeneration

The following chapter discussed ‘the share of high-efficiency cogeneration and the potential established and progress achieved under Directive 2004/8/EC’, in accordance with point h) of Annex VIII to the EED.

The report ‘District heating and cogeneration in the future’ (Official State Report 2005:33) stipulates pursuant to the Cogeneration Directive that:

‘Existing Swedish cogeneration plants are highly efficient. As far as I have been able to ascertain, almost all Swedish cogeneration plants operate at around 90 % efficiency. My assessment is that regardless of whatever reference values for high-efficiency cogeneration plants the Commission may establish, they would be fulfilled by the Swedish cogeneration plants. This is not always the case in the rest of Europe.’ (p. 112)

This assessment is shared by the Swedish Energy Agency.

There is therefore no potential to increase the share of high-efficiency cogeneration in Sweden, since all cogeneration is already highly efficient. There is, however, considerable potential for replacing hot-water production with high-efficiency cogeneration (please see Chapter 4). The definition of high-efficiency cogeneration is given in Annex 3 to this report.

7 Estimated primary-energy saving

The definition of primary energy given in the Energy-Efficiency Directive is ‘gross inland consumption, excluding non-energy uses’. This means that primary energy only includes energy consumed within a given country’s borders. This view would exclude energy consumption linked to the energy carrier’s life cycle, for example, if the energy carrier is situated outside the country’s borders. This is the case with extraction, for example, which usually takes place beyond Sweden’s borders. With regard to conventional types of fossil energy, this usually accounts for 10-15 % of the total primary-energy factors. For non-conventional types of fossil energy, such as oil sand, the proportion is greater.

The Directive refers to Annex IV, which specifies the energy content of various energy carriers for final consumption and which may be used for efficiency calculations. The Directive also states that Member States may apply a different coefficient provided they can justify it.

The definition of primary energy in the Directive means that the change is actually equivalent to the total energy consumption. This is also made clear by the English version of the Directive, since the term ‘primary-energy saving’ does not include use beyond the country’s borders and is excluded from the energy content of the fuel in question.

The Swedish Energy Agency is of the view that there are no unambiguous weighting factors that should be used to formulate instruments. This weighting is already effected by means of energy prices. Instead, the aim should be to create energy markets that work well.

7.1 The Swedish definition of primary energy

Primary-energy consumption means the total quantity of energy spent on producing one unit of energy, from extraction of the raw material for the energy to the supplied goods.

Primary-energy consumption means that consideration is given to losses in both final energy consumption and indirect/upstream energy consumption (extraction, transportation, and upstream conversion in the energy chain). In the case of electricity produced by means of nuclear power, for example, energy is used to extract the uranium and enrich it as nuclear fuel. Energy is then used to transport the nuclear fuel to the reactor. Two-thirds of the energy content is then lost at the nuclear-power plant during conversion into electricity. Approximately 6 % of the electricity thus produced is then lost during transfer to the electricity grid.³¹

The alternative used of a fuel should also be considered, since there is a ‘cost’ (loss) when a resource is used that could have been used for some other purpose. The use of leftover forestry residues for incineration, for example, could thus have a primary-energy factor

³¹ *Carbon-dioxide assessment of energy consumption: What can you do for the climate?*, Foundation report, Swedish Energy Agency (2008).

equivalent to the value of the nutrients that those residues would otherwise have passed on to the soil, or the value of any other alternative uses that they could have had.

There is great inconsistency with regard to the primary-energy weighting of various kinds of energy. The assumptions that need to be made will have implications for the assessment of various kinds of energy. A primary-energy factor (PEF) of 0 means that the fuel that is used does not consume any primary energy, since the resource 'has already been used'. BATT³² (branches and treetops) left over from forestry, for example, could be regarded as a residual product that would otherwise have gone to waste and thus has a PEF of 0. The same applies to waste that could have been incinerated in some way (or sent to landfill prior to the landfill ban). It is, however, entirely possible to argue that both BATT and waste should have a primary-energy factor of between 0 and 1, since there is a value that could have been used elsewhere. It is entirely conceivable that there will be an increase in biogas extraction through the thermal gasification of BATT in the future, so BATT has a higher opportunity cost and thus a higher primary-energy factor.³³

The choice of primary-energy factors is of great importance for the final result in terms of improving energy efficiency in the event of district-heating, district-cooling or cogeneration expansion. Table 1 shows three different primary-energy weighting principles, of which the *change-impact principle* has been selected for the purposes of this report, since it also takes account of long-term production changes. Please see Annex 4 to this report for a comprehensive review of the different principles. In order to see the efficiency of cogeneration expansion, the template values in Annex IV to the Energy-Efficiency Directive have been applied. In other words, this has been done on the basis of the fuel's energy content, which therefore means a PEF of exactly 1.

Table 1 Primary-energy factors for the different energy types according to the three primary-energy weighting principles. PEFs are expressed in MWh of primary energy per MWh supplied for each energy type. The point of delivery for the fuel is a facility for electricity or district-heating production.

	Fossil fuels	Peat	Biofuels (majority)	Waste	Electricity ¹⁾	District heating ¹⁾
Environmental communication	-1	-1	-1	-0.6	1.7/2.6	1
Heating-market committee	-1	-1	-0	-0	1.9	0.3
Change impact	-1	-1	-0	-0	2.9/2.3	0.7/0.6

Source: 'Fjärrsyn' project (2013:15).

³²Branches and treetops.

³³ Göteborg Energi (Gothenburg Energy) is currently building the first stage of the Gothenburg Biomass Gasification Project (GoBiGas) at Rya Harbour in Gothenburg. This is a demonstration facility where biofuel is to be gasified and upgraded into biogas of natural-gas quality. It is planned to become operational in the second half of 2013. The first stage of the project has been granted SEK 222 million of financial support from the Swedish Energy Agency, a decision that was also approved by the European Commission. Source: http://gobigas.goteborgenergi.se/Sv/Nyheter/Pressmeddelande_GoBiGas_projektet_aktuellt_for_delfinansiering_fran_EU

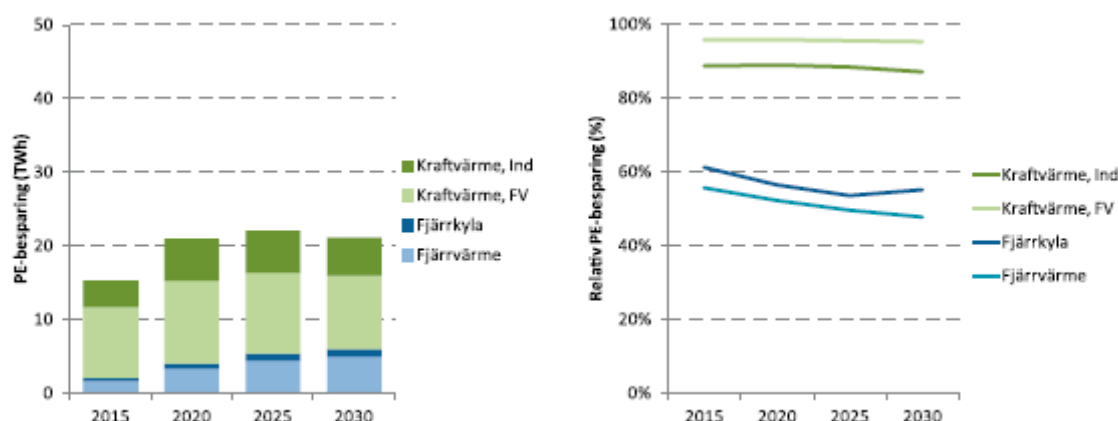
7.2 Primary-energy savings according to the ‘change impact’ principle

The ‘change impact’ principle studies the *impact* of *changes* in the use of energy carriers, for example electricity or district heating, from the system perspective. In purely theoretical terms, it is a principle that should be good at encompassing primary-energy savings. In order to do this, several assumptions need to be made, which will have implications for the result. Not least of these are the assumptions that need to be made concerning how the use of the energy type in question will be affected in the future by changes in relation to current energy consumption. Several types of energy are finite or clearly limited, which means that current consumption affects future changes.

For the purposes of this calculation, it has been assumed that electricity has a relatively high primary-energy factor (of nearly 3), but this will fall over time as electricity production becomes more efficient and less intensive in its need for primary energy in the longer term. District heating is weighted by a factor of approximately 0.7, and combustible waste and most biofuels have a primary-energy weighting of nearly zero, since they are assumed to be residual products. The fact that district heating itself has a primary-energy weighting that is clearly greater than zero is because the principle is based on the *impact* of a change. Furthermore, the impact of a change in consumption on the district-heating system partly involves the input of fuels and energy carriers with a primary-energy weighting of around 1, such as conventional fossil fuels, ‘prime’ biofuels, and peat.

Figure 14 shows the results for primary-energy savings, broken down into district heating, district cooling and cogeneration in the district-heating network and in industry (industrial back pressure). The primary-energy saving is calculated partly by calculating the primary-energy input for the expansion of district heating, district cooling and cogeneration, and partly by calculating the equivalent primary-energy input for the expansion of the alternatives to district heating, district cooling and cogeneration. The difference in primary-energy input between the latter and the former is the primary-energy saving as defined here (‘PE saving’ in the figure). It may be seen that the total primary-energy saving will be just over 20 TWh after 2020. The largest saving can be achieved through cogeneration in the district-heating network. This is because the anticipated expansion of cogeneration (approximately + 2.5 TWh by 2030) is associated with very low primary-energy input (mainly biofuels and waste fuels with a PEF of nearly zero), while the alternative consists of electricity production (for example at condensing power plants) with high primary-energy input. The alternative to district-heating production also requires a certain amount of primary-energy input according to this evaluation principle.

Figure 14 Primary-energy saving in absolute figures (left) and relative figures (right) according to the ‘change-impact’ primary-energy weighting principle.



Swedish	English
PE-besparing (TWh)	PE saving (TWh)
Kraftvärme, Ind	Cogeneration, Ind
Kraftvärme, FV	Cogeneration, district heating
Fjärrkyla	District cooling
Fjärrvärme	District heating
Relativ PE-besparing (%)	Relative PE saving (%)

Industrial back-pressure production is also expected to increase by approximately 2.5 TWh by 2030. The primary-energy saving will therefore be approximately the same for electricity production as for cogeneration in the district-heating network, since the alternative is the same, namely marginal electricity production in the electricity market in Northern Europe. With regard to heating, however, the situation is completely different. The alternative to process-heat production at back-pressure facilities takes place in steam boilers with no turbine or generator but with the same fuel. Consequently, there is also no significant primary-energy gain to be had for process-heat production, since the efficiency levels of the alternative boilers are high. The overall contribution from industrial back pressure is therefore somewhat less than the equivalent contribution from cogeneration in the district-heating network, despite the fact that the increase in electricity production is approximately the same.

Figure 14 also shows the primary-energy saving for cogeneration in relative figures (as a percentage), in other words the absolute primary-energy saving divided by the primary-energy input associated with the alternative production method. This is shown on the right-hand side of Figure 14. For the sake of consistency, the relative primary-energy saving is also given for district heating and district cooling. On this point too, the absolute primary-energy saving is related to the primary-energy input for the alternative (such as individual compression-cooling machines in the case of district cooling). The figure shows that the relative primary-energy saving is significant in all cases, particularly for cogeneration, which is relatively close to a 100 % reduction. On the other hand, this is related to the fact that the primary-energy input for cogeneration expansion is very low according to the ‘change-impact’ principle (with the fuels that are PEF-weighted close to zero). This reduces nearly all of the primary-energy input that would have been necessary for the alternative and separate production of electricity and district heating/process heat.

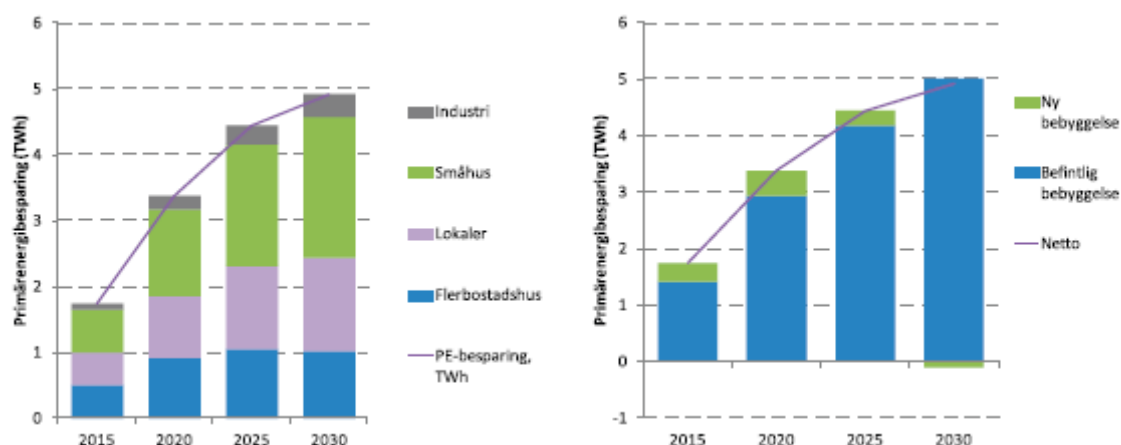
According to the change-impact principle, the primary-energy input for the expansion of district heating is approximately 0.7 MWh of primary energy for each MWh of district heating supplied. This increase in the primary-energy input must be compared to the reduction achieved as a result of district heating replacing electrical heating, biofuels, oil and gas in existing buildings (in the event that biofuels are replaced, no primary-energy saving is achieved, because wood and pellets have primary-energy factors close to zero according to the 'change-impact' principle). For new buildings, it is assumed that heat pumps are the main alternative to district heating. They are very efficient in terms of primary energy, even though electricity has a relatively high weighting according to the 'change-impact' principle. It is therefore far from certain that the use of district heating in new buildings will result in a primary-energy saving.

The use of district cooling is expected to increase in the future. In terms of absolute figures, however, supplies are relatively modest, with an increase of approximately 3 TWh by 2030. This partly explains the small contribution to the primary-energy saving, which is in the order of just over 1 TWh in the long term (Figure 14). Another explanation is that the primary-energy saving is only considerable for free cooling as opposed to the alternative, namely individual compression cooling. For large compression-cooling machines in the district-cooling system, the only gain is in terms of economies of scale. Absorption-cooling machines in the district-cooling system are not particularly efficient in terms of primary energy if district heating is weighted with a primary-energy factor of approximately 1 (approximately 0.7 according to the 'change-impact' principle). Since the future composition of district-cooling production is a major uncertainty factor, there is good reason to perform a simple sensitivity analysis. If it is instead assumed that district cooling will only expand through free cooling, which is the most efficient option in terms of primary energy, this means that the primary-energy saving will be just under 2 TWh, i.e. nearly double that of the baseline scenario. If it is instead assumed that the entire expansion of district cooling will take place through compression cooling, which is the 'worst' option in terms of primary energy according to the 'change-impact' principle, the primary-energy saving will be just under 0.5 TWh.

According to Figure 14, the contribution of district heating to the primary-energy saving will be approximately 4-5 TWh in the long term. This 4-5 TWh is divided up among the various building types as shown in Figure 15. The greatest saving is achieved for detached houses, where new connections to district heating compete with relatively inefficient options such as electrical heating and oil heating. On the other hand, the potential for primary-energy savings through new connections to district heating in new buildings will be relatively limited until 2025, in the order of 0.2-0.5 TWh. This confirms the fact that heat pumps, which are a very energy-efficient heating option for new buildings, make the efficiency gain from connecting to district heating a small one. New connections to district heating up to and including 2030 will result in a small increase in primary energy. This is because of the assumption that the technological development of heat pumps will have resulted in a system-heat factor of 4 by 2030, which means that every kWh of electricity turns into 4 kWh of heat instead of the current 3 kWh or so. At the same time, the primary-energy weighting of electricity according to the 'change-impact' principle will be longer over time. It is assumed that the ratio of the primary-energy factor for electricity to that for district heating will be just over 3.5 in 2030, which is lower than the typical system-heat factor for a new installation. A new connection to district heating from a new-build house will thus result in a primary-energy loss if the alternative is a heat-pump installation.

The text of the Directive states that the alternative to cogeneration must consist of the separate production of district heating (in super-heated water boilers) and electricity (at condensing power plants) with the same fuel. In contrast with the system perspective, such an endeavour can be called ‘fuel-specific alternative production’.

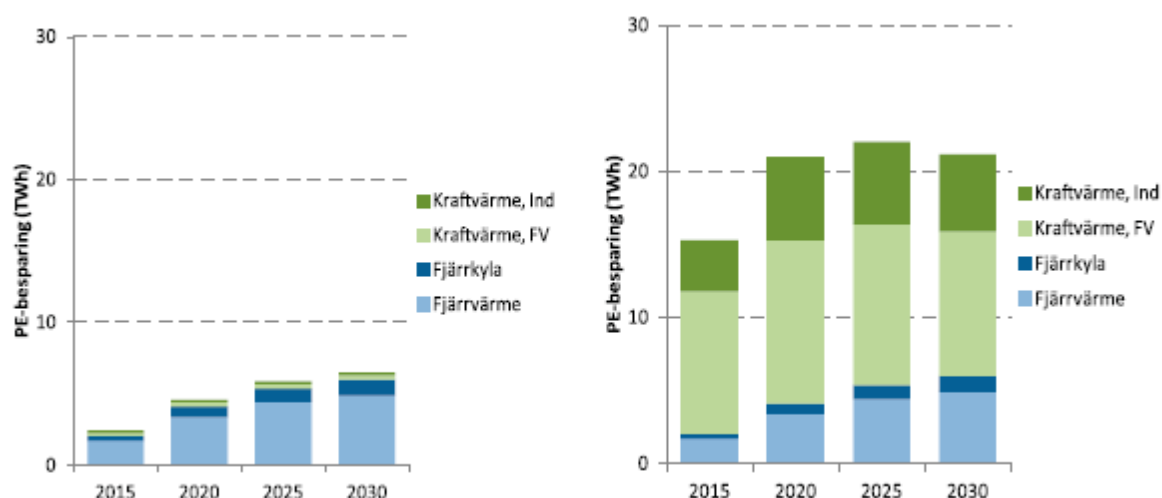
Figure 15 Primary-energy saving from district-heating expansion, broken down according to building type (left) and between existing and new buildings; ‘change-impact’ principle.



Swedish	English
Primärenergibesparing (TWh)	Primary-energy saving (TWh)
Industri	Industry
Småhus	Detached houses
Lokaler	Commercial premises
Flerbostadshus	Multi-dwelling buildings
PE-besparing, TWh	PE saving, TWh
Ny bebyggelse	New buildings
Befintlig bebyggelse	Existing buildings
Netto	Net

Figure 16 (left) clearly shows the impact of choosing the option with an alternative form of fuel-specific production to cogeneration: The primary-energy saving from cogeneration is almost zero. The explanation for this is partly the option itself and partly the ‘change-impact perspective’. Cogeneration with a primary-energy input of almost zero, in other words biofuels and waste, is compared to separate production in super-heated water boilers and at condensing power plants with the same fuel and the same low primary-energy input. The gain from the expansion of cogeneration will therefore be almost zero.

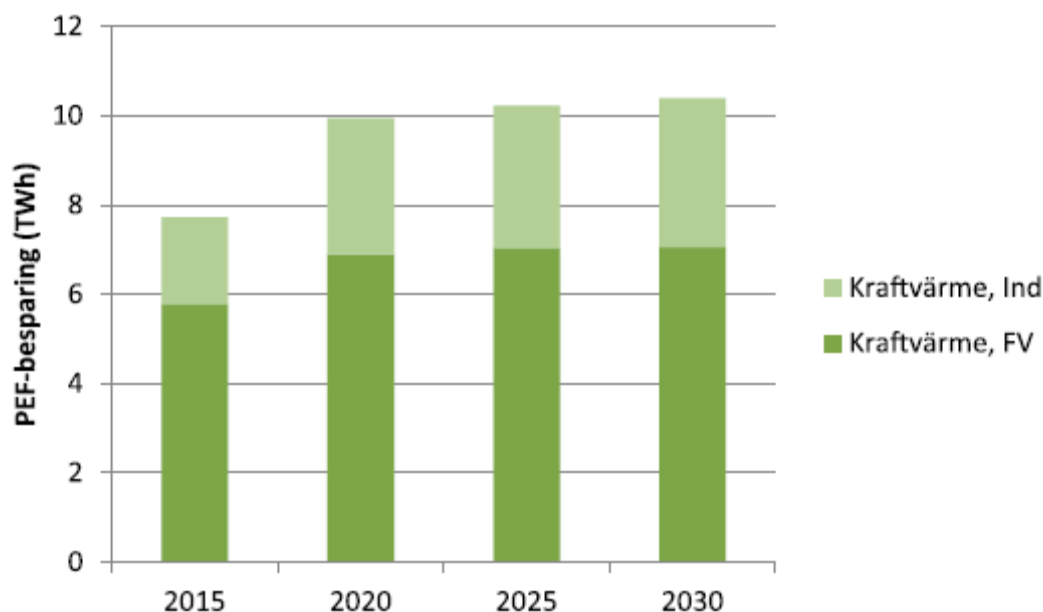
Figure 16 Total primary-energy saving according to the ‘change-impact’ principle in a scenario with an alternative fuel-specific production option (figure on the left) and in a scenario with alternative production being determined from the system perspective (figure on the right).



Swedish	English
PE-besparing (TWh)	PE saving (TWh)
Kraftvärme, Ind	Cogeneration, Ind
Kraftvärme, FV	Cogeneration, district heating
Fjärrkyla	District cooling
Fjärrvärme	District heating

In order to gain an idea of the efficiency of cogeneration expansion where an alternative fuel-specific production method is used (as required by the Directive), a primary-energy factor higher than 0 must be used (please see Figure 16). Figure 17 therefore assumes that biofuels and waste have a PEF of 1, which means that the starting point is the energy content of the fuel. This option is also close to that dictated by the environmental-communication method. Cogeneration expansion in Sweden is assumed to consist exclusively of waste cogeneration and biofuel cogeneration. The total primary-energy savings from cogeneration expansion using this option amount to 10 TWh by 2020 and 10.4 TWh by 2030.

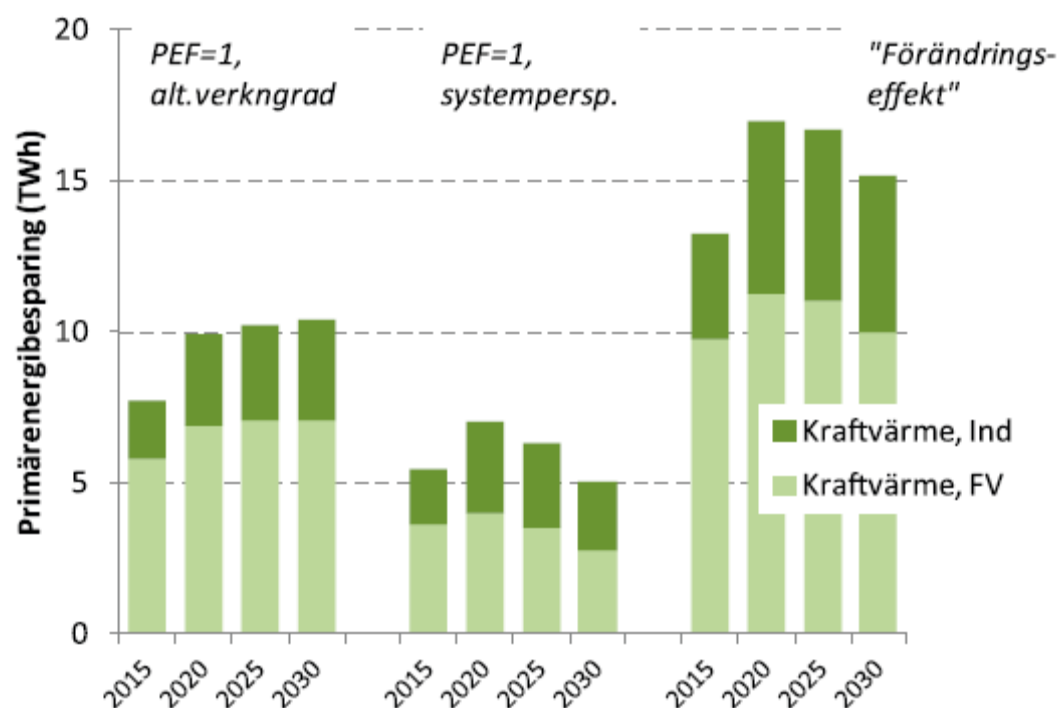
Figure 17 Total primary-energy saving for cogeneration expansion in a scenario where the alternative fuel-specific production option is applied, based on the energy content of the fuel (PEF 1).



Swedish	English
PEF-besparing (TWh)	PEF saving (TWh)
Kraftvärme, Ind	Cogeneration, Ind
Kraftvärme, FV	Cogeneration, district heating

A comparison of how the different assumptions for cogeneration expansion affect the primary-energy savings may be seen in Figure 18. The central bar is based on a primary-energy factor of 1, like the bars on the left (as in Figure 17). It is then assumed that the alternatives to cogeneration production are northern European electricity production and ‘Swedish’ district-heating production (according to the ‘change-impact’ principle). The savings will therefore be lower than required by the Directive for separate production using exactly the same fuel. The fact that the primary-energy saving will be greater in that case (the bars on the left) is primarily because waste cogeneration is compared to separate production in a super-heated water boiler with a ‘normal’ efficiency level and a condensing power plant with what is likely to be a low level of electrical efficiency. Because waste incineration is not ideal for electricity production, for various reasons, the expansion of waste cogeneration will result in very large primary-energy savings. This is because the alternative form of electricity production is assumed to take place at a condensing plant with very high ‘fuel consumption’ for the same quantity of electricity.

Figure 18 Primary-energy savings according to a strict interpretation of the EED (left), according to the system perspective with a PEF of 1 (centre), and from the change-impact perspective (please see Figure 16).



Swedish	English
Primärenergibesparing (TWh)	Primary-energy saving (TWh)
PEF=1, alt.verkngrad	PEF = 1, alternative efficiency level
PEF=1, systempersp.	PEF = 1, system perspective
"Förändringseffekt"	'Change impact'
Kraftvärme, Ind	Cogeneration, Ind
Kraftvärme, FV	Cogeneration, district heating

7.3 Conclusion

The definition of primary energy given in the Directive is actually the same as the total energy consumption in Sweden. This means that long-term changes in the energy system are not taken into account.

The Swedish Energy Agency has found that many assumptions need to be made in order to calculate an energy saving. These assumptions have major implications for the results and for the conclusions that are drawn. It is therefore inappropriate to design instruments on the basis of these calculations. This is not least because energy prices have already had a controlling impact in that they encompass the effects of energy savings in the context of investments.

In light of this assessment, the Swedish Energy Agency has chosen to discuss the primary-energy saving on the basis of the factors laid down in the Directive.

The total primary-energy savings from the potential expansion of cogeneration, district heating and district cooling are estimated to be 9.75 TWh by 2015, 14 TWh by 2020, 15.5 TWh by 2025, and no more than 16 TWh by 2030 (Table 2).

Table 2 Savings in TWh of primary energy according to the EED calculations.

	2015	2020	2025	2030
Cogeneration, Ind.	5.8	6.9	7	7
Cogeneration, district heating	1.9	3	3.2	3.4
District heating	1.7	3.4	4.5	4.9
District cooling	0.3	0.7	0.9	1
TOTAL:	9.75	14	15.5	16.4

At the same time, it is important to be aware that the district-heating market is forecast to shrink on the whole (please see Chapter 3). If the starting point were a net increase, therefore, there would be no improvement to energy efficiency on the whole, because total production of district heating would fall more than could be compensated for by new connections.

The potential for district heating in the future has been estimated at 4 TWh by 2020 and 8 TWh by 2030. On the whole, however, consumption of district heating is estimated to fall by 2 TWh by 2020 and by 4 TWh by 2030. Without any new connections, the reductions would have been 6 TWh by 2020 and 12 TWh by 2030.

8 Map of the national territory

The following chapter satisfies point 1(c) of Annex VIII to the EED, which prescribes the production of a map of the national territory, identifying, while preserving commercially sensitive information:

- i) heating and cooling demand points, including:
 - municipalities and conurbations with a plot ratio of at least 0.3; and
 - industrial zones with a total annual heating and cooling consumption of more than 20 GWh;
- ii) existing and planned district heating and cooling infrastructure;
- iii) potential heating and cooling supply points, including:
 - electricity generation installations with a total annual electricity production of more than 20 GWh; and
 - waste incineration plants;
 - existing and planned cogeneration installations using technologies referred to in Part II of Annex I, and district heating installations.

8.1 Explanations of the maps

The maps for Figures 19, 20 and 21 may be downloaded at the original scale from the Swedish Energy Agency's website: <http://www.energimyndigheten.se/sv/Foretag/>.

Figure 19 shows the plot ratio for the heating base, i.e. the ratio obtained from dividing the floor area of the building by the surface area of a given site.³⁴ According to the interpretative note on the EED, this is defined in more detail as follows: “An area with a plot ratio of 0.3 currently corresponds to a linear heat density of 2.5 MWh/m, since the current specific heat demand is about 130 kWh/m². This is a threshold indicating areas where expert literature considers district heating directly feasible. In France, there were some 176 city districts in 31 cities with a plot ratio higher than 0.3 in 2001. At the same time 82 city districts had a higher than 0.3 plot ratio in Paris. (Linear heat density is the quota of heat annually sold and the total trench length of the district heating pipe system.)” The map is based on data from the Swedish Mapping, Cadastral and Land Registration Authority.

³⁴ ‘... the ratio of the building floor area to the land area in a given territory’. Source: Interpretative note on Directive 2012/27/EU.

Figure 20 shows industries with potential access to waste heat, taken from the European Pollutant Release and Transfer Register (E-PRTR). Municipal ownership is defined more specifically on the basis of the EPRTR v4_2_Sweden Excel workbook on the Swedish Energy Agency's website.

Figure 21 shows all cogeneration plants, condensing power plants and heating plants (super-heated water boilers) in Sweden. The data has been obtained from the property records held by the Swedish Mapping, Cadastral and Land Registration Authority and drawn using Cartesia. The map is interactive when it is downloaded and opened in Adobe, and it shows the exact coordinates and ownership of each facility.

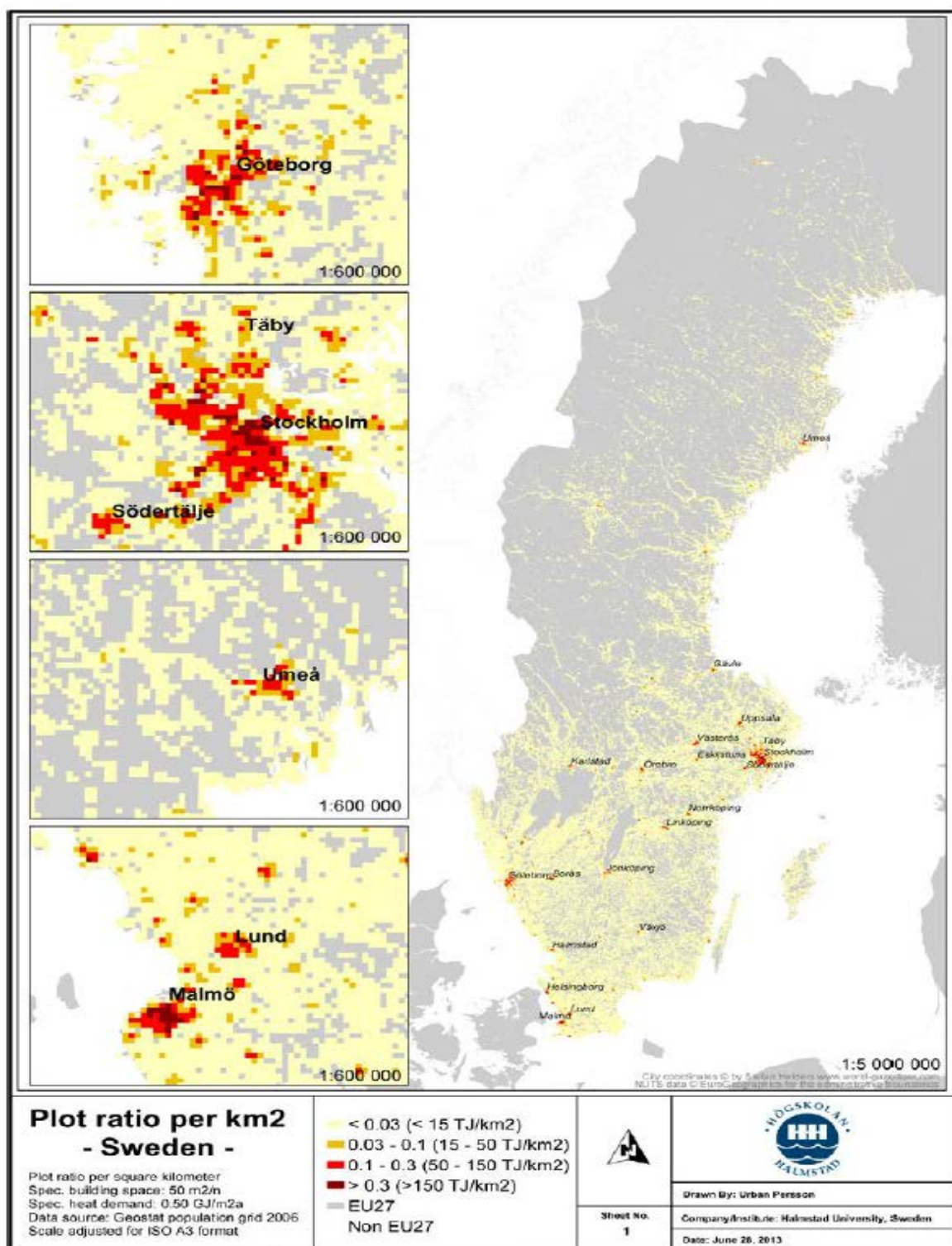
Figure 22 shows paper/pulp and sawmills/timber industry and related industries, i.e. facilities with great potential for waste heat. The map is interactive and may be found on the Swedish Forest Industries Federation website.

Figure 23 shows biofuel-cogeneration plants and waste cogeneration in Sweden. The map was produced by the Swedish Bioenergy Association (Svebio) using data from its member undertakings, and it also takes account of planned development. Because the planned development of cogeneration in Sweden consists exclusively of biofuel cogeneration or waste cogeneration, planned cogeneration has been included in the data for the map. The requirement to incorporate waste-cogeneration facilities has also been satisfied.

Figure 24 shows the Swedish backbone network and includes power lines for 400 and 220 kV with substations, transformer substations, etc. and foreign connections for alternating current (AC) and direct current (DC). Planned development is also included.

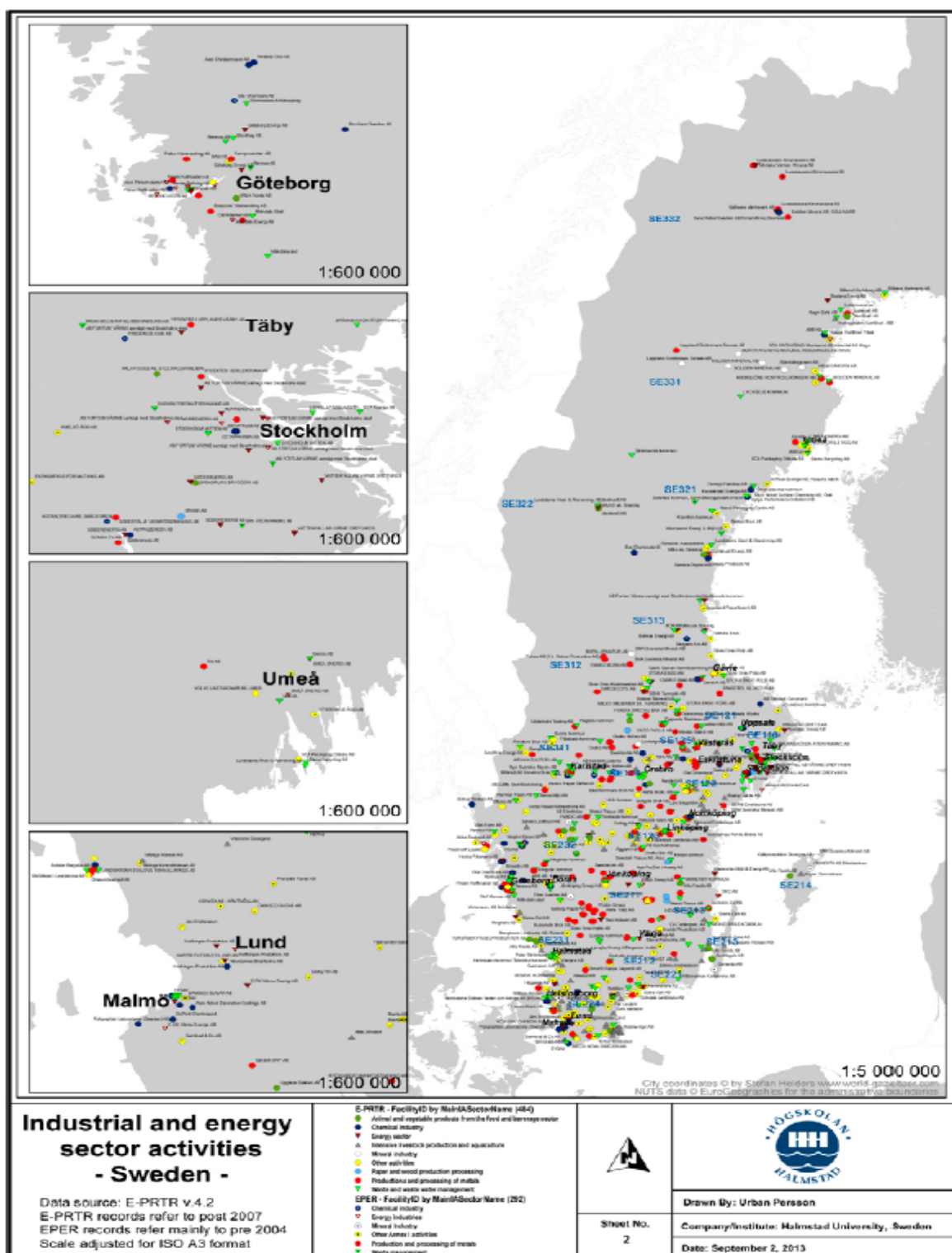
Table 3 has been obtained from the Swedish Waste Management Association, and it provides detailed information about waste-cogeneration plants in Sweden.

Figure 19 Demand points for heating and cooling, broken down according to exploitation figures.



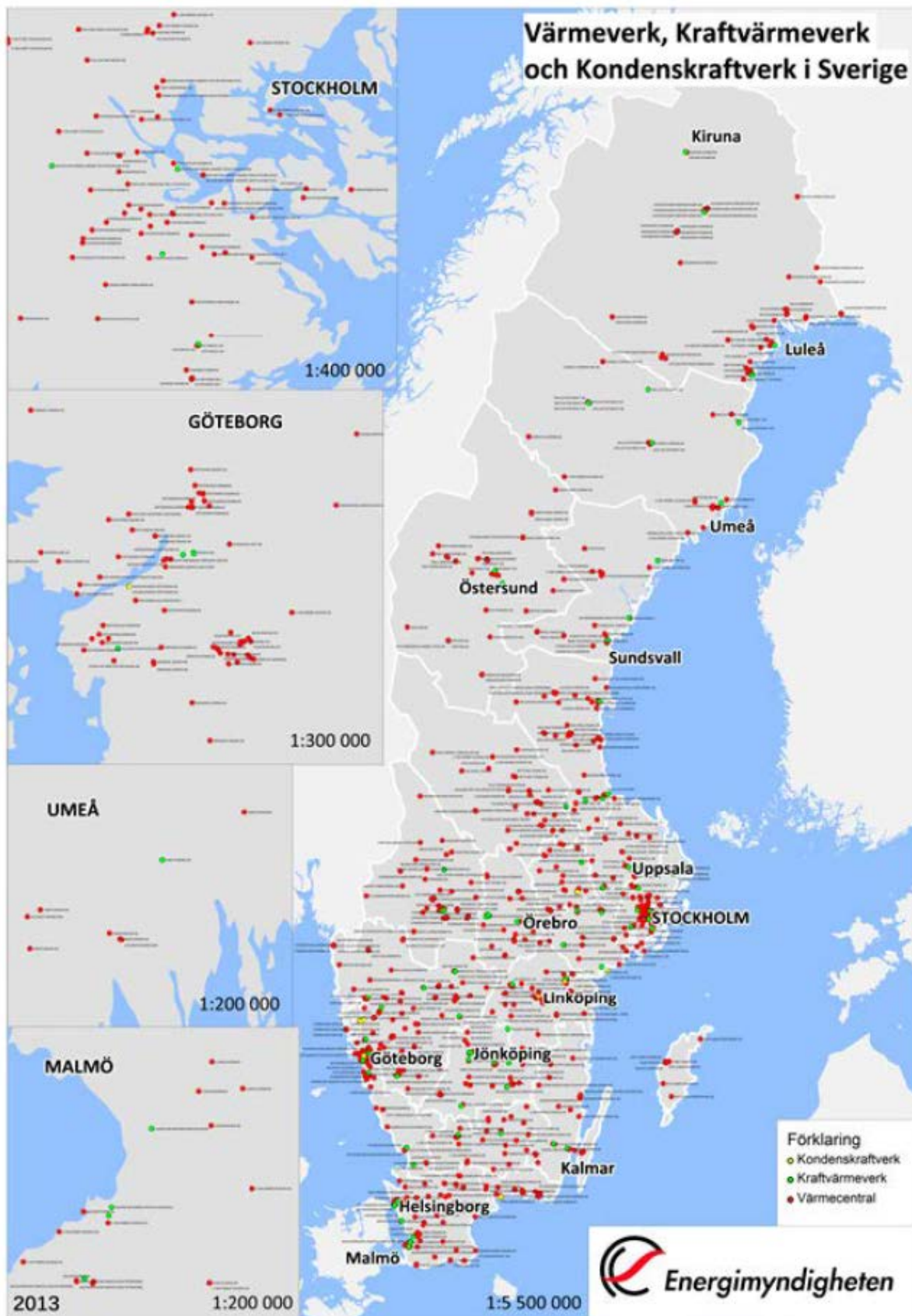
Swedish	English
Göteborg	Gothenburg
HÖGSKOLAN HALMSTAD	HALMSTAD UNIVERSITY

Figure 20 Industrial zones with a total annual heating and cooling consumption of more than 20 GWh



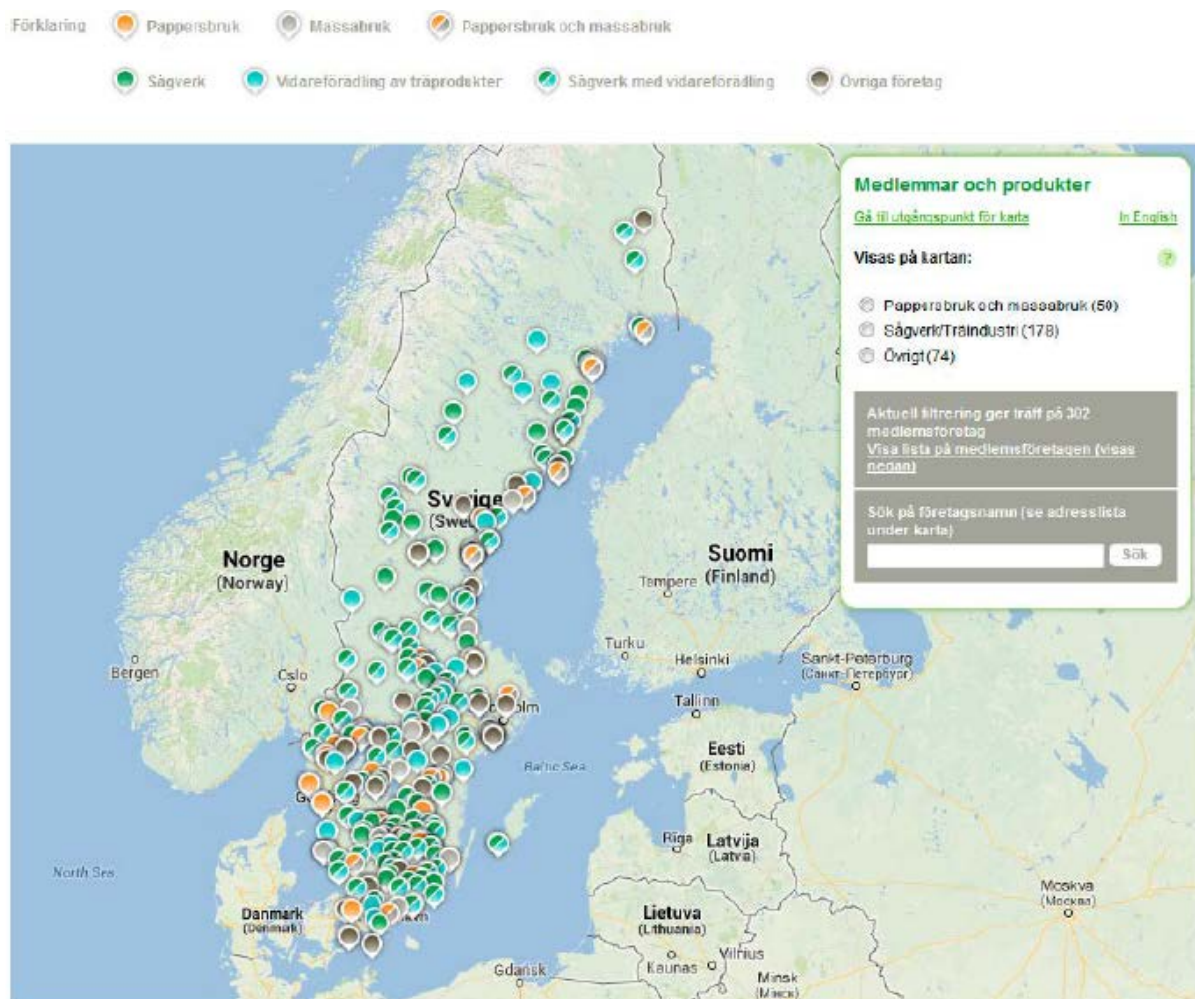
Swedish	English
Göteborg	Gothenburg
HÖGSKOLAN HALMSTAD	HALMSTAD UNIVERSITY

Figure 21 Heating plants, cogeneration plants and condensing power plants in Sweden, 2013.



Swedish	English
Värmeverk, Kraftvärmeverk och Kondenskraftverk i Sverige	Heating plants, Cogeneration plants and Condensing power plants in Sweden
GÖTEBORG	GOTHENBURG
Förklaring	Legend
Kondenskraftverk	Condensing power plant
Kraftvärmeverk	Cogeneration plant
Värmecentral	Heating plant
Energimyndigheten	Swedish Energy Agency

Figure 22 Paper/pulp, sawmills/timber industry and related industries.

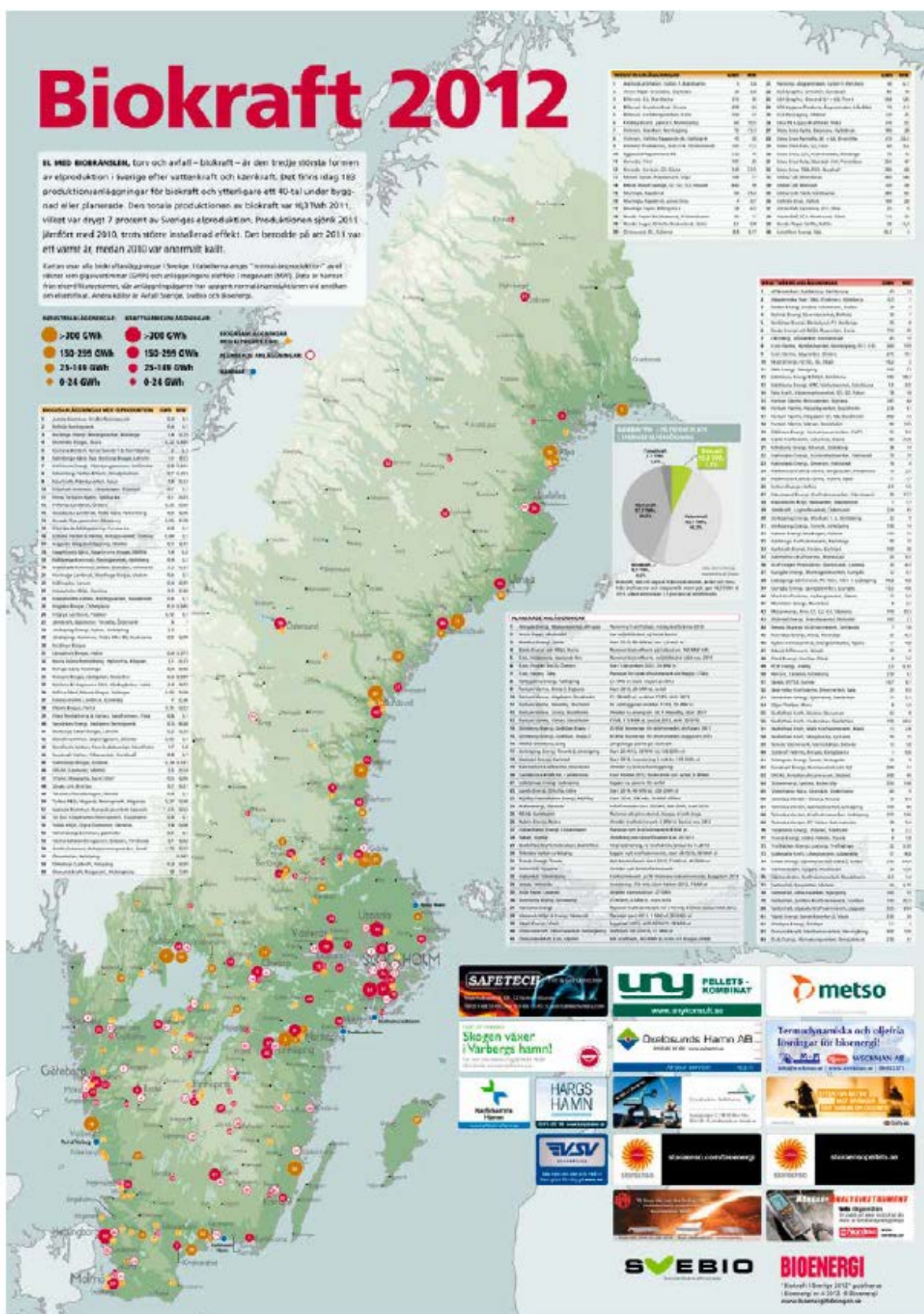


Swedish	English
Förklaring	Legend
Pappersbruk	Paper mills
Massabruk	Pulp mills
Pappersbruk och massabruk	Paper and pulp mills
Sågverk	Sawmills
Vidareförädling av träprodukter	Further processing of timber products
Sågverk med vidareförädling	Sawmills with further processing

Övriga företag	Other undertakings
Medlemmar och produkter	Members and products
Gå till utgångspunkt för karta	Go to starting point for map
Visas på kartan:	Shown on the map:
Pappersbruk och massabruk (50)	Paper and pulp mills (50)
Sågverk/Träindustri (178)	Sawmills/Timber industry (178)
Övrigt (74)	Other (74)
Aktuell filtrering ger träff på 302 medlemsföretag	Current filter gives 302 member undertakings
<u>Visa lista på medlemsföretagen (visas nedan)</u>	<u>Show list of member undertakings (displayed below)</u>
Sök på företagsnamn (se adresslista under karta)	Search by undertaking name (please see list of addresses below map)
Sök	Search

Source: http://www.skogsindustrierna.org/om_oss/medlemmar_1/medlemskarta

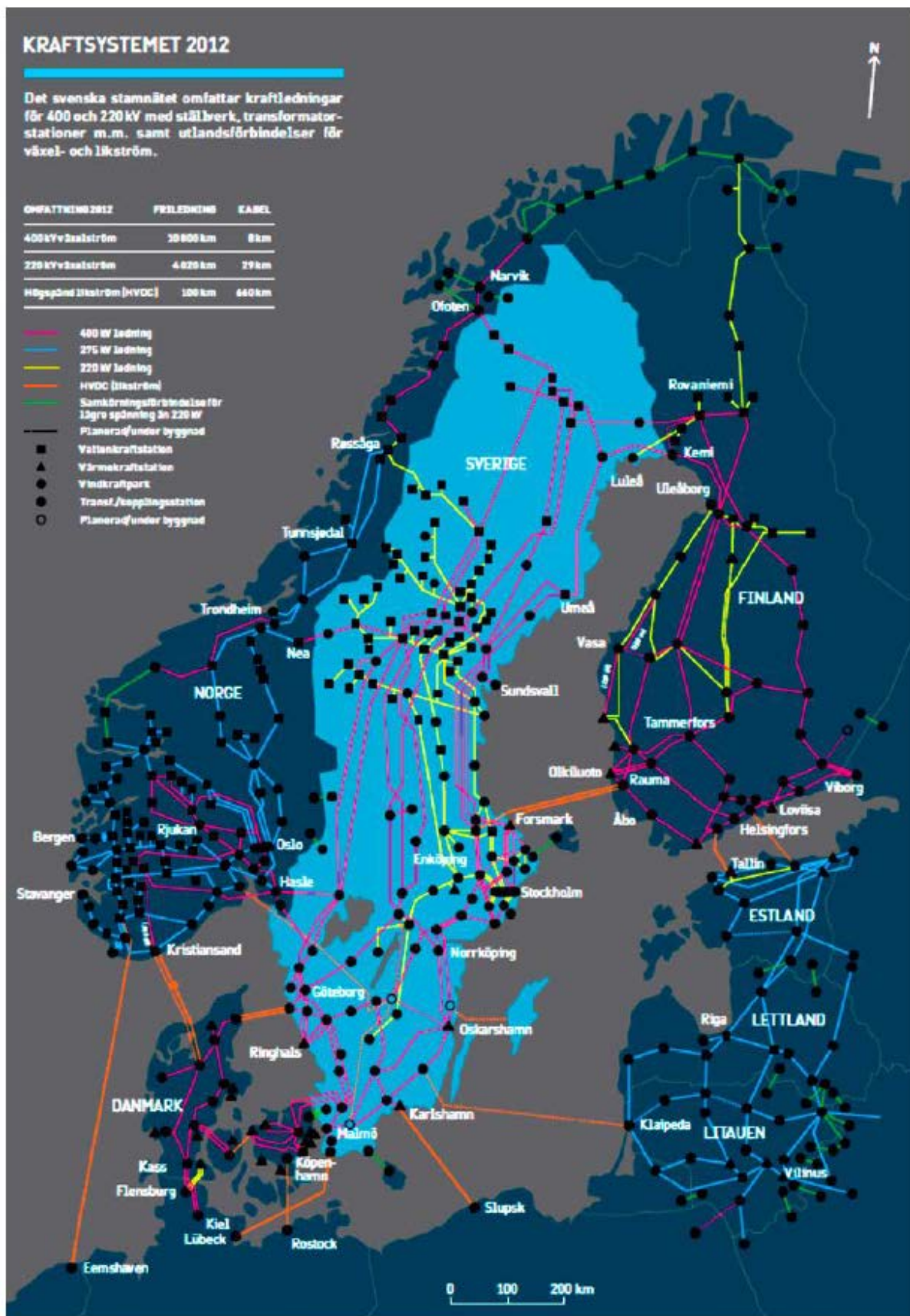
Figure 23 Biofuel-cogeneration plants in Sweden, 2012.



Swedish	English
Biokraft 2012	Biofuel power 2012
EL MED BIOBRÄNSLEN , torv och avfall – biokraft – är den tredje största formen av elproduktion i Sverige efter vattenkraft och kärnkraft. Det finns idag 183 produktionsanläggningar för biokraft och ytterligare ett 40-tal under byggnad eller planerade. Den totala produktionen av biokraft var 10,3 TWh 2011, vilket var drygt 7 procent av Sveriges elproduktion. Produktionen sjönk 2011 jämfört med 2010, trots större installerad effekt. Det berodde på att 2011 var ett varmt år, medan 2010 var onormalt kallt.	ELECTRICITY WITH BIOFUELS , peat and waste – biofuel power – is the third-largest type of electricity production in Sweden after hydro-electric power and nuclear power. There are currently 183 production facilities for biofuel power, and another 40 or so under construction or planned. Total biofuel-power production in 2011 amounted to 10.3 TWh, which is just over 7 % of Sweden's electricity production. It fell in 2011 in comparison with 2010, despite the higher rated power. This was because 2011 was a warm year, while 2010 was unusually cold.
Kartan visar alla biokraftanläggningar i Sverige. I tabellerna anges "normal-årsproduktion" av el räknat som gigawattimmar (GWh) och anläggningens eleffekt i megawatt (MW). Data är hämtat från elcertifikatsystemet, där anläggningsägaren har uppgett normalårsproduktionen vid ansökan om elcertifikat. Andra källor är Avfall Sverige, Svebio och Bioenergi.	The map shows all of the biofuel-power facilities in Sweden. The tables specify 'normal-year production' of electricity, calculated in gigawatt-hours (GWh) and the electrical load of the facility in megawatts (MW). The data has been obtained from the electricity-certificate scheme, where the owners of the facilities have stated their normal-year production when applying for the electricity certificate. Other sources include the Swedish Waste Management Association, the Swedish Bioenergy Association (Svebio) and Bioenergi.
INDUSTRIANLÄGGNINGAR:	INDUSTRIAL FACILITIES:
KRAFTVÄRMEANLÄGGNINGAR:	COGENERATION FACILITIES:
BIOGASANLÄGGNINGAR MED ELPRODUKTION:	BIOGAS FACILITIES WITH ELECTRICITY PRODUCTION:
PLANERADE ANLÄGGNINGAR:	PLANNED FACILITIES:
HAMNAR:	PORTS:
BIOKRAFTEN – PÅ TREDJE PLATS I SVERIGES ELFÖRSÖRJNING	BIOFUEL POWER – THIRD PLACE IN SWEDEN'S ELECTRICITY SUPPLY

Source: http://www.svebio.se/sites/default/files/Biokraftkartan2012_web.pdf

Figure 24 Electricity-generation facilities in Sweden, 2012 (including planned development).



Swedish	English
KRAFTSYSTEMET 2012	POWER SYSTEM 2012
Det svenska stamnätet omfattar kraftledningar för 400 och 220 kV med ställverk, transformatorstationer m.m. samt utlandsförbindelser för växel- och likström.	The Swedish backbone network includes power lines for 400 and 220 kV with substations, transformer substations, etc. and foreign connections for alternating current (AC) and direct current (DC).
OMFATTNING 2012	SCOPE 2012
FRILEDNING	OVERHEAD LINES
KABEL	CABLES
400 kV växelström	400 kV alternating current (AC)
220 kV växelström	220 kV alternating current (AC)
Högsäpnd likström (HVDC)	High-voltage direct current (HVDC)
400 kV ledning	400 kV line
275 kV ledning	275 kV line
220 kV ledning	220 kV line
HVDC (likström)	HVDC (direct current)
Samkörningsförbindelse för lägre spänning än 220 kV	Interconnection for voltages lower than 220 kV
Planerad/under byggnad	Planned/under construction
Vattenkraftstation	Hydro-electric power station
Värmekraftstation	Thermal power station
Vindkraftpark	Wind farm
Transf./kopplingsstation	Transf./switching substation
Planerad/under byggnad	Planned/under construction
NORGE	NORWAY
SVERIGE	SWEDEN
FINLAND	FINLAND
ESTLAND	ESTONIA
LETTLAND	LATVIA
LITAUEN	LITHUANIA
DANMARK	DENMARK

Source: <http://www.svenskenergi.se/Global/Dokument/information/SvK-Kraftsystemet-2012.pdf>

Table 3 Waste-incineration facilities in Sweden 2013.

Municipality	Facility	Technical capacity (tonnes)	Permitted quantity of waste according to licence (tonnes)	Total waste for consumption (tonnes)	of which household waste for incineration (tonnes)
Avesta	Källhag plant	75 000	65 000	59 258	26 238
Boden	Boden Heating Plant	-	100 000	99 515	39 304
Bollnäs	Säversta plant	80 000	80 000	54 480	53 517
Borlänge	District-heating plant, Bäckelund	98 000	98 000	84 074	35 712
Borås	Rya plant	125 000	125 000	116 879	23 638
Eda	Åmotsfors Energi	79 000	80 000	69 445	10 262
Eksjö	Eksjö Energi AB	61 320	65 000	50 431	20 864

Finspång	FTV Heating Plant	36 800	35 000	28 730	26 445
Gothenburg	Sävenäs waste-cogeneration plant	550 000	550 000	542 520	248 730
Halmstad	Kristinehed waste-based heating plant	200 000	200 000	188 721	91 564
Hässleholm	Hässleholm (Beleverket)	52 000	50 000	48 150	31 774
Jönköping	Torsvik cogeneration plant	165 000	200 000	151 767	37 204
Karlskoga	Karlskoga Cogeneration Plant	150 000	100 000	96 127	33 364
Karlstad	Heden waste-based heating plant	55 000	55 000	53 925	45 626
Kil	Kil waste-incineration plant	15 000	20 000	14 079	0
Kiruna	Kiruna Heating Plant	-	98 000	70 537	10 039
Kumla	SAKAB Incineration	200 000	200 000	157 535	9 401
Köping	Norsa waste-incineration plant	38 500	N/A	29 127	19 253
Lidköping	PC Filen	100 000	130 000	99 106	38 700
Linköping	Gärstad plant	470 000	420 000	419 755	147 357
Ljungby	Ljungby Energi AB	60 000	60 000	58 048	48 077
Malmö	Sysav incineration plant	650 000	550 000	549 980	221 787
Mora	Mora waste incineration	25 000	25 000	21 594	16 208
Norrköping	E.ON Händelö plant	450 000	1 010 000	301 500	198 000
Skövde	The 'Heat Source' plant	60 000	70 000	60 703	32 762
Stockholm	Högdalen plant	-	770 000	739 093	410 099
Sundsvall	Korsta cogeneration plant	230 000	260 000	191 971	95 785
Södertälje	Söderenergi	517 000	-	-	-
Uddevalla	Lillesjö waste-cogeneration plant	130 000	130 000	105 575	60 377
Umeå	Dåva cogeneration plant	190 000	190 000	166 595	64 564
Uppsala	Vattenfall AB Heat Uppsala	375 000	475 000	364 900	161 000
Västervik	Stegholm plant	50 000	85 000	47 884	13 000
Total				5 042 004	2 270 651

Source: Swedish Waste Management Association

8.2 Existing and planned heating and cooling infrastructure

This chapter responds to the requirements of the Directive according to point 1(c)(ii) and 1(f) of Annex VIII, namely identification of energy efficiency potentials of district heating and cooling infrastructure.

Planned expansion of the district-heating network³⁵

A questionnaire administered to member undertakings of the Swedish District Heating Association shows that district-heating undertakings intend to continue expanding their networks.³⁶ Total network length is expected to increase by a quarter by 2015, when it is estimated to be 24 300 kilometres. The pace of expansion of the district-heating network is,

³⁵ District heating 2015 – Sector forecast.

³⁶ The responses are based on the members' own estimates of how much district heating, electricity and district cooling they will supply in 2015, based on what was known about the market, taxes and changes in energy policy in June 2009. Some 90 % of member undertakings of the Swedish District Heating Association responded to the questionnaire.

however, faster than the increase in district-heating supplies. This means that the undertakings intend to compensate for factors such as improved energy efficiency and a warmer climate by expanding their networks to reach more customers. A consequence of this is that the heating density will be lower and losses from the distribution system will increase. The district-heating undertakings that responded to the questionnaire estimate that they will supply district heating to a total of 30 or so new places in 2015.

Planned expansion of district cooling³⁷

Questionnaire responses show that member undertakings of the Swedish District Heating Association intend to increase supplies of district cooling by 2015 from the current level of nearly 0.8 TWh to just over 1.3 TWh in 2015. The increase is both because several undertakings intend to supply district cooling, with 28 % of undertakings believing that they will sell district cooling in 2015 compared to 22 % in 2007, and because some undertakings are expanding their networks for such supplies. The district-heating undertakings consider 'free cooling' (such as cold water from lakes) and absorption-cooling machines to be the two most important production methods for district cooling in 2015.

Planned investment in cogeneration

Total electricity production from cogeneration plants in the forestry industry and in the district-heating system will increase by just under 3 TWh, from 18 TWh in 2010 to 21 TWh in 2020. Nearly all of the expansion projects reported in the questionnaire (please see section 3.3.2) will be implemented by 2016. The undertakings estimate that they will invest SEK 33.4 billion in increased electricity production. Of these investments, some SEK 29.4 billion will be invested in cogeneration plants in the district-heating sector, and SEK 4 billion in those in the forestry industry.³⁸

A total of five paper and pulp mills are planning to make seven investments over the period surveyed. Two of them will take place in 2011, one in 2012, two in 2013, one in 2016, and one in 2018. In total, the planned investments will amount to SEK 4 290 million. They will include a brand-new facility on a new site with greater district-heating capacity, a new boiler, turbine and fuel management for established sites, and five investments in new turbines and boilers. The results of these investments will include additional electrical power and electricity production of 200 MW and 1.5 TWh respectively (Figure 25).

³⁷ District heating 2015 – Sector forecast.

³⁸ *Expansion of cogeneration in Sweden up to 2020.*

Figure 25 Planned investments.

Planned investments (Year, SEK million)	2011	2012	2013	2016	2018	Total
Brand-new facility on site	15					15
New boiler, turbine and fuel management on established site			1 800			1 800
New boiler and turbine	250	2 000	25	100	100	2 475
Greater district-heating capacity	(15)					
Total	265	2 000	1 825	100	100	4 290

9 Strategies, policies and measures that may be adopted up to 2020 and up to 2030

This chapter gives a response in relation to the measures that may be adopted up to 2020 and up to 2030 to develop the markets for cogeneration, district heating and district cooling in accordance with point (g) of Annex VIII to the EED. The idea is that profitable measures resulting from the cost-benefit analysis that has been performed and which form the basis for assessing the expansion of district heating, cogeneration and district cooling must be proposed. In Sweden, this expansion is being taken care of by market players, and the State lays down the framework to which those players must adhere. When expansion is profitable, therefore, it is implemented by means of market forces. Because the district-heating market has largely been expanded in Sweden already, there is little or no scope for State investment to expand it further. In addition to this, any such State investment would most likely have resulted in a distortion of competition in the heating market. On the other hand, the district-heating market could be improved. This chapter will therefore discuss the measures that could be used to develop and improve the functioning of the market. For a precise specification in accordance with the EED, please see Annex 5 to this report.

With a view to developing the district-heating market, the Swedish Government has commissioned the Swedish Energy Markets Inspectorate (EI) and the Swedish Energy Agency (EM) to investigate a total of three possible measures. These mandates are to be regarded as possible measures for developing the district-heating market up to 2020 and up to 2030. The Swedish Energy Agency has, however, rejected the EI's proposal for the testing of price changes and regulation of access to the district-heating network (please see sections 9.2 and 9.3). The measures to review the National Board of Housing, Building and Planning Building Regulations (BBR) and the taxation of the heating market are discussed in sections 9.4 and 9.5.

9.1 Measure 1: Principles for reporting the potential for residual heat when designing new district-heating production

The Ministry of Enterprise, Energy and Communications memorandum *Proposed measures for developed district-heating markets for the benefit of consumers and residual-heat suppliers* (N2012/1676/E) stipulates that it is important for the heat that is produced to be produced at the lowest possible socio-economic cost. The question of residual heat is relevant when district-heating undertakings design new district-heating plants. The report on Third-Party Access (Official State Report 2011:44) discusses several cases where industrial residual heat has not been used to the extent considered possible by industry. There have been some cases where district-heating undertakings have built their own plants instead of using residual heat. It is not clear whether or not these decisions were socio-economically justified. The Swedish Government is therefore of the view that district-heating undertakings should be ordered to report the potential for district heating and any additional costs of using residual heat when designing new facilities.

On 7 June 2012, the Swedish Government commissioned the Swedish Energy Agency to investigate and propose a principle for reporting the potential for residual heat when designing new district-heating production.³⁹ The Energy-Efficiency Directive (2012/27/EU) was adopted on 25 October 2012 by agreement of the European Parliament and the Council. This has affected the implementation of the investigation. Because Article 14(5) of the Energy-Efficiency Directive imposed requirements that partly corresponded to the mandate from the Swedish Government, the Swedish Energy Agency finished the report by proposing that those requirements be transposed into Swedish law.

On 1 March 2013, the Swedish Energy Agency submitted the report, entitled 'Principles for reporting the potential for residual heat when designing new district-heating production', to the Swedish Government. In the report, the Swedish Energy Agency proposes how the cost analysis that undertakings are to be ordered to perform should be designed, as well as the restrictions that should apply with regard to licensing procedures.⁴⁰

The Swedish Government memorandum entitled 'Proposal on the implementation of the Energy-Efficiency Directive in Sweden' describes in detail the wording of the 'Draft Act on Certain Cost-Benefit Analyses in the Energy Sector'.⁴¹

It was proposed that the Act enter into force on 1 June 2014.

9.2 Measure 2: Testing of price changes and principle of equal treatment

The Ministry of Enterprise, Energy and Communications memorandum (N2012/1676/E) takes the view that '*The testing of price changes should be introduced to protect consumers from unreasonable price rises.*'

According to the Ministry of Enterprise, Energy and Communications, the reasons for this are that the conditions for competition are limited and the barriers to entry to the district-heating market are considerable. Because customers are economically and technically restricted in their heating methods, it is important to strengthen the position of customers in order to avoid unreasonable price rises. This should be done by introducing testing of price changes. This would avoid any cost-driven separation of distribution from trade and production. This solution is also preferable to the regulation of distribution prices, because that would risk a cost-driven scenario.

The memorandum stipulates that an authority should be commissioned to investigate how the testing of price changes should be designed in order to ensure that district-heating undertakings do not raise prices unreasonably. The testing of price changes must be based on the district-heating undertakings' current price level or on a historical base year. The proposal to test price changes is important in strengthening the position of consumers in the district-heating market. Such testing must serve as the guarantee needed by customers who are

³⁹ 'Mandate to investigate and propose a principle for reporting the potential for residual heat when designing new district-heating production'. N2012/2937E.

⁴⁰ ER 2013:09.

⁴¹ <http://www.regeringen.se/content/1/c6/21/38/38/5728a468.pdf>

connected to district heating and customers who intend to connect to district heating in order for them to have confidence in district heating as a heating method.

On 16 May 2012, the Swedish Government decided to commission the Swedish Energy Markets Inspectorate (EI) to investigate and propose the design of a model for testing price changes, as well as a principle of equal treatment for customers in the same customer category. The EI submitted its report to the Swedish Government in April 2013.⁴²

The report proposes that a district-heating index be used to create the conditions for allowing undertakings to cover their costs in the long term. According to the proposal, such an index should be based on cost trends in the sector over the last three years in order to avoid any unwanted variations. By basing the index on the overall cost trend in the sector, those undertakings with a cost trend above the index will have a direct need to improve efficiency in order to preserve their profitability. According to the proposal, any increases may not surpass the level given by the index. In the event that this were to occur, the following year's price change expressed as a percentage would be reduced by twice the excess amount, meaning that the scope for a price rise in that year would be cut by twice as much as the compensation to customers for the fact that the undertaking had raised its prices by more than the approved scope.

The EI proposes that the index be developed on the basis of information in the annual reports submitted to it, so that the cost trend for all district-heating undertakings has an equal weighting. Because the annual reports must be submitted to the EI no later than seven months after the year to which they relate, the index may lag behind to a certain extent. The index relating to price changes in 2015, for example, is based on the cost trend among district-heating undertakings in 2011-2013.

The proposal includes the possibility of saving the scope for a price rise for a subsequent year if the undertaking chooses to raise its prices by less than the index for the year in question. It is, however, proposed that the possibility of using the saved index scope for a later date should be accompanied by a limit, in order to avoid the risk of exposing customers to large price rises when the undertaking in question wants to make use of its accumulated scope for price changes. EI is of the view that the possibility of using an accumulated scope for price rises should be restricted to 1.5 times the index decided upon for the year in question, and that there should be a limit on the length of time for which an accumulated scope for price changes may be saved.

The report has been sent to the Ministry of Enterprise, Energy and Communications for consultation.

Nonetheless, the Swedish Energy Agency and several of the other parties consulted have rejected the proposal, primarily on the grounds that the introduction of a principle to test price changes, such as that proposed, would result in price rises and thus work in the opposite manner to that intended.

⁴² EI R2013:07.

9.3 Measure 3: Regulated access to the district-heating network

The Ministry of Enterprise, Energy and Communications memorandum (N2012/1676/E) takes the view that regulated access should be introduced for residual-heat suppliers and other district-heating producers.

The reason for this is that regulated access makes the potential for residual heat more likely to be fulfilled, and it gives residual-heat suppliers greater opportunities for having their case heard. In the first instance, a greater proportion of residual heat means that the proportion of biofuels in district-heating production will fall, which in turn means that biofuels can be freed up for use at other district-heating plants where residual heat is not an option because it is unavailable.

The stated background to this is that there are currently few objective reasons for district-heating undertakings to refuse to receive residual heat if the parties can agree on a contract that works well. There is untapped potential for the use of residual heat in the district-heating network, amounting to roughly double that used at present. Industrial supplies of residual heat currently amount to approximately 3.1 TWh. Industrial residual heat is supplied to approximately 70 district-heating networks in the country. At the same time, the assessment of potential shows that the large district-heating markets with the best conditions for competition have little or no untapped residual heat. In most cases, comprehensive pipeline extensions are required in order to exploit large quantities of industrial residual heat in the current district-heating system.

The report on Third-Party Access discusses several cases where industrial residual heat has not been used to the extent considered possible by industry. The report states that municipal boundaries and varying ownership scenarios can be reasons for the failure to achieve collaboration on the exploitation of residual heat in some cases.

On 16 May 2012, the Swedish Government decided to commission the Swedish Energy Markets Inspectorate (EI) to investigate and propose the design of a model for investigating and proposing the detailed design of a model for regulated access to the district-heating network by heat producers. The EI submitted its report to the Swedish Government in April 2013.⁴³

The proposal set out in the report gives external heat producers the opportunity to connect to the district-heating network in cases where no voluntary agreement has been reached with the owner of the network. Regulated access means that the external heat producer is responsible for all of the investment costs, but also receives all of the profits for a ten-year period. Following expiry of the initial agreement, the parties are asked to conclude a new agreement on continued collaboration. The report proposes that access to the district-heating network could be refused if there are particular reasons for doing so. It gives the following example of such a reason: ‘a connection from fossil-based waste-heat production could result in a loss of customers, since the fuel mix used by the heat producer wishing to have access is inconsistent with the environmental profile of the district-heating undertaking’.

⁴³ EI R2013:04.

The report has been sent to the Ministry of Enterprise, Energy and Communications for consultation.

The Swedish Energy Agency rejected the proposal, among other reasons because it is of the view that the conditions for district-heating undertakings to be able to refuse regulated access citing an environmental profile should be clarified. The Swedish Energy Agency also questions whether regulated access should always have to apply for 10 years, and it considers that the conditions for the right of ownership of the connections should be clarified.⁴⁴

9.4 Measure 4: Review of the National Board of Housing, Building and Planning Building Regulations to achieve competitive and technical neutrality

On 19 September 2013, the Swedish Government decided to commission the National Board of Housing, Building and Planning to review and increase the stringency of the energy-management levels in the Board's regulations.

The National Board of Housing, Building and Planning must report on this mandate in the form of a written report with an analysis and proposed energy-management levels, to be submitted to the Government Offices of Sweden (Ministry of Health and Social Affairs) by no later than 2 June 2014. This review should include all climate zones and heating methods for both homes and commercial premises. Among other things, the National Board of Housing, Building and Planning should take account of the conditions for various lifestyles and the impact of other required technical features, as well as the socio-economic, property-economic and environmental aspects. The aim must be for the new provisions to enter into force on 1 January 2015.

A further review of the energy requirements is planned in conjunction with the inspection station in 2015, in relation to nearly-zero-energy buildings. The technical neutrality of the energy requirements must also be reviewed at that inspection station. Any increases in stringency that are environmentally, property-economically and socio-economically justified must be implemented.

9.5 Measure 5: Review of tax rules that cause distortion

In order to operate a district-heating plant, electricity is required for pumps, fans and fuel input. Biofuels and waste use more electricity for operation than oil-fired boilers do. District-heating undertakings pay the full rate of electrical-energy tax on their own consumption of electricity (29.3 öre/kWh), while industry has a considerably lower rate of tax (0.5 öre/kWh).⁴⁵ This could result in a distortion of competition and an economic barrier to replacing oil consumption for heat production.

⁴⁴ <http://energimyndigheten.se/PageFiles/31274/2013-4104%20Yttrande.pdf>

⁴⁵ Source: Swedish District Heating Association.

The draft State Budget for 2014⁴⁶ proposes that a review be conducted as a measure for improving market conditions:

‘Distortion of competition between heat production in industry and heating undertakings should be avoided as far as possible where production is carried out for the same purpose. Energy tax of 0.5 öre per kWh is levied on the electricity consumed by industry and the land-based sectors. A higher rate of energy tax applies for some electricity that is used by heating undertakings for the production of heat supplied to industry or the land-based sectors. This taxation should be reviewed.’

The amended tax rules must enter into force in 2015.

The report *Taxation of micro-produced electricity, etc.* (Official State Report 2013:46) is another ‘measure’ that proposes the abolition of the special tax exemption for self-generated wind-powered electricity. The tax exemption distorts competition both within the electricity-certificate scheme and in the heating market, since heating by means of heat pumps, for example, is encouraged through the use of tax-exempt, self-produced electricity from wind power to operate the pumps. This means that the tax rules are not stakeholder-neutral.

The report (Official State Report 2013:46) proposes that the special tax exemption be abolished on 1 January 2014.

⁴⁶ BILL 2013/14:1, EXPENDITURE HEADING 21.

10 An estimate of public support measures for heating and cooling

The existing public support measures are limited to overarching instruments. They exist primarily in the form of the electricity-certificate scheme, which is a market-based support scheme for renewable electricity. The electricity-certificate scheme does not, however, constitute State aid under the EU rules on State aid, in accordance with a decision by the European Commission. How much will go towards biofuel cogeneration will depend on a number of different factors such as the price of electricity, the price of alternative fuels, the price trend for electricity certificates, and the relative result between wind power and cogeneration, for example. Any future research initiatives for technological development in the areas of cogeneration, district heating and district cooling could also have an impact. The abolition of carbon-dioxide taxation for heat produced from cogeneration as of 1 January 2013 means that one of the barriers to the expansion of cogeneration and thus, indirectly, of district heating will have been removed. The carbon-dioxide tax on industrial back-pressure plants was abolished in 2011, which constitutes distortion against cogeneration plants in the pure sense. Public funds are also spent on research into district heating within the framework of the 'Fjärrsyn' programme administered by the Swedish District Heating Association. The total budget for the programme is SEK 66 million for the 2013–2017 period. The Swedish Energy Agency will finance up to 40 % of the programme, and the Swedish District Heating Association will finance the remaining 60 %.

11 Bibliography

Taxation of micro-produced electricity, etc. (Official State Report 2013:46).

EI R2013:07, *Testing of price changes and principle of equal treatment for district heating.*

EI R2013:04, *Regulated access to the district-heating network.*

Electricity from new and future facilities 2011, Swedish Electricity Research Centre Report 11:26.

ER 2013:09, *Principles for reporting the potential for residual heat when designing new district-heating production.*

Directive 2012/27/EU of the European Parliament and of the Council on energy efficiency, 25 October 2012.

District-heating report 2005, '*District heating and cogeneration in the future*', Official State Report 2005:33, Stockholm 2005.

'Fjärrsyn' research report (2013:23) *District-heating pipes with hybrid insulation.*

District heating 2015 – Sector forecast, *District heating will continue to grow* (2009).

Proposal on the implementation of the Energy-Efficiency Directive in Sweden, N2013/2873/E.

Gode J., Höglund J., Särnholm E., Martinsson F., Lindblad M. and Bingel E. 2012, '*Environmental communication with key figures and indicators*', 'Fjärrsyn' report 2012:4, ISBN: 978-91-7381-085-1.

Interpretative note on Directive 2012/27/EU 2012/27/EU on energy efficiency, amending directives 2009/125/EC and 2010/30/EC, and repealing directives 2004/8/EC and 2006/32/EC, Article 14: Promotion of efficiency in heating and cooling.

Combined district heating and cooling, 'Fjärrsyn' report 2011:8.

Expansion of cogeneration in Sweden up to 2020 – with a focus on the impact of the electricity-certificate scheme, November 2011.

Environmental Fact Book (2011), *Estimated emission factors for fuel, electricity, heat and transport.*

Profu 2005, '*Cogeneration in the future*', Swedish Electricity Research Centre report 05:37, November 2005.

Profu 2006, '*Marginal electricity and environmental assessments of electricity*', Swedish Electricity Research Centre Report 06:52, August 2006.

Profu 2008, *'Impact of changes in electricity consumption/production – model calculations'*, Swedish Electricity Research Centre Report 08:30, April 2008.

Profu 2009, *'District heating in the future – Needs'*, 'Fjärrsyn' report 2009:21.

Profu 2010a, *'Data/information on national potential for the application of high-efficiency cogeneration following Article 6 and Annex IV of the Cogeneration Directive 2004/8/EC, 15-15-15 scenario'*, commissioned by the Swedish Energy Agency, 2010.

Profu 2010b, *'Analysis of biofuel consumption in the district-heating sector and industrial back pressure, linked to the MARKAL calculations, commissioned by the Swedish Energy Agency'*, 2010.

Profu 2011, *'District heating in the future – Needs'*, 'Fjärrsyn' report 2011:2.

Profu 2012, *'Basis for the Swedish Energy Agency's Long-Term Forecast, 2012'*, 2012.

Profu 2013, *Potential for cogeneration, district heating and district cooling*, 'Fjärrsyn' report 2013:15.

BILL 2013/14:1 EXPENDITURE HEADING 21, *Draft State Budget for 2014*, 2013.

Swedish Government memorandum – *Proposal on the implementation of the Energy-Efficiency Directive in Sweden* (2013).

Swedish District Heating Association 2009a, *District heating 2015 – sector forecast*, 2009.

Swedish District Heating Association 2011, *'Expansion of cogeneration in Sweden up to 2020'*, in conjunction with Swedenergy, the Swedish Forest Industries Federation, and the Swedish Bioenergy Association (Svebio), November 2011.

Swedish District Heating Association 2012b, *'Consultation response on Memorandum II (including supplementary information): Proposal and evaluation concerning nearly-zero-energy buildings'*, 6 February 2012.

Temperature-efficient district-heating systems, 'Fjärrsyn' report (2012:2).

Mandate to investigate and propose a principle for reporting the potential for residual heat when designing new district-heating production'. N2012/2937E.

Trygg L., Difs K., Wetterlund E., Thollander P. and Svensson I-L. 2009, *'Optimum district-heating systems in symbiosis with industry and society – for a sustainable energy system'*, 'Fjärrsyn' report 2009:13, ISBN: 978-91-7381-028-9.

Thermal Engineering Research Association 2011, *'Environmental Fact Book 2011 – Estimated emission factors for fuel, electricity, heat and transport'*.

Heating-market committee 2012, '*Heating-market committee agreement 2012 – Concerning the outlook for the entered environmental value of properties heated by means of district heating*'.

ÅF/Confederation of Swedish Enterprise 2011, '*The future energy supply in Sweden*'.

Annex 1: Article 14(1)–(4) of the EED, 2012/27/EU

Promotion of efficiency in heating and cooling

1. By 31 December 2015, Member States shall carry out and notify to the Commission a comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling, containing the information set out in Annex VIII. If they have already carried out an equivalent assessment, they shall notify it to the Commission.

The comprehensive assessment shall take full account of the analysis of the national potentials for high-efficiency cogeneration carried out under Directive 2004/8/EC.

At the request of the Commission, the assessment shall be updated and notified to the Commission every five years. The Commission shall make any such request at least one year before the due date.

2. Member States shall adopt policies which encourage the due taking into account at local and regional levels of the potential of using efficient heating and cooling systems, in particular those using high-efficiency cogeneration. Account shall be taken of the potential for developing local and regional heat markets.

3. For the purpose of the assessment referred to in paragraph 1, Member States shall carry out a cost-benefit analysis covering their territory based on climate conditions, economic feasibility and technical suitability in accordance with Part 1 of Annex IX. The cost-benefit analysis shall be capable of facilitating the identification of the most resource- and cost-efficient solutions to meeting heating and cooling needs. That cost-benefit analysis may be part of an environmental assessment under Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment (1).

4. Where the assessment referred to in paragraph 1 and the analysis referred to in paragraph 3 identify a potential for the application of high-efficiency cogeneration and/or efficient district heating and cooling whose benefits exceed the costs, Member States shall take adequate measures for efficient district heating and cooling infrastructure to be developed and/or to accommodate the development of high-efficiency cogeneration and the use of heating and cooling from waste heat and renewable energy sources in accordance with paragraphs 1, 5, and 7.

Where the assessment referred to in paragraph 1 and the analysis referred to in paragraph 3 do not identify a potential whose benefits exceed the costs, including the administrative costs of carrying out the cost-benefit analysis referred to in paragraph 5, the Member State concerned may exempt installations from the requirements laid down in that paragraph.

Annex 2: Cost-benefit analysis in accordance with ANNEX IX to the EED

General principles of the cost-benefit analysis

The purpose of preparing cost-benefit analyses in relation to measures for promoting efficiency in heating and cooling as referred to in Article 14(3) is to provide a decision base for qualified prioritisation of limited resources at society level.

The cost-benefit analysis may either cover a project assessment or a group of projects for a broader local, regional or national assessment in order to establish the most cost-effective and beneficial heating or cooling option for a given geographical area for the purpose of heat planning.

Cost-benefit analyses for the purposes of Article 14(3) shall include an economic analysis covering socio-economic and environmental factors.

The cost-benefit analyses shall include the following steps and considerations:

(a) Establishing a system boundary and geographical boundary

The scope of the cost-benefit analyses in question determines the relevant energy system. The geographical boundary shall cover a suitable well-defined geographical area, e.g. a given region or metropolitan area, to avoid selecting suboptimised solutions on a project by project basis.

(b) Integrated approach to demand and supply options

The cost-benefit analysis shall take into account all relevant supply resources available within the system and geographical boundary, using the data available, including waste heat from electricity generation and industrial installations and renewable energy, and the characteristics of, and trends in heat and cooling demand.

(c) Constructing a baseline

The purpose of the baseline is to serve as a reference point, to which the alternative scenarios are evaluated.

(d) Identifying alternative scenarios

All relevant alternatives to the baseline shall be considered. Scenarios that are not feasible due to technical reasons, financial reasons, national regulation or time constraints may be excluded at an early stage of the cost-benefit analysis if justified based on careful, explicit and well-documented considerations.

Only high-efficiency cogeneration, efficient district heating and cooling or efficient individual heating and cooling supply options should be taken into account in the cost-benefit analysis as alternative scenarios compared to the baseline.

(e) Method for the calculation of cost-benefit surplus

- i) The total long-term costs and benefits of heat or cooling supply options shall be assessed and compared.
- ii) The criterion for evaluation shall be the net present value (NPV) criterion.
- iii) The time horizon shall be chosen such that all relevant costs and benefits of the scenarios are included. For example, for a gas-fired power plant an appropriate time horizon could be 25 years, for a district heating system, 30 years, or for heating equipment such as boilers 20 years.

(f) Calculation and forecast of prices and other assumptions for the economic analysis

- i) Member States shall provide assumptions, for the purpose of the cost-benefit analyses, on the prices of major input and output factors and the discount rate. Official Journal of the European Union, OJ L 315, 14.11.2012, p. 42.
- ii) The discount rate used in the economic analysis for the calculation of net present value shall be chosen according to European or national guidelines (1).
- iii) Member States shall use national, European or international energy price development forecasts if appropriate in their national and/or regional/local context.
- iv) The prices used in the economic analysis shall reflect the true socio economic costs and benefits and should include external costs, such as environmental and health effects, to the extent possible, i.e. when a market price exists or when it is already included in European or national regulation.

(g) Economic analysis: Inventory of effects

The economic analyses shall take into account all relevant economic effects.

Member States may assess and take into account in decision making costs and energy savings from the increased flexibility in energy supply and from a more optimal operation of the electricity networks, including avoided costs and savings from reduced infrastructure investment, in the analysed scenarios.

The costs and benefits taken into account shall include at least the following:

- i) Benefits
 - Value of output to the consumer (heat and electricity)
 - External benefits such as environmental and health benefits, to the extent possible
- ii) Costs
 - Capital costs of plants and equipment
 - Capital costs of the associated energy networks

- Variable and fixed operating costs
- Energy costs
- Environmental and health cost, to the extent possible

(h) Sensitivity analysis:

A sensitivity analysis shall be included to assess the costs and benefits of a project or group of projects based on different energy prices, discount rates and other variable factors having a significant impact on the outcome of the calculations.

The Member States shall designate the competent authorities responsible for carrying out the cost-benefit analyses under Article 14. Member States may require competent local, regional and national authorities or operators of individual installations to carry out the economic and financial analysis. They shall provide the detailed methodologies and assumptions in accordance with this Annex and establish and make public the procedures for the economic analysis.

Annex 3: Methodology for determining the efficiency of the cogeneration process⁴⁷

Values used for calculation of efficiency of cogeneration and primary energy savings shall be determined on the basis of the expected or actual operation of the unit under normal conditions of use.

a) High-efficiency cogeneration

For the purpose of this Directive high-efficiency cogeneration shall fulfil the following criteria:

- Cogeneration production from cogeneration units shall provide primary energy savings calculated according to point (b) of at least 10 % compared with the references for separate production of heat and electricity,
- Production from small-scale and micro-cogeneration units providing primary energy savings may qualify as high-efficiency cogeneration.

b) Calculation of primary energy savings

The amount of primary energy savings provided by cogeneration production defined in accordance with Annex I shall be calculated on the basis of the following formula:

$$PES = \left(1 - \frac{1}{\frac{CHP H_{\eta}}{Ref H_{\eta}} + \frac{CHP E_{\eta}}{Ref E_{\eta}}} \right) \times 100\%$$

Where:

PES is primary energy savings.

CHP H_{η} is the heat efficiency of the cogeneration production defined as annual useful heat output divided by the fuel input used to produce the sum of useful heat output and electricity from cogeneration.

⁴⁷ As defined in Annex II of the EED.

Ref H_{η} is the efficiency reference value for separate heat production.

CHP E_{η} is the electrical efficiency of the cogeneration production defined as annual electricity from cogeneration divided by the fuel input used to produce the sum of useful heat output and electricity from cogeneration. Where a cogeneration unit generates mechanical energy, the annual electricity from cogeneration may be increased by an additional element representing the amount of electricity which is equivalent to that of mechanical energy. This additional element will not create a right to issue guarantees of origin in accordance with Article 14(10).

Ref E_{η} is the efficiency reference value for separate electricity production.

(c) Calculations of energy savings using alternative calculation

Member States may calculate primary energy savings from a production of heat and electricity and mechanical energy as indicated below without applying Annex I to exclude the non-cogenerated heat and electricity parts of the same process. Such a production can be regarded as high-efficiency cogeneration provided it fulfils the efficiency criteria in point (a) of this Annex and, for cogeneration units with an electrical capacity larger than 25 MW, the overall efficiency is above 70 %. However, specification of the quantity of electricity from cogeneration produced in such a production, for issuing a guarantee of origin and for statistical purposes, shall be determined in accordance with Annex I.

If primary energy savings for a process are calculated using alternative calculation as indicated above the primary energy savings shall be calculated using the formula in point (b) of this Annex replacing: ‘CHP H_{η} ’ with ‘ H_{η} ’ and ‘CHP E_{η} ’ with ‘ E_{η} ’, where: H_{η} shall mean the heat efficiency of the process, defined as the annual heat output divided by the fuel input used to produce the sum of heat output and electricity output.

E_{η} shall mean the electricity efficiency of the process, defined as the annual electricity output divided by the fuel input used to produce the sum of heat output and electricity output. Where a cogeneration unit generates mechanical energy, the annual electricity from cogeneration may be increased by an additional element representing the amount of electricity which is equivalent to that of mechanical energy. This additional element will not create a right to issue guarantees of origin in accordance with Article 14(10).

(d) Member States may use other reporting periods than one year for the purpose of the calculations according to points (b) and (c) of this Annex.

(e) For micro-cogeneration units the calculation of primary energy savings may be based on certified data.

f) Efficiency reference values for separate production of heat and electricity

The harmonised efficiency reference values shall consist of a matrix of values differentiated by relevant factors, including year of construction and types of fuel, and must be based on a well-documented analysis taking, inter alia, into account data from operational use under realistic conditions, fuel mix and climate conditions as well as applied cogeneration technologies.

The efficiency reference values for separate production of heat and electricity in accordance with the formula set out in point (b) shall establish the operating efficiency of the separate heat and electricity production that cogeneration is intended to substitute.

The efficiency reference values shall be calculated according to the following principles:

1. For cogeneration units, the comparison with separate electricity production shall be based on the principle that the same fuel categories are compared.
2. Each cogeneration unit shall be compared with the best available and economically justifiable technology for separate production of heat and electricity on the market in the year of construction of the cogeneration unit.
3. The efficiency reference values for cogeneration units older than 10 years of age shall be fixed on the reference values of units of 10 years of age.
4. The efficiency reference values for separate electricity production and heat production shall reflect the climatic differences between Member States.

Annex 4: An investigation into three different primary-energy weighting principles⁴⁸

1) The ‘environmental-communication’ principle. This primary-energy weighting principle is based exclusively on the primary-energy factors discussed in the ‘Fjärrsyn’ report *‘Environmental communication with key figures and indicators’* (Gode *et al.* 2012). This in turn is largely based on a very detailed, comprehensive life-cycle study of various fuels and energy types, namely the Environmental Fact Book (Thermal Engineering Research Association 2011). In short, all fuels are allocated a primary-energy factor (PEF) of just over 1, which means just over 1 MWh of primary energy for each MWh of fuel supplied. The reason that it is greater than 1 is that it includes the primary-energy input for extraction and distribution to the point of supply (for example a power plant). Hard coal, for example, is given a PEF of 1.15. Biofuels also have a PEF of just over 1. The only exception among the fuels is combustible waste, which has a PEF of 0.61 (in Gode *et al.* 2012 but not in Thermal Engineering Research Association 2011). Some waste is therefore regarded as ‘lost’ and therefore does not have any primary-energy input associated with it.

Industrial waste heat is weighted with a PEF of around zero for the same reason. The primary-energy weighting of electricity and district heating applies the ‘environmental-communication’ principle from what is known as the ‘accounting perspective’. This is based exclusively on statistics for the existing production system for electricity and district heating, and on the view that all consumption of electricity and district heating, irrespective of whether it is existing or future consumption, must be weighed up against *mean* production of these types of energy. With regard to electricity consumption in Sweden, and in accordance with the principle applied here, this means Nordic mean electricity in the short term and European mean electricity in the longer term, because the argument is that the Swedish/Nordic electricity market will be more closely linked to the continental European electricity markets in the longer term. Consumption of district heating, on the other hand, is weighed up against mean Swedish production (for practical reasons it is impossible to deal with a primary-energy weighting based on every single, local production system separately).

In the report (Gode *et al.* 2012) forming the basis for the ‘environmental-communication’ principle, two values are given for the primary-energy factor for Swedish district heating. One of these values is approximately 1.1, assuming that the mean value is weighed up against the size of the various systems. The other value is approximately 0.8, assuming that the mean value is not weighed up against that size. Since this estimate has also flagged up various uncertainties, we have chosen a value of 1 as representative of the primary-energy factor for mean Swedish district heating when applying this principle.

2) The ‘heating-market committee’ principle is the second principle that has been defined for the primary-energy weighting. It is based on the agreement within the Heating-Market Committee, i.e. a confederation made up of the Swedish District Heating Association, the Swedish Property Federation, the Swedish Union of Tenants, the Swedish Association of Public Housing Companies (SABO), the national housing-association cooperative ‘Riksbyggen’, and the HSB housing cooperative (Heating-Market Committee 2012). The ‘heating-market committee’ principle is based on the same PEFs as the ‘environmental-

⁴⁸ Potential for cogeneration, district heating and district cooling, ‘Fjärrsyn’ (2013:15).

communication’ principle above, but with some important differences. The majority of biofuels used to generate electricity and district heating are assumed to have a PEF of approximately 0. This is explained by the fact that these fuels are treated as ‘residual’ or ‘waste’ fuels in the context of other operations where the actual primary energy is allocated instead. For example, BATT is an example of a residual product when raw materials are extracted for the forestry industry, while pellets and briquettes are the result of processing waste from the timber industry (for example from sawdust and plane shavings). The reason that the PEFs for these fuels are not exactly zero but only ‘nearly zero’ (such as 0.03 for BATT) is that there is some primary-energy input associated with extraction and distribution. The fuel itself does not, however, contain any primary energy according to this principle. Combustible waste is also allocated a PEF of approximately 0. Peat, however, has a PEF of just over one, just like fossil fuels. Just as with the ‘environmental-communication’ principle above, the accounting perspective is primarily used for electricity and district heating. Because the majority of district heating is produced using fuels with a PEF of nearly zero, mean district heating in Sweden has a relatively low PEF of approximately 0.3 (Swedish District Heating Association 2012). The PEF for electricity is the result of the common platform for environmental assessments of electricity and district heating shared by the Swedish District Heating Association and Swedenergy. The electricity is thus assessed in accordance with the properties of what is known as the residual mix, in other words the electricity left over when a reduction/correction is made for product-specific electricity such as ‘Good Environmental Choice’ electricity and imports and exports to and from Sweden. It also follows from this approach that the electricity consumption associated with product-specific or origin-labelled electricity can mean that the assessment results in a lower primary-energy factor for the electricity in question. No such calculation has been performed for this report. The results therefore apply to a case where the electricity consumer has not made any active choice concerning the origin of the electricity. Some guidance concerning the average characteristics of electricity may be found in the primary-energy factors based on mean Nordic electricity in accordance with the ‘environmental-communication’ principle.

3) The ‘change-impact’ principle is based on the same PEFs as with the ‘heating-market committee’ principle as far as fossil fuels, biofuels, waste-based fuel and industrial waste heat are concerned. There are, however, differences in relation to electricity and district heating. These energy carriers are viewed partly from a ‘change leads to impact’ perspective and partly from a forward-looking perspective (‘impact’ in the sense of ‘consequence’). This includes the *impact* of *changes* in a *system* that is being developed. Such changes themselves result from a choice or decision (such as an investment decision). These considerations differ fundamentally from the ‘accounting perspective’ of the first two principles. The consequence of a change in electricity or district-heating consumption (which is the case here, for example an *expansion* of district-heating consumption) is unlikely to be a corresponding change in mean production of electricity or district heating. This impact occurs in the form of *deviations* from the future trend in the system in terms of its ‘basic execution’. ‘Basic execution’ means a trend that does not take account of a change in electricity or district-heating consumption where the consequences or impact of that change must be quantified. Another way of saying it is that we analyse the impact of ‘marginals’. The ‘long-term marginal impact’ occurs as a result of changes taking place over a long period of time (for example new connections to district heating or an increase in electricity consumption for some reason), and it includes both changes in the production of existing capacity and investments in new capacity. In other words, the long-term marginal impact may include a mixture of different types of technology and different fuels. This composition may differ

considerably from mean production. The calculations of long-term marginal impact are updated continuously as the conditions in the world around us change.

The same model has been chosen for both electricity and district heating. The description of district-heating production has been simplified in the model in so far as [*sic*]

The starting point is that a 'Swedish aggregate' includes all Swedish district-heating production. This PEF weighting for district heating is therefore based on a forward-looking change in (impact on) total Swedish district-heating production.

This also means a dynamic in the PEF weighting of electricity and district heating that therefore changes over time. It is, however, entirely the result of the initial change in electricity or district-heating needs. This primary-energy weighting principle has a considerably more complex design than the first two principles. On the one hand, some form of model is required, and on the other there is often variation in the result from the model, which to a great extent depends on the assumptions made about trends in the world around us. It is not, however, a failure of the method itself; rather it is symptomatic of the uncertainty that prevails with regard to future developments. In such a scenario, naturally, it is easier and more transparent to use existing statistics and assume that any changes in the use of electricity and district heating will be managed by means of changes in mean production. Nonetheless, the electricity market and, in general, district-heating production do not work like that, which suggests that there are some disadvantages to this approach. Because the calculations of potential clearly focus on the situation moving forwards, a primary-energy approach that also has a forward-looking perspective is the preferred assessment.

Annex 5: EED, Annex VIII g)(i)–(vi)

Strategies, policies and measures that may be adopted up to 2020 and up to 2030 to realise the potential in point (e) in order to meet the demand in point (d), including, where appropriate, proposals to:

- i) increase the share of cogeneration in heating and cooling production and in electricity production;
- ii) develop efficient district heating and cooling infrastructure to accommodate the development of high-efficiency cogeneration and the use of heating and cooling from waste heat and renewable energy sources;
- iii) encourage new thermal electricity generation installations and industrial plants producing waste heat to be located in sites where a maximum amount of the available waste heat will be recovered to meet existing or forecast heat and cooling demand, Official Journal of the European Union, OJ L 315, 14.11.2012, p. 40;
- iv) encourage new residential zones or new industrial plants which consume heat in their production processes to be located where available waste heat, as identified in the comprehensive assessment, can contribute to meeting their heat and cooling demands. This could include proposals that support the clustering of a number of individual installations in the same location with a view to ensuring an optimal matching between demand and supply for heat and cooling;
- v) encourage thermal electricity generating installations, industrial plants producing waste heat, waste incineration plants and other waste-to-energy plants to be connected to the local district heating or cooling network;
- vi) encourage residential zones and industrial plants which consume heat in their production processes to be connected to the local district heating or cooling network;

Annex 6: Input data for the cost-benefit analysis

The potential for efficient district heating is based on ‘*District heating in the future – Needs*’. The price assumptions are based on the *Long-Term Forecast 2008* (the same assumptions as for *District heating in the future*) and the *EnEff* report. Various cost assumptions are discussed in detail in Annex 1 to ‘*District heating in the future – Needs*’. The assumptions are given here in Tables 4, 6, 8, 12, 13 and 16.⁴⁹

The potential for high-efficiency cogeneration in the district-heating system is 14.7 TWh for both 2020 and 2030 (please see Chapter 3.2). This is a mean primarily from two different studies, namely *District heating in the future* (‘Fjärrsyn’ report 2011:2) and Profu, *Basis for the Swedish Energy Agency’s Long-Term Forecast 2012*, but five other studies have also been used to ensure that the result is correct. The majority of studies are robust and the result is also given in the form of a sensitivity analysis. The tables below show the details of the assumptions that have been made for the most important reports. Where these assumptions manifest themselves, the results of the various studies may be seen in Figure 8.

B6.1.1 Exchange rate

It has been assumed that exchange rates will remain unchanged over the period covered by the forecast, and that they will be equal to the official exchange-rate levels that applied in 2007. The exchange rates appear in Tables 4 and 5.

Table 4. Exchange rates assumed for the forecast period. Source: Swedish Energy Agency, Long-Term Forecast 2008, used in ‘District heating in the future’.

SEK/EUR	9.25
SEK/USD	6.76

Table 5 Exchange rates assumed for the forecast period. Source: Swedish Energy Agency, Long-Term Forecast 2012.

SEK/EUR	9.3
SEK/USD	7.55

Source: Swedish Central Bank

⁴⁹ *Efficient heating and cooling* means a heating and cooling option that, compared to a baseline scenario reflecting a business-as-usual situation, measurably reduces the input of primary energy needed to supply one unit of delivered energy within a relevant system boundary in a cost-effective way, as assessed in the cost-benefit analysis referred to in this Directive, taking into account the energy required for extraction, conversion, transport and distribution.

B6.1.2 Assumed prices

Table 6 Fossil-fuel prices (SEK/MWh, free national limit and excluding tax).

Source: Swedish Energy Agency, Long-Term Forecast 2008, used in 'District heating in the future'.

	2005	2010	2015	2025	2050
Coal	60	67	70	70	70
Heavy fuel oil	186	238	238	238	238
Light fuel oil	309	448	448	448	448
Natural gas	162	207	207	207	207

Table 7 Fossil-fuel prices (SEK2007/MWh, free national limit and excluding tax).

Source: Swedish Energy Agency, Long-Term Forecast 2012.

	Scenario	2007	2010	2020	2030	2040	2050
Crude oil, spot (USD/barrel)	Baseline	79	74	112	128	135	138
Coal	Baseline	94	101	113	120	125	129
Heavy fuel oil	Baseline	222	257	402	453	475	485
Light fuel oil	Baseline	349	379	607	689	723	738
Natural gas	Baseline	201	185	283	323	337	345

Table 8 Biofuel prices and potential. Source: Swedish Energy Agency, 'Long-Term Forecast 2008' and Profu's own estimates, used in both 'District heating in the future' and 'Long-Term Forecast 2012'.

Fuel price (SEK/MWh)				Potential (TWh per annum)	
	2005	2015	2025	2015	2025
Return liquor	-	-	-	45	50
Solid by-products from the forestry industry ¹⁾	95–121	155–171	205–221	20	23
Wood chips from forestry, class I ²⁾	135	182	221	9	11
Wood chips from forestry, class II ³⁾	144	194	235	9	11
Wood chips from forestry, class III ⁴⁾	151	213	252	4	5
Wood chips from forestry, class IV ⁵⁾	165	226	266	12	15
Energy forest and straw	137–190	191–220	220–231	15	15
Processed timber fuel ⁶⁾	204	289	352	12	17
Peat ⁷⁾	112	110	128	4	5
Combustible waste ⁸⁾	–230	–240	–253	21	24
Wood, households	-	-	-	11	11

¹⁾ By-products from the industry (wood chips from sawmills, timber waste, bark, etc.). Divided into two subcategories: one for internal industrial use, and one available to a common market with other the rest of the energy system.

²⁾ BATT and root wood, with shorter transport distances.

³⁾ BATT and root wood, with longer transport distances.

⁴⁾ Pulp-wood quality.

⁵⁾ Pulp-wood quality plus imports.

⁶⁾ Pellets, briquettes, and powder. The distribution cost for use in detached houses is added.

⁷⁾ Excluding sulphur tax.

⁸⁾ Various categories divided up into mixed household and industrial waste, recycled wood chips and other recycled fuels. The fuel price for mixed waste includes the reception charge.

B6.1.3 Taxes

Table 9. Carbon-dioxide and energy tax for various sectors. Source: Ministry of Finance (2009), 'More efficient taxes in the climate and energy sector', DS 2009:24. Used in both 'District heating in the future' and 'Long-Term Forecast 2012'.

	CO₂ tax (öre/kg)	Energy tax (öre/kWh)
Homes and services	105 (General level)	General level according to Table 10
Super-heated water boilers	99 (equiv. to 6 % reduction) ¹⁾	General level according to Table 10.
Cogeneration (in heat production)	7 (equiv. to 93 % reduction)	2.5 (for all fossil fuels)
Industry (ETS)	0 (equiv. to 100 % reduction).	2.5 (for all fossil fuels)
Industry (non-ETS)	31 as of 2011 (equiv. to 70 % reduction) 62 as of 2015 (equiv. to 40 % reduction)	2.5 (for all fossil fuels)

¹⁾ It should be noted that, in the draft Budget for 2014, the Swedish Government proposes to reduce the CO₂ tax for heat production within the EU ETS from 94 % to 80 % of the general CO₂ tax rate.

Table 10 Assumed taxes on fuels for heat production and electricity (general level). Source: Ministry of Finance (2009), 'More efficient taxes in the climate and energy sector', DS 2009:24. Used by both 'District heating in the future' and 'Long-Term Forecast 2012'.

	Energy tax (SEK/MWh)	Carbon-dioxide tax (SEK/MWh)¹⁾
Heavy fuel oil	80	294
Light fuel oil	80	286
Coal	80	352
Natural gas	80	210
Electricity for households, services and district-heating prod. (South Sweden)	282	-
Electricity for industry	5	-

¹⁾ The model assumes a general rate of carbon-dioxide tax per kg of CO₂ for all fossil fuels. The tax is expressed in SEK/MWh and may vary somewhat depending on the emission coefficient assumed.

B6.1.4 Price of emission allowances

'District heating in the future' assumes that the price level of emission allowances will remain constant at EUR 30/tonne throughout the period covered by the calculation.

The prices of emission allowances according to the Long-Term Forecast 2012 may be found in Table 11 below.

Table 11 Assumed prices of emission allowances during the forecast period.
Source: Swedish Energy Agency, Long-Term Forecast 2012.

	2010	2020	2030	2040	2050
EUR/tonne CO ₂	15	17	37	54	52

B6.1.5 Electricity-certificate scheme

Table 12 Assumed production targets for renewable electricity production under the electricity-certificate scheme. Source: Swedish Energy Agency, Long-Term Forecast 2008, used in 'District heating in the future'.

Model year	2009	2016	2023	2030	2037	2044
Production target defined in the model (TWh) ¹⁾	18.5	23.9	29.7	29.7	29.7	-
Increase compared to 2002	12	192	25	25	25	-

¹⁾ The modelled production target has been adjusted after some existing capacity (small-scale hydro-electric power) was phased out.

B6.1.6 Costs

Table 13 Typical data for gas-based power production and cogeneration production. Source: Swedish Energy Agency, Long-Term Forecast 2008, used in 'District heating in the future' and 'Long-Term Forecast 2012'.

	Investment	Fixed operations and maintenance	Variable operations and maintenance	Efficiency level (%)	Alpha value	Lifetime (years)
Condensing power	7 000 SEK/kW electricity	40 SEK/kW electricity	15 SEK/MWh electricity	57	-	21
Cogeneration	8 000 – 9 500 SEK/kW electricity ¹⁾	70 SEK/kW electricity	20 SEK/MWh electricity	50 (electricity)	1.2	21

¹⁾ Depending on size.

Table 14 Typical data for a conventional biofuel-cogeneration plant with flue-gas condensing on two scales (assumptions are based on Profu's own estimates and, to some extent, on Swedish Electricity Research Centre 2011, 'Electricity from new facilities 2011'). Used in 'District heating in the future'.

	Investment (SEK/kWh electricity)	Fixed operations and maintenance (SEK/kW electricity)	Variable operations and maintenance (SEK/MWh electricity)	Efficiency level (%)	Alpha value	Lifetime (years)
Large plant (> 50 MW electricity)	21 000	220	35	32 (electricity)	0.41	21
Small plant (~ 30 MW electricity)	26 000	310	60	28 (electricity)	0.36	21

Table 15 Typical data for a conventional biofuel-cogeneration plant with flue-gas condensing on two scales (assumptions are based on Profu's own estimates and, to some extent, on Swedish Electricity Research Centre 2011, 'Electricity from new facilities 2011'). Used in 'Long-Term Forecast 2012'.

	Investment (SEK/kWh electricity)	Fixed operations and maintenance (SEK/kW electricity)	Variable operations and maintenance (SEK/MWh electricity)	Efficiency level (%)	Alpha value	Lifetime (years)
Large plant (> 50 MW electricity)	~ 25 000	220	35	32 (electricity)	0.41	21
Small plant (~ 30 MW electricity)	~ 30 000	310	60	28 (electricity)	0.36	21

Table 16 Typical production costs for district heating at heating plants, used in 'District heating in the future'.

	Investment (SEK/kW heat)	Fixed operations and maintenance (SEK/kW heat)	Variable operations and maintenance (SEK/MWh heat)	Efficiency level (%)	Lifetime (years)
Natural gas	1 450	22	20	90	21
Biofuel	4 000	100	25	88	21

Table 17 Typical production costs for district heating at heating plants. Source: Swedish Energy Agency, Long-Term Forecast 2012.

	Investment (SEK/kW heat)	Fixed operations and maintenance (SEK/kW heat)	Variable operations and maintenance (SEK/MWh heat)	Efficiency level (%)	Lifetime (years)
Natural gas	2 000	22	20	90	21
Biofuel	5 000	100	25	88	21

B6.2 Assumptions underlying the potential for industrial cogeneration

The overall estimate of back-pressure potential (please see Chapter 3) is 8.6 TWh of electricity for 2020 and 8.8 TWh for 2030. The selected potential is a mean of the levels for ‘Sectors 2011’,⁵⁰ and ‘Profu 2010, high’.⁵¹

The assumptions forming the basis for the potential according to the ‘Analysis of biofuel consumption and industrial back pressure, linked to the MARKAL calculations’ is discussed below.⁵²

B6.2.1 Exchange rate

The exchange rate is assumed to be SEK 9.3 = EUR 1.

B6.2.2 Assumed prices

Table 18 Fossil-fuel prices (SEK₂₀₀₇/MWh, free national limit and excluding tax). Source: Swedish Energy Agency, ‘Long-Term Forecast 2010’.

	<i>Scenario</i>	2005	2010	2020	2030	2050
Crude oil (USD/barrel)	<i>Baseline and</i>	59	76	98	113	113
	<i>Higher GDP</i>	59	99	128	147	147
	<i>Higher foss. prices</i>					
Coal	<i>Baseline and</i>	60	73	90	95	95
	<i>Higher GDP</i>	60	88	116	123	123
	<i>Higher foss. prices</i>					
Heavy fuel oil	<i>Baseline and</i>	186	252	308	345	345
	<i>Higher GDP</i>	186	312	381	427	427
	<i>Higher foss. prices</i>					
Light fuel oil	<i>Baseline and</i>	309	463	609	709	709
	<i>Higher GDP</i>	309	618	810	942	942
	<i>Higher foss. prices</i>					
Natural gas	<i>Baseline and</i>	162	227	320	369	369

⁵⁰ ‘Fjärrsyn’ project (2013:15).

⁵¹ The analysis of biofuel consumption and industrial back pressure, linked to the MARKAL calculations is discussed below.

⁵² The assumptions are, however, documented in the calculations using MARKAL NORDIC in the Long-Term Forecast 2010.

Higher GDP	162	287	412	476	476
Higher foss. prices					

Table 19 Biofuel prices and potential. Source: Swedish Energy Agency, 'Long-Term Forecast 2010' and Profu's own estimates.

Fuel price (SEK ₂₀₀₇ /MWh)				Potential (TWh per annum)	
	2005	2015	2025	2015	2025
Return liquor	-	-	-	45	50
Solid by-products from the forestry industry ¹⁾	95–121	155–171	205–221	20	23
Wood chips from forestry, class I ²⁾	135	182	221	9	11
Wood chips from forestry, class II ³⁾	144	194	235	9	11
Wood chips from forestry, class III ⁴⁾	151	213	252	4	5
Wood chips from forestry, class IV ⁵⁾	165	226	266	12	15
Energy forest and straw	137–190	191–220	220–231	1.5	1.5
Processed timber fuel ⁶⁾	204	289	352	12	17
Peat ⁷⁾	112	110	128	4	5
Combustible waste ⁸⁾	–150–80	–150–90	–150–103	21	24
Wood, households	-	-	-	11	11

¹⁾ By-products from the industry (wood chips from sawmills, timber waste, bark, etc.). Divided into two subcategories: one for internal industrial use, and one available to a common market with other the rest of the energy system.

²⁾ BATT and root wood, with shorter transport distances.

³⁾ BATT and root wood, with longer transport distances.

⁴⁾ Pulp-wood quality.

⁵⁾ Pulp-wood quality plus imports.

⁶⁾ Pellets, briquettes, and powder. The distribution cost for use in detached houses is added.

⁷⁾ Excluding sulphur tax.

⁸⁾ Various categories divided up into mixed household and industrial waste, recycled wood chips and other recycled fuels. The fuel price for mixed waste includes the reception charge.

B6.2.3 Taxes

Table 20 Carbon-dioxide and energy tax for various sectors. Source: Ministry of Finance (2009), 'More efficient taxes in the climate and energy sector', DS 2009:24. Used in 'District heating in the future' and 'Long-Term Forecast 2012'.

	CO ₂ tax (öre/kg)	Energy tax (öre/kWh)
Homes and services	105 (General level)	General level according to Table 21
Super-heated water boilers	99 (equiv. to 6 % reduction)	General level according to Table 21
Cogeneration (in heat prod)	7 (equiv. to 93 % reduction)	2.5 (for all fossil fuels)
Industry (ETS)	0 (equiv. to 100 % reduction).	2.5 (for all fossil fuels)
Industry (non-ETS)	31 as of 2011 (equiv. to 70 % reduction) 62 as of 2015 (equiv. to 40 % reduction)	2.5 (for all fossil fuels)

Table 21 Assumed taxes on fuels for heat production and electricity (general level). Source: Ministry of Finance (2009), 'More efficient taxes in the climate and energy sector', DS 2009:24. Used in 'District heating in the future' and 'Long-Term Forecast 2012'.

	Energy tax (SEK/MWh)	Carbon-dioxide tax (SEK/MWh) ¹⁾
Heavy fuel oil	80	294
Light fuel oil	80	286
Coal	80	352
Natural gas	80	210
Electricity for households, services and district-heating production (South Sweden)	282	-
Electricity for industry	5	-

¹⁾ The model assumes a general rate of carbon-dioxide tax per kg of CO₂ for all fossil fuels. The tax is expressed in SEK/MWh and may vary somewhat depending on the emission coefficient assumed.

B6.2.4 Price of emission allowances

All of the calculations include the EU emission-allowances system for carbon dioxide. In accordance with the Swedish Energy Agency's mandate specification, this price is assumed to be EUR 16/tonne (approximately 15 öre/kg of CO₂ with the assumed exchange rate) throughout the entire period covered by the calculations and in all three scenarios.

B6.2.5 Electricity certificates

Table 22 Assumed production targets for renewable electricity production under the electricity-certificate scheme.

Model year	2009	2016	2023	2030	2037	2044
Production target defined in the model (TWh) ¹⁾	18.5	23.9	29.7	29.7	29.7	-
Increase compared to 2002	12	19.2	25	25	25	-

¹⁾ The modelled production target has been adjusted after some existing capacity (small-scale hydro-electric power) was phased out.

B6.2.6 Production costs

Table 23 Typical data for gas-based power production and cogeneration production.

	Investment (SEK/kW electricity ¹⁾)	Fixed operations and maintenance (SEK/kW electricity)	Variable operations and maintenance (SEK/MWh electricity)	Efficiency level (%)	Alpha value	Lifetime (years)
Condensing power	7 000	40	15	57	-	21
Cogeneration	8 000 – 9 500	70	20	50 (electricity)	1.2	21

¹⁾ Depending on size.

A sustainable energy system that benefits society

The Swedish Energy Agency works to achieve a sustainable energy system that combines ecological sustainability, competitiveness and security of supply.

We develop knowledge about more efficient energy use and other energy matters, and disseminate it to households, businesses and authorities.

Development aid may be awarded for renewable energy sources, such as intelligent electricity networks and future transport and fuels. Swedish businesses have opportunities for growth by making their innovations and new business ideas a reality.

We participate in international collaboration to achieve the climate targets, and we manage various instruments such as the electricity-certificate scheme and the trading of emission allowances. We also develop national analyses and forecasts, as well as Sweden's official statistics for the energy sector.

All of the Swedish Energy Agency's reports are available on its website: www.energimyndigheten.se.



Swedish Energy Agency, P.O. Box 310, 631 04 Eskilstuna, Sweden
Telephone +46 (0)16 544 20 00, Fax +46 (0)16 544 20 99
E-mail registrator@energimyndigheten.se
www.energimyndigheten.se