ecoheatcool

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ECOHEATCOOL

Work package 4

Possibilities with more district heating in Europe

Final Report

This report is published by Euroheat & Power whose aim is to inform about district heating and cooling as efficient and environmentally benign energy solutions that make use of resources that otherwise would be wasted, delivering reliable and comfortable heating and cooling in return.

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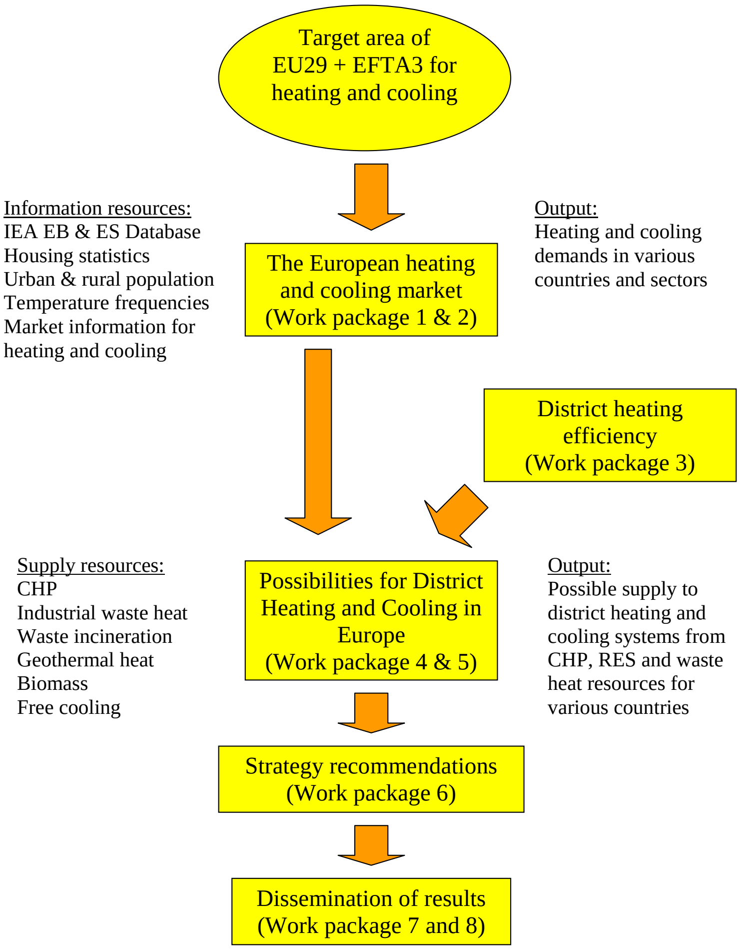
The ECOHEATCOOL project structure



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Austrian Association of Gas and District Heat Supply Companies, Austria

Swedish District Heating Association, Sweden

Norwegian District Heating Association, Norway

Confederation of European Waste to Energy Plants, Belgium

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Contents

1 Executive summary

The main purpose with this report (Work Package 4 of the ECOHEATCOOL project) have been to present an overall quantification of the benefits of expanded use of district heating in Europe. This quantification is based on the definition and description of the European heat market during 2003 presented in the preceding report from Work Package 1. The target area covers 32 countries, including the EU25 member states, four accession countries (Bulgaria, Croatia, Romania, and Turkey), and three EFTA countries (Iceland, Norway, and Switzerland). The main source for statistical information was the IEA Energy Balances and 2003 was chosen as the reference year for the analyses.

The quantification of the overall benefits with district heating is introductory supported by descriptions of

- The fuel and heat supply to district heating systems during 2003
- The five major strategic heat source options for district heating
- Institutional and market barriers for district heating
- Projections for future district heat sales

The fuel and heat supply to district heating systems are dominated by the use of heat from CHP plants, corresponding to 68 % of all district heat generated. The renewable part in the district heat supply (14 %) is also higher than the corresponding fraction (7%) in the overall primary energy supply. Hereby, the European district heating systems have together succeeded to fulfil the EU ambition of a 12 % renewable share in 2010. The total share of renewables and heat retrieved from other activities amounted to 78 % for all heat generated, proving that the European district heating systems are in general successful in avoiding direct heat only generation with fossil fuels.

The five major strategic heat source options are normally identified as combined heat and power (CHP), waste incineration, industrial surplus heat, geothermal heat, and combustible renewables such as biomass. The total available potential for these resources are about 200 times higher than the current district heat deliveries and about 20 times higher than the current total net heat demand for the industrial, residential, and service sectors in the target area. The highest potential appears for geothermal heat, but the available heat resources from CHP and biomass are also significant. Hence, no limitations appear with respect to available strategic fuel and heat sources for more district heating in Europe.

Major barriers for district heating have during recent years been low fuel and electricity prices, focus on short term investments, existing legal frameworks, energy supply focus, ownership shifts, price regulation, distorted market prices, cost allocation methods, social obligations, and the introductory rules in the new European emissions trading system.

The total net heat demand for the industrial, residential, and service sectors in 2003 has been estimated to 20,8 EJ/year. The additional possible potential for district heat sales has been estimated to 6,8 EJ/year, which is 3,4 times higher than the current district heat sales of 2,0 EJ/year. Hence, no limitations appear with respect to available heat demands for expansion of the European district heating systems.

The overall benefits with district heating were identified as higher energy efficiency, higher security of supply, and lower carbon dioxide emissions. The overall benefits have been estimated for three cases: The current (2003) situation, Improved heat generation at current heat sales, and Doubling heat sales with the improved composition of heat generation.

In the case of doubling the heat sales, higher energy efficiency would be registered as the primary energy supply can be reduced with 2,14 EJ/year, corresponding to the whole energy balance of Sweden. The higher security of supply for the same case became a reduction of the import dependency with 4,45 EJ/year, corresponding to 5,5 % of all primary energy supply or more than the whole energy balance of Poland. The reduction of carbon dioxide emissions from the first to the third case was estimated to 404 million tons annually, corresponding to 9,3 % of the total carbon dioxide emissions from fuel combustion in the target area. This reduction corresponds also to the total annual carbon dioxide emissions from fuel combustion in France. However, this environmental benefit of district heating have not been recognised on the international policy level concerning climate change.

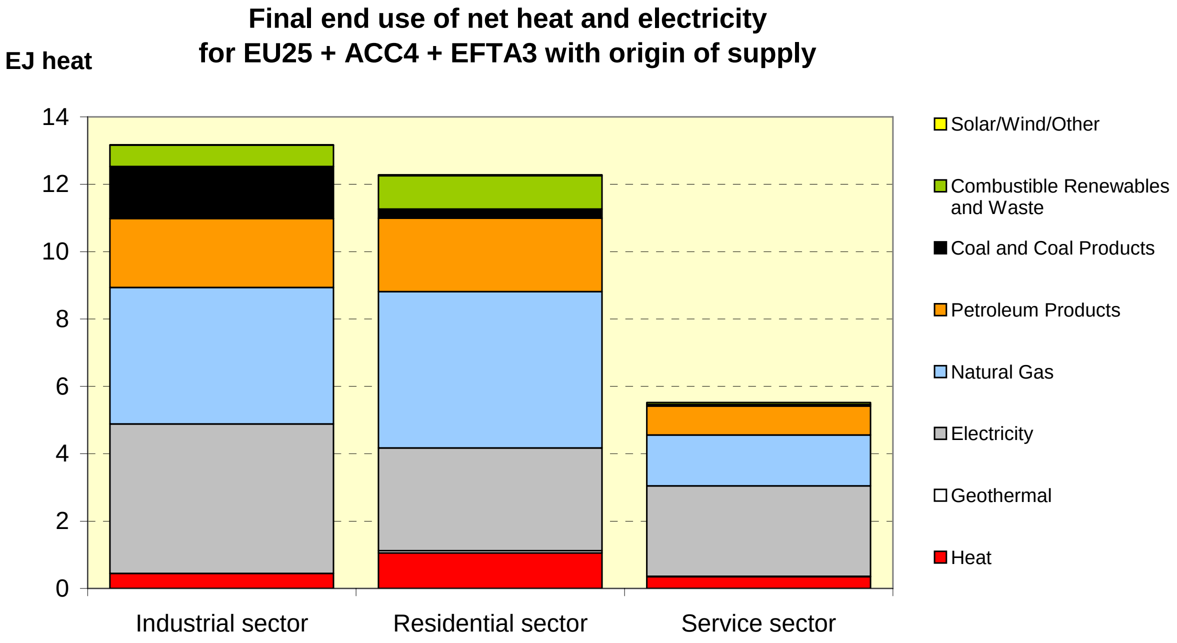
The final conclusion was that just above 5000 district heating systems exist currently in the target area. Many of them are classified as small and medium-sized enterprises (SME). Their staffs know how to operate the systems and are very familiar with the local users and their heat demands. If changes have to be implemented in the European district heating systems, mainly existing organisations, technologies, and business models can be utilised. There is no need for completely new organisations, new technologies, or new business models in order to obtain higher energy efficiency, higher security of supply, and lower carbon dioxide emissions by improving district heat generation and doubling district heat sales. However, an extensive dissemination program can be needed in order to transfer vital knowledge between countries and between district heating systems.

2 Introduction

This is the main report from Work Package 4 (WP4) of the Ecoheatcool project. The focus for this work package is the structure and the supply situation in the European district heating sector. The Work Package 1 (WP1) report (Ecoheatcool, 2005) preceded this report with a detailed description of the whole European heat market. That description contained the background, the structure, and the current supply situation based on the 2003 national energy balances according to (IEA, 2005).

The target area for this WP4 report is the same as in WP1: The current EU25 (divided into the EU15 and NMS10 groups), four accession countries (Bulgaria, Croatia, Romania, and Turkey) in the ACC4 group, and three EFTA countries (Iceland, Norway, and Switzerland) in the EFTA3 group.

District heat is mainly used for covering heat demands for space heating and hot water preparation in the residential, service, and industrial sectors. Furthermore, some district heat is also used in the industrial sector for low-temperature heat demands. The district heat use in the target area during 2003 is summarised in Figure 1. Demand related issues was presented in the WP1 report (Ecoheatcool, 2005) and is therefore not further discussed in this report.



3,4 % of district heat

8,6 % of district heat

6,3 % of district heat

In total, the market share was 6,0 % for district heat when electricity was included. Otherwise the market share was 8,9 %.

Figure 1, Summary of the net heat and electricity demands in the target area during 2003 with sources of origin. From (Ecoheatcool, 2005).

The main aim for this fourth part of the Ecoheatcool project is to quantify the overall benefits from the extended use of district heating. The benefits considered here are the higher security of supply due to a higher self-sufficiency of energy supply, the higher energy efficiency in the energy transformation sector, and the lower carbon dioxide emissions. These three benefits appear since domestic renewables and surplus heat recycled from others parts of the energy system are used in the energy supply to district heating systems. The three benefits will be estimated for three different situations:

- The current use of more than 5000 district heating systems in the target area of 32 countries

- Improved systems, by a probable and possible substitution of the heat generation in the current district heating systems
- Doubling heat sales, by increasing the heat sales from expansion of existing systems and introduction of new systems.

The three benefits are estimated for these three situations in order to support the vision that more district heating can support the European demand for a more safe, more efficient, and more sustainable energy system.

The content of this report is organised in the following manner: The rest of this introduction chapter contains a description of the fundamental idea, a brief world history of district heating, and the current heat sales of district heat in Europe. In chapter 3, the current (2003) composition of the energy supply is presented together with the corresponding carbon dioxide emissions. A more in-depth presentation of the current use and the available potential for the five strategic resources for heat generation is presented in chapter 4. A short overview of institutional and market barriers for expansion of district heating is found in chapter 5. The future expectations and possibilities for expansion of district heat sales are discussed in chapter 6. In chapter 7, the benefits with respect to security of supply, energy efficiency, and carbon dioxide emissions are estimated. The conclusions from the analysis in this report is finally summarised in chapter 8. Each chapter is ended with a list of references and other literature sources appropriate for the chapter. The same is valid for each section in chapter 4.

The description in this report is mainly supported by energy statistics from (IEA, 2005), which is the best, most reliable, and most accessible energy database for the target area. But this IEA database is not perfect as earlier noted in the WP1 report.

The most severe defect in the IEA energy balances for this WP4 report is that fuel supply to pure cogeneration mode in combined heat and power (CHP) plants in conjunction with district heat supply cannot be properly identified. The current information includes also fuel for electricity generated in condensing mode in the same plants. The same is valid for amounts of electricity generated in CHP plants.

Another defect is that pure district heat distributed through local piping systems cannot be identified. IEA reports all heat commercially sold to another party, which also includes direct heat deliveries without use of common pipe networks. This issue was also discussed in the WP1 report and the conclusion was that 89 % of the heat reported by IEA in the target area during 2003 was district heat distributed through common pipe networks (Ecoheatcool, 2005). In this WP4 report, all heat amounts reported by IEA is considered to be district heat, giving a quite broader definition of district heat than normally defined.

In some cases, deviations also appear to other information sources from Euroheat & Power, national statistical agencies, or national district heating associations. When properly identified, the principal author has corrected some obvious deviations. However, some deviations still appear concerning some national situations.

2.1 Fundamental idea of district heating

District heating is an energy service provided for immediate use directly by the customers and was commercially introduced in the United States in the late 19th century and in Europe in the early 20th century as a very early example of outsourcing.

The main fundamental idea of district heating today is to use local fuel or heat resources that would otherwise be wasted, in order to satisfy local customer heat demands by using a heat distribution network of pipes as a local market place. This idea contains the three obligatory elements of a competitive district heating system: The suitable cheap heat source, the demands from the heat market and the pipes as a connection between demands and sources. These three elements must all be local in order to obtain short pipes for minimizing the capital investment in the distribution network. Suitable heat demands are space heating and preparation of domestic hot water appearing in residential, public, and commercial buildings. Low temperature industrial heat demands are also suitable for district heating.

The five suitable strategic local heat and fuel resources for district heating include:

- Useful upgraded waste heat from thermal power stations (combined heat and power (CHP) and also called cogeneration)
- Useful heat obtained from waste incineration
- Useful surplus heat from industrial processes or fuel refineries
- Natural geothermal heat sources
- Fuels difficult to handle and manage in small boilers as most combustible renewables as wood waste, peat, straw, or olive residues.

These heat sources must have low cost in order to compensate for the required capital investments in the distribution network and complementing heat generation plants for peak and back-up heat demands. The latter is needed in order to meet customer heat service demands at extremely low outdoor temperatures and when the regular heat sources are temporarily unavailable.

Throughout the history of district heating, centralisation of heat generation has been a major driving force for district heating. Economy of scale for boiler cost, boiler efficiency, staff, and environmental protection were the strong arguments. These arguments are not so very strong anymore, since small efficient heat pumps or small efficient condensing wall-hung natural gas boilers are available on the market. But still elements of economy of scale are present in district heating. The required heat generation capacity for preparing domestic hot water in 1000 or 10000 apartments is only 1% of the total capacity required for separate direct generation in each apartment. District heat distribution is also more cost effective and energy efficient in large cities than in small towns, since the capacity of a distribution pipe increase with the square of the pipe diameter, but both the cost for and the heat loss from the pipe are direct proportional to the pipe diameter.

The main customer benefits are:

- Comfortable, simple, and reliable delivery
- Less floor space for own heating equipment
- Less capital investment in own heating equipment
- Lower fire risk when avoiding fuel use in buildings
- Only payment for the design heat capacity used and not for the oversized local boiler once bought

Another strong side of district heating is the high degree of flexibility in the heat supply in a large system. The operator can easily change the merit order for the available heat sources if the prevailing market conditions change the heat generation costs of the heat sources. The market conditions are for sure not constant with respect to prices of fuels, electricity, green certificates, and carbon dioxide emission quotas. This flexibility gives certain robustness with a considerable net present value for the district heat customers and system owners.

The main conclusion is then: District heating is an efficient method for distribution of heat recycled from secondary heat sources such as various surplus/waste heat sources and distribution of heat from low-grade non-fossil fuels. Substitution of fossil primary energy supply for heating is essential to the fundamental idea of district heating. Consequently, both primary energy supply and carbon dioxide emissions are lower for district heat compared to the current market alternatives. On the other hand, district heating is an inefficient method of distributing heat from direct centralised heat only generation from fossil primary energy supply. A district heating system cannot survive in the long term with just burning natural gas in large heat-only boilers.

For the energy scientist reading this report, the fundamental idea of district heating can also be expressed in the following manner: Use of secondary waste heat from power generation for district heating is a direct acceptance and consequence of the fundamental second law of thermodynamics. The major part of the exergy content in each fuel is shaved off in the CHP plant as electricity. The remaining exergy and all anergy are used for heating of the buildings connected to the district heating system. Hereby, the exergy content for heating is adjusted for the actual temperature level of the final heat demand. When fuels are used directly for heating without this exergy shaving, all useful exergy is destroyed in the boiler by generating heat with low exergy content. A long-term sustainable energy system must maximise the use of the exergy content in each fuel available in order to maximise the final use of available resources and minimise the environmental impact. Most current district heating systems are already operating according to this long-term sustainable principle.

2.2 Early examples of district heating in the World

The fundamental idea of district heating and the use of the five strategic heat sources have emerged from all the district heating projects initiated throughout the years. However, just centralisation of heat generation has sometimes played an important role for the introduction of district heating.

The oldest district heating system in the world still in operation today is located in Chaudes-Aigues, a small town in the Cantal district in France. It is based on a geothermal heat source with a temperature of 82°C and was already in operation as early as in the 14th century. Old municipal documents reveals that two citizens did not pay their heat fees properly in 1332. The hot water was partly distributed in drilled tree trunks as distribution pipes.

Birdsill Holly, an inventor and hydraulic engineer, is often given the credit of being the first to put district heating on a successful commercial basis. After an experiment in 1876 of a loop of steam pipes buried in his garden in Lockport, USA, Holly started a steam supply system in October 1877. Inspired by Holly, several new district heating systems were started in some North American cities in the 1880's. The fuel source was steam coal. In New York, the Manhattan steam system went in operation in 1882. This old steam district heating system still exists as the steam division of Consolidated Edison and delivered 29 PJ of heat during 2003. However, the current market share for district heating is low, since few American cities have major district heating systems today. But the district heating principle is widely used in university campus areas and in some commercial downtown areas.

In Europe, the early experiences of US district heating systems were followed in several small applications in the late 19th century, especially in Germany: The Hamburg town hall in 1893 and the Berlin Technical University in 1884. An early more extended district heating system was also built in Dresden 1900, although it was not a typical commercial project. The main institutional purpose was to reduce the fire risk in 11 royal and public buildings containing invaluable art treasures and located together in the old city centre. Fernheizwerk Hamburg Gmbh initiated a more commercial project for Hamburg in 1921. The main driving force for the project was the high cost of fuel in Germany after the First World War, according to Abraham Margolis, the company chief engineer. The Hamburg system was quickly followed in Germany by Kiel in 1922, Leipzig in 1925 and Berlin in 1927. Outside Germany, district heating systems were started in Copenhagen in 1925, Paris in 1930, Utrecht in 1927, Zürich in 1933, and Stockholm and Helsinki in 1953. However, Swedish heating engineers had already visited the new German systems in the 1920's. Reykjavik, Iceland started a geothermal district heating system in 1930, which today supply almost all the 160000 inhabitants with heat for space heating and domestic hot water, 10,7 PJ during 2003.

All these early projects constitute the background for the existing district heating in the EU15 countries. The initiatives were taken on the municipal level and the systems grew on commercial conditions by competition with other heating methods. In the 70's, district heating became a part of the national energy policy in some countries, initiated by the two global oil crises.

In the former USSR, a general utilization of CHP and district heating was outlined in the electrification plan GOELRO in 1920 in order to reduce the future fuel demand. The first heat was delivered in St. Petersburg in 1924. Teploset Mosenergo was established in 1931 for managing the heat distribution in Moscow, although the heat deliveries had began already in 1928. This department of Mosenergo delivered 287 PJ heat during 2003. Mosteploenergo, another local distributor, supplied further 70-80 PJ. Together, these companies constitute the most extensive district heating system in the world. The second largest is the St. Petersburg system and the third is the Kiev system in Ukraine.

These early Soviet projects constitute the background for all district heating systems in the former planned economies in Central and Eastern Europe. The initiatives were based on national energy policies focused on reducing primary energy supply for electricity generation by using the CHP principle and a community responsibility for urban heating. The district heating systems were developed according to planning decrees and not based on competition with other commercial heating methods.

This short historical survey reveals that the district heating systems in EU15 and NMS10 have two different backgrounds, but they will share a common future, since the conditions on the whole European heat market will be more harmonised with respect to fuel prices, emission trading, and competition from other heating alternatives.

2.3 Current district heat sales

The deliveries of district heat for final consumption by customers during 1992 and 2003 and the corresponding growth rates are summarised in Table 1 for all 32 countries in the target area.

No district heat deliveries have been identified in the IEA Energy Balances for Cyprus, Malta, Spain, and Turkey. But some few systems have recently started in Spain (as in Barcelona) and 13 geothermal systems have been identified from other sources in Turkey. Some minor heat deliveries was identified in Ireland (0,1PJ) and Greece (1.0 PJ), where district heating systems are operating in Kozani, Ptolemais, Amyntaio, and Megalopoli. These 6 countries are not further considered in the following three chapters of this report.

Total district heat sales were 1950 PJ during 2003 according to Table 1 and the definition is that all heat reported sold by (IEA, 2005) is considered to be district heat. Further 69 PJ was identified as own use in some countries, giving a total district heat demand of 2019 PJ. Total amount of district heat generated was 2302 PJ, giving total distribution heat losses of 283 PJ in district heating networks. These heat losses are inevitable from the 142000 km of trench length of pipes, mainly buried into the ground. The relative heat loss was 12,3% for the whole target area. But the magnitude of the relative heat loss varies by region and country. The highest heat losses appeared in the ACC4 (17,4%) and the EFTA3 (16,5%) countries, while the lowest losses was found in the EU15 countries (10,0%). The average heat loss in the NMS10 countries was 14,4%.

The magnitude of the relative distribution loss depends on four parameters: degree of pipe insulation, the pipe diameter, the temperature level, and linear heat density (heat sales per meter of trench length). In general, the degree of insulation is lower in NMS10, ACC4 and old EU15 systems, mainly explaining the identified variation of heat losses between the regions. However, the linear heat densities are higher in large cities compared to towns and villages. Hence, the large compact city district heating systems have lower heat losses than sparse systems in towns and villages.

The implication of a heat distribution loss in a district heating systems can also be discussed. It is obvious that if a district heating system is based on heat only boiler generation from fossil primary energy supply, the heat distribution loss increase both primary energy supply and carbon dioxide emissions. But that kind of a district heating system is not long term viable according to the fundamental idea of district heating. More viable systems are based on heat recycled or obtained from the five strategic resources presented in section 2.1. In these viable cases, the heat distribution loss increases neither the primary energy supply nor the carbon dioxide emissions. A heat loss can only be lost once and never lost twice with respect to primary energy supply. In the best of cases, a 100% heat loss is retrieved into a district heating system and 10% is lost again in the distribution heat loss, giving the possibility of supplying a 90% heat loss to the heat market. This is in fact a factor 10 change with respect to heat loss reduction.

Average annual growth rates are also presented in Table 1 for the last 11 years. High growth rates in Portugal (20%), Netherlands (16%), Belgium (8%), and Finland (6%) can be explained by more industrial heat deliveries from CHP plants. High growth rates for ordinary district heating systems can be found in Italy (8%), Norway (7%), and Austria (6%). Lower growth rates in Sweden and Denmark (2% each) are a consequence of the fact that district heating has a high market share in these countries. Germany and France are examples of old, but unmature district heating countries having unchanged heat sales during the last 11 years. The highest decreases appeared in Romania (-11%), Bulgaria (-10%), Estonia (-9%), Latvia (-7%), Lithuania (-6%), and Poland (-6%). The main explanation for these high annual decreases is the lost deliveries to industrial heat consumers. The decrease to residential and other consumers have been limited. The district heating systems in Hungary, Croatia, and Slovenia seems to have managed the transition to market economy very well with almost unchanged heat sales during the last 11 years.

The heat deliveries in the whole target area decreased in average with 2 % per year, but only with 1% in EU25 area. The expansion was 3% per year in the EU15 countries and 2% in the EFTA3 countries, while the decrease in the NMS10 countries was 5% per year. Two thirds of the EU25 district heat deliveries appear now in EU15 and one third in NMS10. But since much more people live in EU15, the relative use of district heat is still higher in NMS10.

Table 1. District heat deliveries in the target area countries during 1992 and 2003. Source: (IEA,2005) with own corrections for France, Italy, Latvia, Iceland, and Switzerland. Corrections are bolded.

Country	Label	Group	Heat sales 1992, PJ	Heat sales 2003, PJ	Annual average growth rate between 1992 and 2003
Austria	AT	EU15	29	54	6%
Belgium	BE	EU15	10	21	8%
Denmark	DK	EU15	84	103	2%
Finland	FI	EU15	85	159	6%
France	FR	EU15	**90**	**86**	0%
Germany	DE	EU15	356	354	0%
Greece	GR	EU15		1	
Ireland	IE	EU15		0,1	
Italy	IT	EU15	**7**	**17**	8%
Luxembourg	LU	EU15		2	
Netherlands	NL	EU15	19	98	16%
Portugal	PT	EU15	1	9	20%
Spain	ES	EU15			
Sweden	SE	EU15	135	170	2%
United Kingdom	UK	EU15		75	
Cyprus	CY	NMS10			
Czech Republic	CZ	NMS10	**151**	111	-3%
Estonia	EE	NMS10	59	21	-9%
Hungary	HU	NMS10	61	57	-1%
Latvia	LV	NMS10	**62**	27	-7%
Lithuania	LT	NMS10	66	33	-6%
Malta	MT	NMS10			
Poland	PL	NMS10	607	309	-6%
Slovak Republic	SK	NMS10	28	43	4%
Slovenia	SI	NMS10	8	8	0%
Bulgaria	BG	ACC4	125	38	-10%
Croatia	HR	ACC4	10	11	0%
Romania	RO	ACC4	372	101	-11%
Turkey	TR	ACC4			
Iceland	IS	EFTA3	**19**	**18**	0%
Norway	NO	EFTA3	4	8	7%
Switzerland	CH	EFTA3	12	**15**	2%
			2400	1950	-2%

EU15	816	1150	3%
NMS10	1042	609	-5%
EU25	*1858*	*1759*	*0%*
ACC4	508	150	-10%
EFTA3	35	41	2%
	2400	1950	-2%

Own use in some countries	69
Total demand	2019
Distribution heat losses	283
Total heat generated	2302

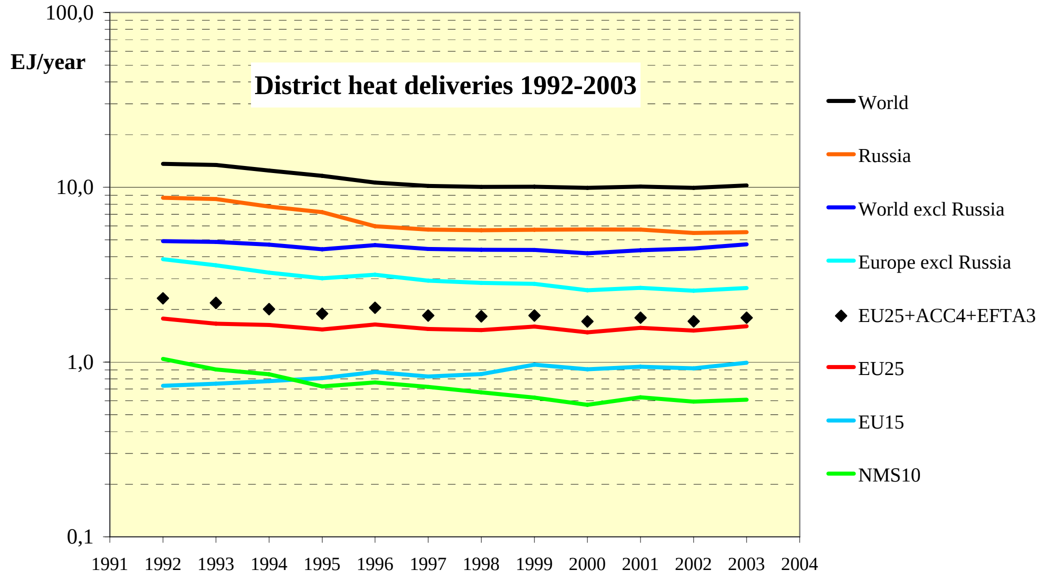


Figure 2. Development of district heat delivered between 1992 and 2003 for various parts of the world. Source: (IEA, 2005) with own corrections for some European countries.

Similar trends can be identified for district heating systems outside the target area of 32 European countries. This is illustrated in Figure 2, showing district heat sales in various parts in the world between 1992 and 2003. On world level, district heat sales have decreased since 1992. The main reason for this situation is the reduction of the Russian heat deliveries between 1992 and 1996, due to the loss of industrial heat customers and the reduction of end use heat demands in buildings. But still a majority of all world heat deliveries appear in Russia. For other former Soviet Union countries, as Belarus, Ukraine, Moldova, the situation has been similar to the Russian situation. In most of these countries, heat deliveries have reached a stable level without further expected reductions.

Outside Europe and Russia, district heat sales have had an annual growth rate of about 5% per year. This depends mainly on the strong expansion of district heating in China and Korea. The Korean average annual growth rate was 24% during the last 11 years. The corresponding growth rate was 7% for China. However, industrial heat deliveries constitute 72% of all Chinese deliveries. The IEA Energy Balances report a slight decrease for district heat deliveries in the United States. However, only a minor fraction of the true district heat deliveries in the USA are reported by IEA. Major district heating systems in university campus areas and at military sites are managed by the same body responsible for the buildings, not fulfilling the IEA definition of heat sold.

Within the EU25, the total district heat deliveries have almost been unchanged. But the EU15 countries have had an expansion of the same magnitude as the reduction in the NMS10 countries.

The main conclusion is then that Korea, China and EU15 expanded the district heating systems between 1992 and 2003, while deliveries decreased in the former planned economies in the former Soviet Union and in Central and Eastern Europe.

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3 Fuel and heat supply during 2003

3.1 *Fuel and heat input*

The fuel, heat and electricity supply for district heat generation during 2003 is summarised in Table 2 for the whole target area. Own corrections have been made with respect to missing information or minor deviations in the IEA Energy Balances for Denmark (solar thermal), France (all supply), Germany (surplus heat), Sweden (combustion renewables, electricity, and heat), Italy (all supply), Iceland (geothermal), and Switzerland (natural gas and electricity). Fuel volumes for CHP plants are allocated by IEA according to the energy allocation principle. Hereby, electricity and heat generation are assumed to have the same conversion efficiency when CHP plants are used. This allocation principle allocates the whole benefit of CHP to the electricity side.

Fossil fuels as coal, oil and natural gas dominates the energy supply for district heat by a 83% share, reflecting that European district heating systems in general have the same dependency of fossil fuels as the rest of the European energy system. But large variations appear among the 26 countries. This is evident from Figure 3, where the national compositions of energy supply are presented:

- Coal dominates in Poland, Czech republic, Slovenia, and Bulgaria.
- Natural gas dominates the energy supply for district heat in many EU15, NMS10, and ACC4 countries.
- Heat from nuclear reactors is used in limited amounts in five countries.
- Geothermal heat dominates in Iceland, but significant contributions exist also in France and Italy.
- Solar heat is only reported by IEA from Denmark, but installations appear also in other countries.
- Combustible renewables (mainly solid biomass) have considerable shares in Sweden, Austria, Denmark, Finland, and the three Baltic States.
- Waste incineration dominates in Norway and Switzerland and significant contributions appear in most EU15 countries.
- Some electricity is used in Sweden, Norway, and Iceland as input to large electric boilers and heat pumps.
- Heat considers here recycling of industrial surplus heat and heat obtained from the cold side of large heat pumps mainly in Sweden, which also has the most diversified energy supply of all countries.

The share of heat from CHP plants in total heat generated was 68,3 % during 2003 in the target area according to Table 2. This magnitude is based on the current routines for international energy statistics for CHP plants. These are summarised by (OECD/IEA/Eurostat, 2005) as: "*A CHP plant is one that contains a CHP generating unit. If the plant contains, in addition, an electricity-only or a heat-only unit, the plant should still be considered a CHP plant unless statistics of fuel use and output are available for the individual units. In this case, reporting should be on the basis of the units rather than the plant.*" The implication of this statement is that international energy statistics for CHP plants is a mixture of pure CHP operation together with operation of some electricity-only and heat-only units. Hence, the 68,3% CHP heat share is for sure an overestimation, since the contribution of eventual heat-only units located in some plants are not known. Eurostat is currently developing these CHP reporting routines, but has not yet reached the stage of fully transparent CHP statistics for Europe. Eurostat have managed to separate electricity generation in condensing and cogeneration modes, but fuel supply is still unallocated between the two different operation modes. The consequences of this situation will be further discussed in section 4.1.1.

National shares of CHP heat in heat generated are presented in Figure 4. National CHP shares vary from 20-30% (France, Sweden, Iceland, and Norway) up to 100 % (Belgium, Luxembourg, Netherlands, Portugal, and United Kingdom). These CHP shares are also further discussed in section 4.1.1.

The renewable share in heat generated was 14,1 % during 2003 in the target area according to Table 2. The renewable share is here defined as the sum of the shares for geothermal heat, solar heat, combustible renewables, and all waste. Hence, this definition neglects the fossil part of waste. On the other hand, recycled surplus heat from industrial processes is not included. The corresponding share for all primary energy supply in the target area was 7,3%. So district heating systems are in general more renewable than the whole energy system. This situation can partly be explained by high national taxes for fossil fuels in some countries and partly by the use of waste incineration as a major driving forces for district heating in some other countries.

The European Union has a target of 12% renewables in all primary energy supply for 2010. This target was expressed in the Renewable White Paper (European Commission, 1997). Hence, the European district heating systems already fulfils the European target for 2010 as a group. In (EREC, 2004), a proposal is made for a 20% renewable target for 2020.

Figure 5 shows how the renewable share varies in different national district heating sectors. The highest shares appear in Iceland (97%), Norway (63%), Switzerland (61%) and Sweden (53%). Further four countries fulfil the new EREC 20% renewable target: Denmark (33%), Austria (29%), Finland (23%), and France (22%). In general, EU15 (20%) and EFTA3 (76%) countries have much higher renewable shares than NMS10 (3%) and ACC4 (0%) countries.

It is obvious that some national district heating sectors have been very successful in achieving high renewable shares in district heat generated. It should be possible to transfer these experiences to other countries within the European district heating community by a large dissemination project.

The combined effect of the use of renewables, heat recycled from fossil and nuclear CHP plants, from industrial processes, and by large heat pumps is presented country by country in Figure 6. The figure shows how well each national district heating sector fulfils the fundamental idea of district heating. In the whole target area, the combined renewable and recycled share was 78 %. Again, EU15 (86%) and EFTA3 (92%) countries have much higher combined renewable and recycled heat shares than NMS10 (64%) and ACC4 (75%) countries. This means that more than one third of the district heat generated in NMS10 countries is based on heat only generation of fossil fuels. The corresponding fraction is one fourth in the ACC4 countries.

Table 2. Energy supply for district heat generated during 2003 for the whole target area of EU25+ACC4+EFTA3. Source: IEA Energy Balances with own corrections for Denmark, France, Germany, Sweden, Italy, Iceland, and Switzerland.

Energy supply	Heat generated , PJ	Share
Coal and Coal Products	827	35,9%
Petroleum Products	160	7,0%
Natural Gas	928	40,3%
Nuclear	6	0,3%
Geothermal	26	1,1%
Solar Thermal	0,05	0,002%
Combustible renewables	165	7,1%
Waste	135	5,9%
Electricity	13	0,6%
Heat	42	1,8%
Total	2302	
CHP share	1573	68,3%
Renewable share	325	14,1%

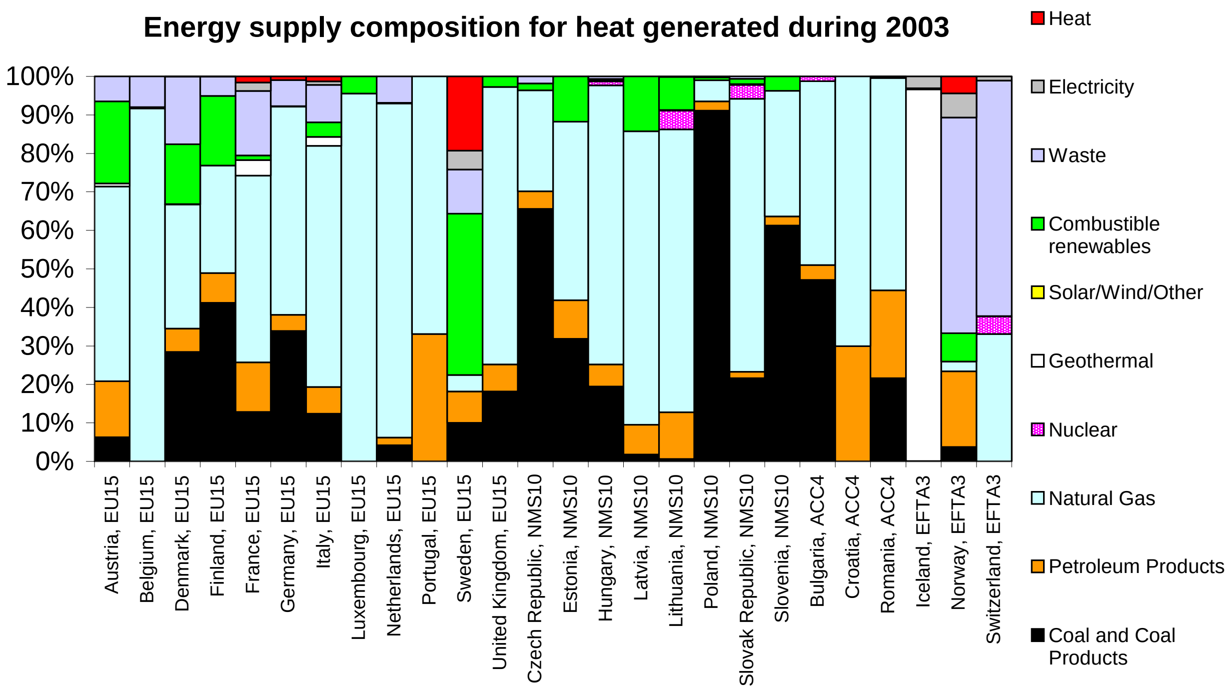

Figure 3. The composition for the energy supply in district heat generation during 2003. When CHP plants were used, the energy allocation principle was used (assuming equal conversion efficiency for power and heat). 6 countries omitted due to no or very low district heat supply (Cyprus, Greece, Ireland, Malta, Spain, and Turkey). Source: IEA Energy Balances with own corrections.

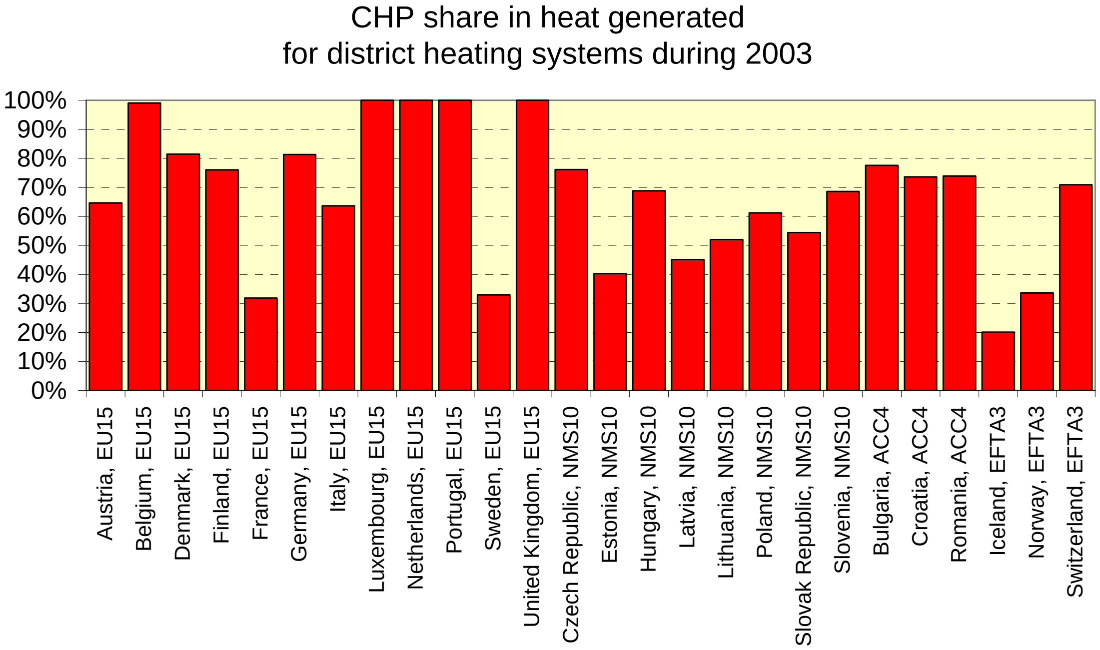

Figure 4. Share of CHP heat in district heat generation during 2003. 6 countries omitted due to no or very low district heat supply (Cyprus, Greece, Ireland, Malta, Spain, and Turkey). Source: IEA Energy Balances with own corrections.

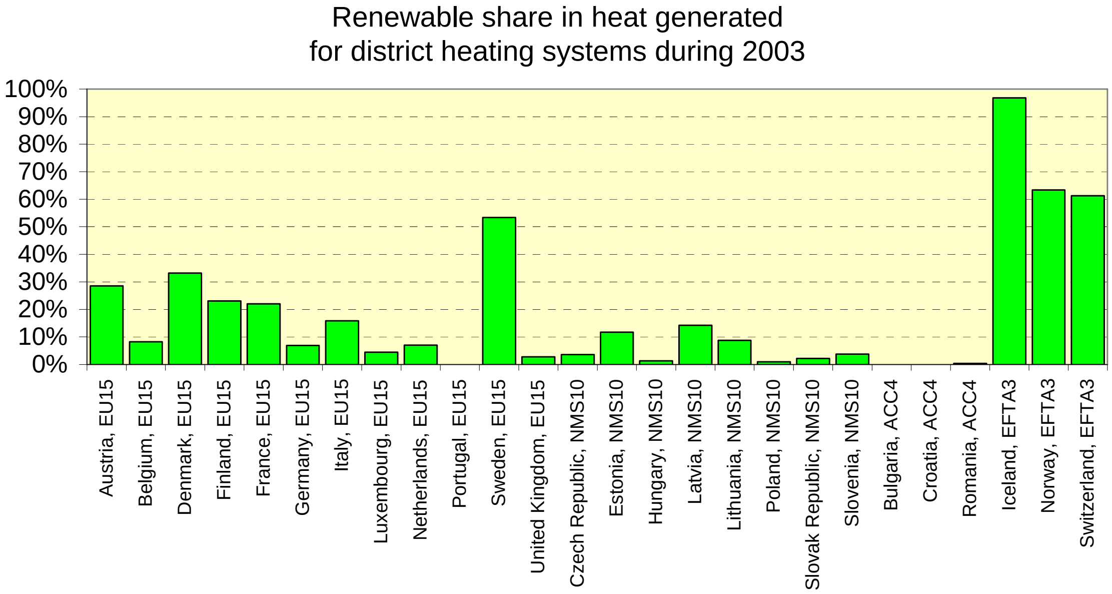

Figure 5. Renewable share in heat generated during 2003. 6 countries omitted due to no or very low district heat supply (Cyprus, Greece, Ireland, Malta, Spain, and Turkey). Source: IEA Energy Balances with own corrections. Renewables are here defined as the sum of shares for geothermal, solar, combustible renewables, and waste.

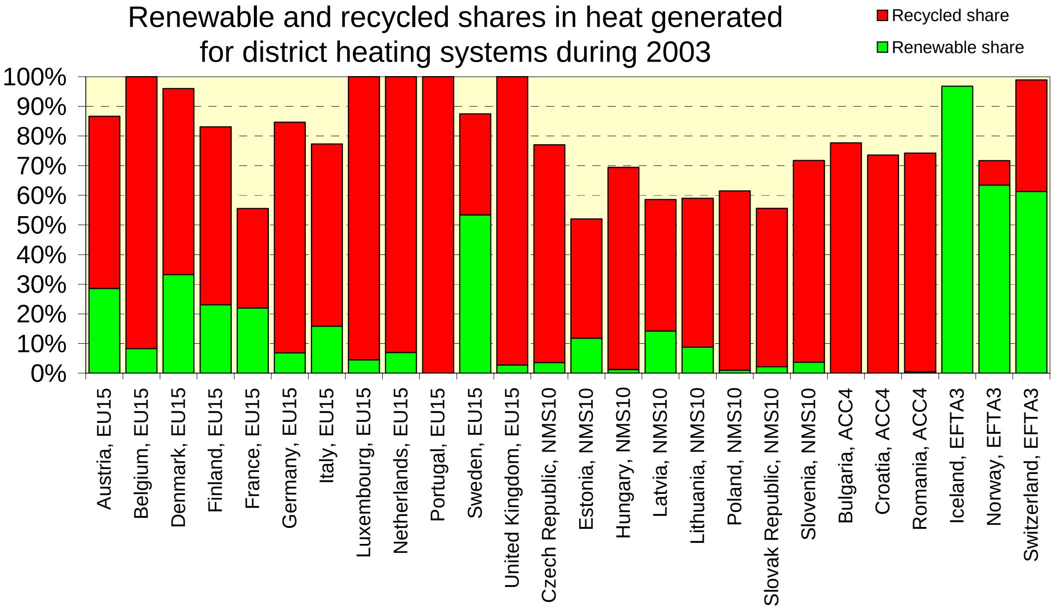

Figure 6. Renewable and recycled shares in heat generated during 2003. 6 countries omitted due to no or very low district heat supply (Cyprus, Greece, Ireland, Malta, Spain, and Turkey). Source: IEA Energy Balances with own corrections. Recycled heat is here defined as the sum of heat from fossil and nuclear CHP together with surplus heat recovered from industrial processes and with heat pumps.

3.2 Corresponding carbon dioxide emissions

The actual carbon dioxide emissions for district heat generated from CHP and heat-only plants cannot be presented directly from available energy statistics. International CHP statistics (both by IEA and Eurostat) do not separate fuel supply from condensing and cogeneration modes in CHP plants. Only the total CHP fuel supply is available. Neither can this information be obtained from the carbon dioxide emission statistics in (IEA, 2005), since this database is based on the same unallocated CHP fuel supply as the IEA Energy Balances.

Instead, the carbon dioxide emissions have been estimated from volumes of heat generated by fuel allocated in the IEA Energy Balances, standard conversion efficiencies, and the specific carbon dioxide emission by fuel. The same standard conversion efficiencies as assumed for industries in table 2 in the Ecoheatcool WP1 report was used. These conversion efficiencies were 85% for coal, 85% for oil, and 90% for natural gas. The specific carbon dioxide emission factors of 93 g/MJ coal, 75 g/MJ oil, and 56 g/MJ natural gas were used in the estimation.

The national estimations of carbon dioxide emissions from district heat delivered to final consumers are presented in Figure 7. The emissions per MJ heat are low in Iceland and Sweden due to high shares of renewables. Also in Norway and Switzerland, the emissions are low, but due to high share of waste incinerated. The emissions are also lower in Austria compared to other countries due to significant use of biomass. The highest emissions appear in Bulgaria, Czech Republic, Poland, and Romania, due to high fractions of coal used and high distribution heat losses. The average for the whole target area was 83 g per MJ heat sold, based on the heat delivered of 1950 PJ and the emissions of 162 million tons. The corresponding emissions are 66 g/MJ heat when natural gas is used in local boilers and 96 g/MJ for boilers using oil.

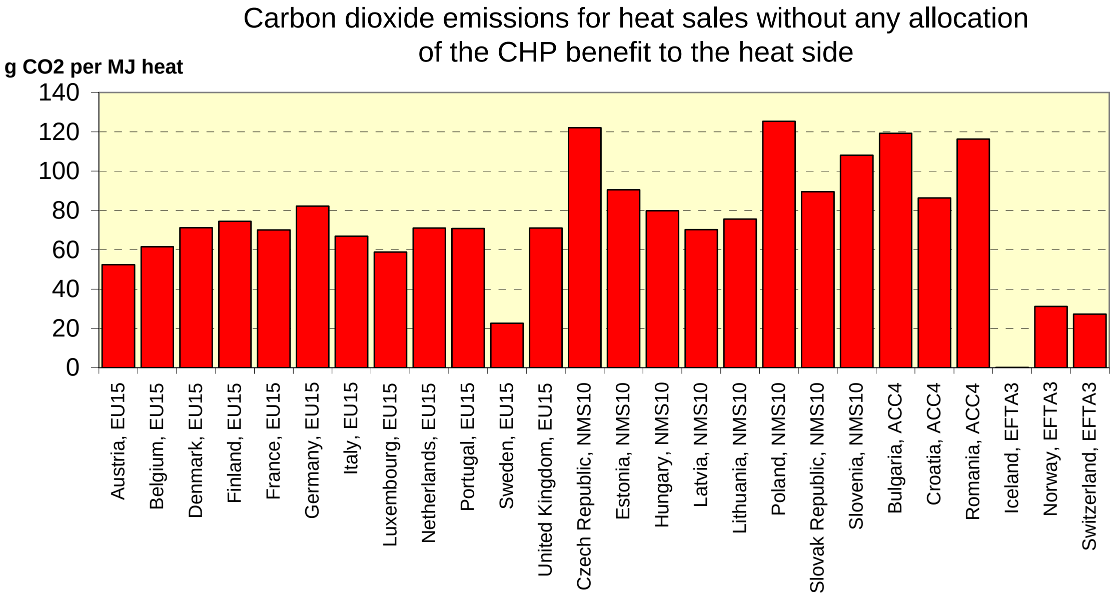

Figure 7. Specific carbon dioxide emissions during 2003 for district heat delivered to final customers. Source: Own estimations from volumes of district heat generated reported in the IEA Energy Balances.

In Figure 7, no allocation of the CHP benefit has been made to the heat side. This benefit is defined as the difference between the higher carbon dioxide emissions from alternative electricity generation and the lower carbon dioxide emissions from the electricity generated in the CHP plant. Figure 7 presumes that the whole CHP benefit with respect to carbon dioxide emissions is allocated to the electricity side in the CHP plants. Consequently, that means that Figure 7 presumes that the fossil fuel used has been converted in heat only boilers and not at all in CHP plants. If some part of the CHP benefit is allocated to the heat side, the emissions in Figure 7 will be lower. One common allocation method is to apply the overall emission reduction percentage for both the electricity and the heat sides. If the whole CHP benefit is allocated to the heat side, the emissions for heat generated will be substantially lower, sometimes below zero, especially when the power-to-heat ratio is high.

These allocations of carbon dioxide emissions would have been possible to perform, if national volumes of electricity generated in cogeneration modes in CHP plants connected to district heating systems would have been available in international energy statistics. This approach has been used in section 7.3 where the overall benefits of the European district heating systems are estimated. The carbon dioxide emissions without allocation of the CHP benefit were 80 g/MJ for 2003 when also own heat use was included. When the CHP electricity is valued according to replacing gas combined cycle plants, the corresponding carbon dioxide emissions for the heat was 73 g/MJ. A further lower emission rate of 22 g/MJ is obtained if coal condensing is regarded as avoided electricity generation. This example shows that allocation of the CHP benefit is essential when carbon dioxide emissions are estimated for heat sold from district heating systems.

3.3 National Primary Resource Factors

The method of primary resource factors was presented in (Ecoheatcool, 2005). The primary resource factor (PRF) is the ratio between the total consumption on non-regenerative energy and the total heat consumption for a building. The benefit of CHP is allocated to the heat consumption by using a negative PRF of 2,5 for electricity generated in CHP plants, reflecting the low conversion efficiency for marginal thermal power generation. A PRF over 1 shows that only fossil fuels are used for the heat demand, while a PRF of zero reveals that no fossil fuels are used. A negative PRF shows that the use of fossil fuels decrease with the heat use.

Actual national PRF cannot be estimated from the IEA energy balances, since fuel supply and electricity generated in CHP plants are not properly allocated between condensing and cogeneration modes. However, some national PRF are available from national sources: Italy (0,95), Finland (0,60), and Sweden (0,25). The PRF average for the target area is later estimated to 0,80 in section 7.4.

These estimations show that the variation of PRF is large between countries and that the use of fossil fuels are still high in the European district heating systems.

3.4 References

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4 Strategic Heat Source Options

4.1 Combined heat and power generation

Throughout the world history of district heating, CHP has been the main driving force for district heating. Most European district heating systems have been initiated in order to exploit these inevitable and large heat losses from thermal power generation. This driving force was very strong 100 years ago, when the conversion efficiency for electricity-only generation was very low, below 10%. Today, when the world record for the best power cycles is reaching the conversion efficiency level of 60%, the driving force is of course lower. But the existing power stations are not as efficient as best available technology. The average conversion efficiency for electricity-only generation in the target area during 2003 was 38% when coal was used as fuel, 43% for oil, and 55% for natural gas (estimations based on IEA Energy Balances). These existing power stations are also centralised, therefore transmission and distribution electricity losses must be subtracted before reaching the final customers. CHP plants are located more near the final consumption centres, since the heat distribution pipes need to be short. These decentralised CHP plants belong to the expression of "distributed generation", having the advantage of lower electricity distribution losses corresponding to about 3-4 % of all electricity use.

4.1.1 Current heat use from CHP

As discussed earlier in section 3.1, international energy statistics concerning CHP plants are not perfect. In Table 3, CHP statistics have been summarised for the target area during 2003 from the IEA Energy Balances and for EU25 during 2002 from the Eurostat. This is the latest available year from the special Eurostat CHP statistics (Eurostat, 2001, 2003 & 2006).

Table 3. Current statistics concerning electricity and heat generation in CHP plants for the whole target area concerning IEA Energy Balances and for EU25 concerning Eurostat information.

	Public CHP plants					Autoproducer plants				
			Fuel supply					Fuel supply		
IEA Energy Balances, the whole target area for 2003, PJ	Elect.Output-main activity producer CHP plants	Heat Output-main activity producer CHP plants	Main Activity Producer CHP Plants	Total conversion efficiency	Power-to-heat ratio	Elect.Output-autoproducer CHP plants	Heat Output-autoproducer CHP plants	Autoproducer CHP Plants	Total conversion efficiency	Power-to-heat ratio
Coal and Coal Prod	857	587	2766	52%	1,46	72	57	224	58%	1,27
Petroleum Products	83	80	387	42%	1,03	133	10	255	56%	13,72
Natural Gas	499	609	1944	57%	0,82	296	20	743	42%	14,69
Combustible renew	25	70	130	73%	0,36	58	26	132	64%	2,25
Waste	17	71	132	67%	0,24	24	41	124	52%	0,59
Total	1481	1418	5358	**54%**	**1,04**	583	154	1476	**50%**	**3,79**

Eurostat, EU25 for 2002

Total	587	1192	3486	**51%**	**0,49**	490	1653	3001	**71%**	**0,30**

Summary for electricity in TWh	Public CHP plants	Autoproducer plants	Total
IEA 2003	411	162	573
Eurostat 2002	163	136	299

Estimation of electricty generated in CHP plants connected to distric heating	IEA Heat output, PJ	Eurostat power-to-heat ratio	Estimated electricity output, PJ	Estimated electricity output, TWh
Public CHP plants	1418	0,49	699	194
Autoproducer plants	154	0,30	46	13
Total	1571	0,47	744	207

The following conclusions can be drawn from a short analysis of Table 3:

- It is obvious that large volumes of electricity-only generation are included in the statistics, since the conversion efficiencies are low and the power-to-heat ratios are high. This is valid for both public and autoproducer plants in the IEA statistics and for public plants in the Eurostat statistics
- The share of heat from autoproducer plants in the IEA statistics is low since own use in industrial plants is moved to industrial final consumption. This total heat volume should correspond to the heat delivered to district heating systems from industrial CHP plants.
- The total IEA heat volume should be probable, although doubt about some heat-only generation inside CHP plants still appears.
- It is also obvious that Eurostat have succeeded to remove electricity-only generation from the CHP statistics, but since the conversion efficiency is low for public plants, the corresponding fuel supplies have not been fully removed. The conversion efficiency for public CHP plants was only 51 % during 2002 according to Table 3.

The implications from these conclusions are:

- It is not possible to obtain actual power generation from CHP plants connected to district heating systems from the international CHP statistics, neither by country nor by region. Neither is this information available from (Euroheat & Power, 2005).
- It is not possible to estimate the actual carbon dioxide emissions from true CHP generation since not all fuel supply from electricity-only generation has been removed from the CHP statistics.

Since it seems that both the Eurostat power-to-heat ratios and the IEA CHP volumes for district heat generated are probable, the overall power generation from CHP plants connected to district heating can be estimated for the whole target area, but not for individual countries or regions. This estimation has been performed in the lower right corner of Table 3. The estimation ends up with 744 PJ or 207 TWh during 2003. This estimation will be later used in chapter 7, when the overall benefits of district heating will be estimated for the whole target area.

The European Commission has officially focused on CHP since the promotion CHP communication in 1997. The target of doubling the 1994 EU15 CHP share of 9% of all power generation to 18 % until 2010 was seen as realistically achievable. This share was 9,9% for EU25 in 2002 according to (Eurostat, 2006), so little progress has been made since 1997. The CHP directive followed the 1997 CHP communication in 2004.

Since the European target for CHP is set on the electrical side, much effort is made in many countries for increasing the electricity output without increasing heat generation. The CHP plants become more efficient with higher power-to-heat-ratios, but it gives low driving forces for expanding the district heating systems.

Many countries also apply CHP remuneration as feed-in tariffs for new and small units. The main explanation for this market aid is that the European electricity market was liberalised in 1999 before the benefits of CHP were fully valued by the energy market. Today, with the European trading system for carbon dioxide emission quotas and many national certificate systems in operation, the energy market contains some more internalisation of the CHP benefits. However, these internalisation measures do not currently fully recognise the CHP benefits, which will be discussed later in chapter 5.

The current use of CHP heat generated by capita for district heating is presented in Figure 8. Finland and Denmark are here the European champions. Many countries have low values since they are lacking district heating systems as heat sinks for CHP plants.

In Figure 9, the national combinations of CHP share in district heat generated and all district heat generated by capita are presented for the target area. It is obvious that it should be possible to increase the CHP share in Sweden, the three Baltic countries, Slovak Republic, and Poland. The market shares for district heating are high in these countries, but the CHP shares in district heat generated are low. Hence, existing district heating systems are waiting to be exploited by CHP plants in these countries. Values from Germany, Czech Republic, Denmark, and Finland shows that it is possible to have a national average CHP share in district heating systems at the level of 80%.

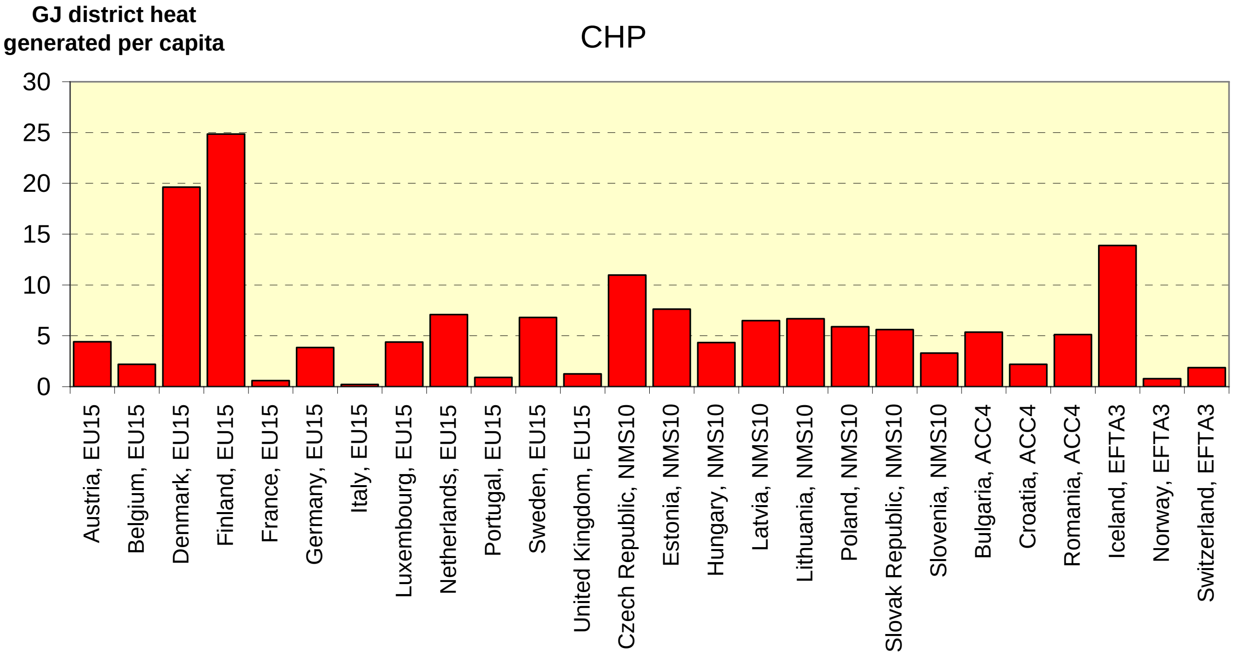

Figure 8. CHP heat generated for district heating per capita during 2003.

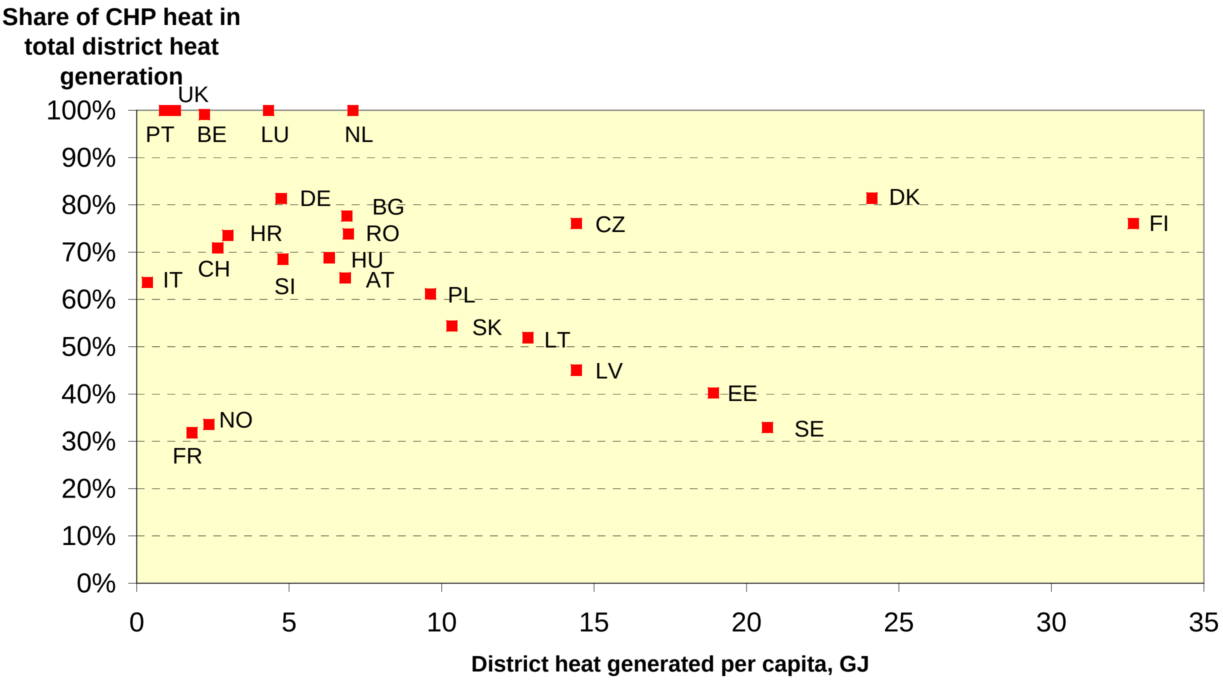

Figure 9. National combinations of district heat generated per capita and the CHP share in total heat generation during 2003.

4.1.2 Current heat losses from thermal power generation

The high magnitude of current heat losses from all thermal power generation in the target area during 2003 is presented in Figure 10. The total fuel supply was 31,8 EJ and 12,7 EJ of electricity was generated. This gave the residual heat volume of 19,2 EJ, of which 1,6 EJ was recycled in district heating systems by public CHP plants and further 1,8 EJ was directly recycled for heat demands in industrial sites in autoproducer CHP plants. This gave the final heat loss from all electricity generation of 15,8 EJ. This amount of final heat losses after heat recycling represents 19 % of all primary energy supply in the target area.

The final heat losses are associated in proportion of 50 % to fossil fuels. Therefore, the final heat losses are associated to 671 million tons of carbon dioxide emissions, corresponding to 15 % of all carbon dioxide emissions from fuel combustion in the target area.

The main overall purpose with a new CHP plant is to reduce the final heat losses from electricity generation. At a given demand of electricity on the market, a new CHP plant will replace electricity generated in an electricity-only power plant, probably using coal with low conversion efficiency. Other power plants will not reduce their electricity generation, because they have lower marginal costs. Also, the amount of electricity generated in hydropower and wind power plants do not vary by consumption, but with rainfalls and winds. Hence, new CHP plants never replace electricity from hydro-, wind or nuclear power plants.

Hereby, the corresponding heat losses from that reversing thermal power plant in condensing mode will also decrease when the electricity generation decrease. An analogy would be to say that the condensing heat losses are removed and transferred from the reversing thermal power plant and added to the new CHP plant. A common non-professional view is that you should not introduce a new heat loss from a new CHP plant for supply to a district heating system. The discussion above shows that this view is a clear misunderstanding. No new heat losses are introduced when a new CHP plants is inaugurated. Instead, the overall final heat loss from electricity generation is often reduced, since the new CHP plant often has higher electricity efficiency than the reversing condensing power plant.

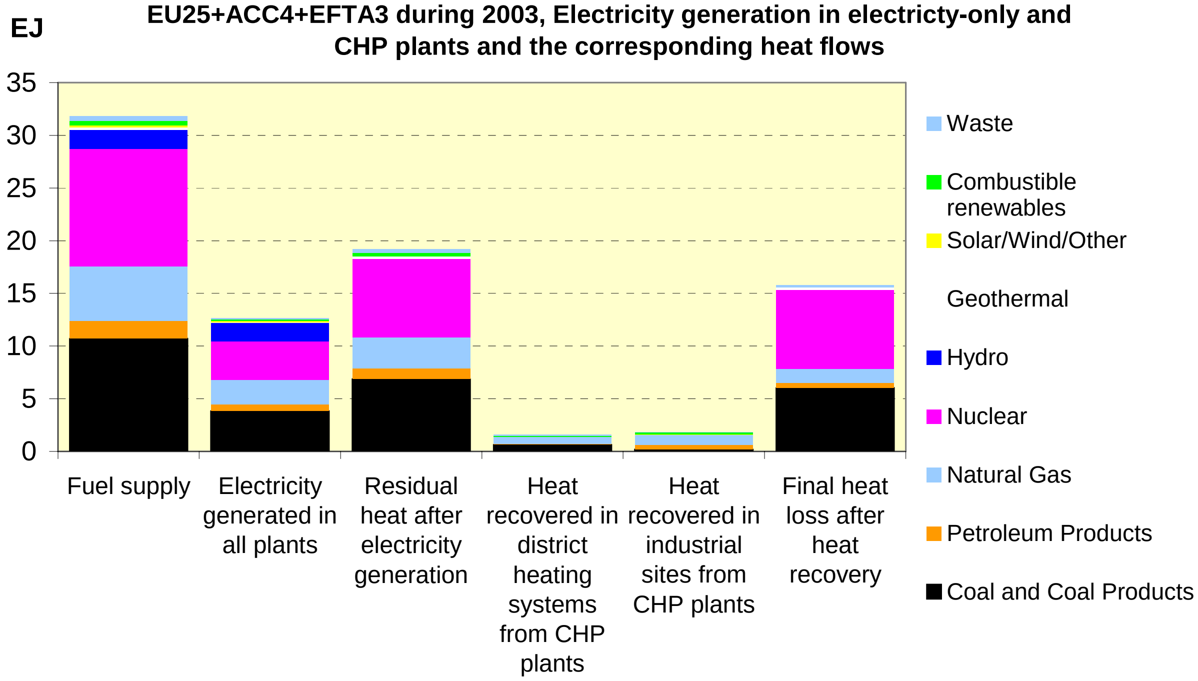

Figure 10. Summary of energy flows for electricity generation in the target area during 2003.

For heat generated from CHP plants, two stages of future possibilities appear:

- The CHP share should increase from the current share of 68 % to about 80 %
- The current overall average power-to-heat ratio should increase from the current level of 0,33. An increase with 40 % would give a new average power-heat-ratio of 0,46.

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4.2 *Waste-to-energy*

4.2.1 Current heat use from waste incineration

The current use of heat from waste incineration in waste-to-energy plants in European district heating systems is presented in Figure 11. The highest per capita values are found in Denmark, Sweden, Finland, Switzerland, and Norway. However, Finland has very few conventional waste-to-energy plants and the 2003 use of waste referred to co-firing of industrial wood waste in CHP plants and refuse derived fuel (RDF) in several small units. Waste incineration appears also in other EU15 countries, but to a lower extent, with respect to district heat generation per capita. Almost no waste incineration for district heat generation appears in NMS10 and ACC4.

Switzerland and Norway is examples of countries with small district heating sectors, but existing systems use waste-to-energy plants to a large extent. This fact is also visible in Figure 3. In these two countries, hydropower has for long time dominated the national power balances, giving almost no market space for CHP. A more integrated European power market can change these old patterns.

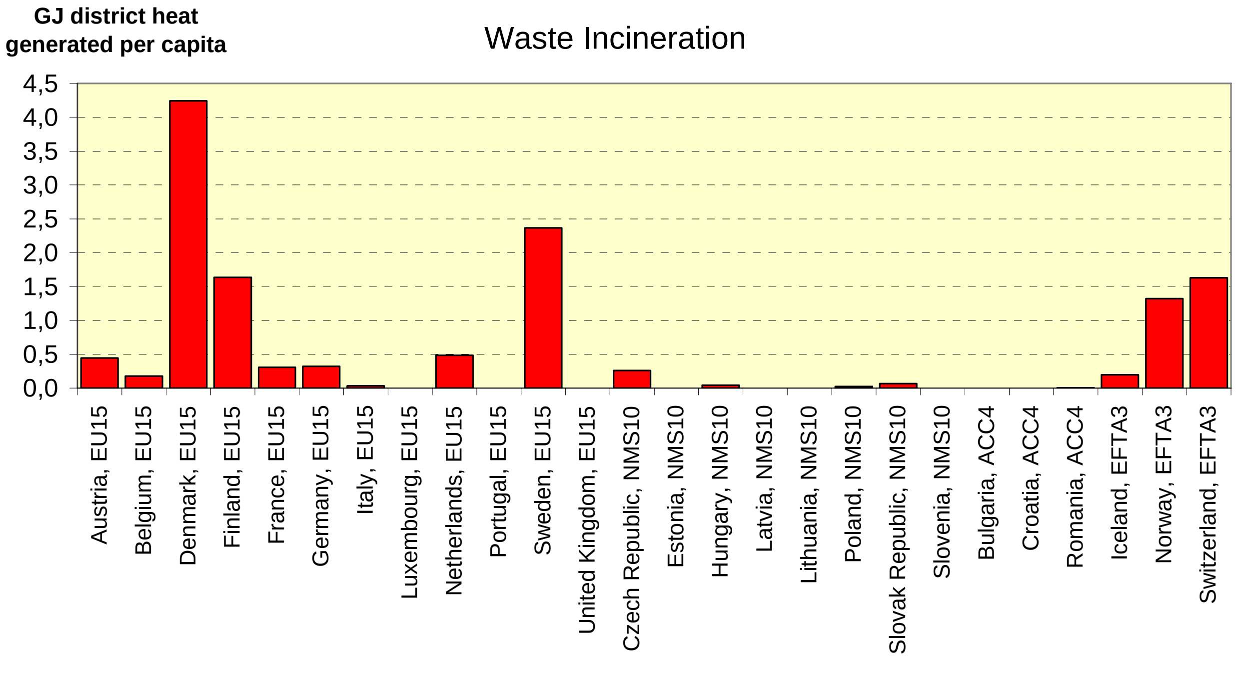

Figure 11. District heat generated per capita from waste to energy plants during 2003. Source: IEA energy balances.

4.2.2 Current waste management

In the 2005 proposal for a renewed waste framework directive (European Commission, 2005), the priorities with respect to waste management are expressed as: "Member States are to take measures, as a matter of priority, for the prevention or reduction of waste production and its harmfulness and, secondly, for the recovery of waste by means of re-use, recycling and other recovery operations". Hence, waste incineration belongs to the second step in the waste hierarchy:

1. Reduce waste by waste prevention
2. Reuse the product, recycle the material (including composting), or recover heat and electricity by waste incineration
3. Disposal in a landfill

Waste incineration is then primarily an alternative to landfill disposal and should not be seen as a competitor to reusing and recycling. Actually, recycling and energy recovery are complementary options to divert waste from landfills.

According to the Eurostat online database, 279 millions tons of municipal waste was generated and collected in the whole target area during 2002 (omitting Luxembourg, Croatia, and Switzerland due to missing information). 82 million tons (29%) were reused and recycled, while 41 million tons (15%) went to waste incineration. The remaining 156 million tons (56%) were transported to landfills. The waste incineration part is still small compared to the landfill part. Hence, more waste-to-energy plants would contribute to less landfill disposals. Many countries support the transition from landfill disposal to reuse & recycle and waste incineration by landfill bans and taxes, (CEWEP, 2005). Some countries also apply incineration taxes in order to promote reuse & recycle at the expense of waste incineration.

However, the waste management practises varies among the target area countries, see Figure 12. Belgium, Denmark, France, Netherlands, Sweden, and Norway are good examples of countries having both high fractions of reuse & recycle and waste incineration. Some countries have neither waste incineration plants nor any organisation for reuse & recycle. But waste incineration becomes more common. Between 1995 and 2003, the average annual growth rate per capita was 4% in EU25.

According to the IEA Energy balances, the total calorific value of waste for incineration was 492 PJ in the target area during 2003. This corresponds to 49 million tons of waste, by assuming an average calorific value of 10 GJ/ton. CEWEP, the European organisation for Waste-to-Energy plants, reports at their website about a supply of 52,6 million tons of waste to 407 plants during 2003. The CEWEP figure verifies then the energy supply reported in the IEA Energy Balances. The municipal waste fraction in incineration can also be estimated to be about 80%. The remaining volumes came from industrial and hazardous waste.

A waste incineration plant is either built for CHP generation or separate generation of heat or electricity. Heat recycling from waste incineration is more common in countries with established district heating systems. Out of the 492 PJ calorific value supplied in 2003, 97 PJ (20%) came out as electricity and 135 PJ (27%) as heat. The overall total conversion efficiency became then only 47%, revealing that as much as 53 % was released as heat losses in flue gases, cooling waters and cooling towers. Most of these heat losses can easily be retrieved as heat, if appropriate heat sinks are available in the neighbourhood.

However, among the target area countries, the proportions of electricity, heat, and losses are very different, see Figure 13. High total conversion efficiencies are found in Denmark, Finland, Sweden, Czech Republic, and Norway. Some countries have low total conversion efficiencies, since only electricity is recovered in the waste incineration plants.

In some countries (Italy, Belgium, Switzerland, Netherlands, and France), the total heat losses from waste incineration have or have almost the same magnitude as the current volumes of heat generated in all national district heating systems, see Figure 14. These large volumes of surplus heat from waste incineration can be used to create new district heating systems. Using absorption chillers for cooling buildings during warm summer days can increase the heat demand during the non-heating season. Heat from the district heating systems (and the waste incineration plants) can then feed the absorption chillers.

In the past, waste incineration was a significant source of highly toxic dioxin emissions. These emissions appeared, when the incineration temperature was low and chloride compounds was present in the incineration. This environmental problem has been managed during the last 20 years and dioxin emissions from waste incineration are not significant any more compared to other sources, (BMU, 2005) and (RVF, 2005). All current emission limits are defined in the directive on the incineration of waste (European Parliament and Council, 2000). The directive became effective from 28 December 2002 for new plants and 28 December 2005 for old plants. Best available technology (BAT) for waste incineration is described in (EC DG JRC, 2005).

About 10% of the typical European municipal waste has a fossil content (plastics etc). This gives a typical fossil carbon dioxide emission of 25 gram per MJ in the waste. Further 65 grams are emitted per MJ from the renewable part of the waste. However, methane with a GWP factor of 23 will be emitted, if the same waste will be deposited in a landfill. If more than 30% of the energy content of the renewable part will be converted into methane in a landfill, the net fossil carbon dioxide emission from waste incineration will be negative. Hence, with respect to global warming, waste incineration is more sustainable than landfills.

For waste incineration, the following future possibility appear:

- Increase heat generated from waste incineration from 135 to 350 PJ/year at the current heat sales. This can firstly be achieved, by increasing the overall total conversion efficiency for waste incineration plants from the current 47% to about 70%, and secondly, by increasing the incinerated volume from the current 50 million tons of waste.

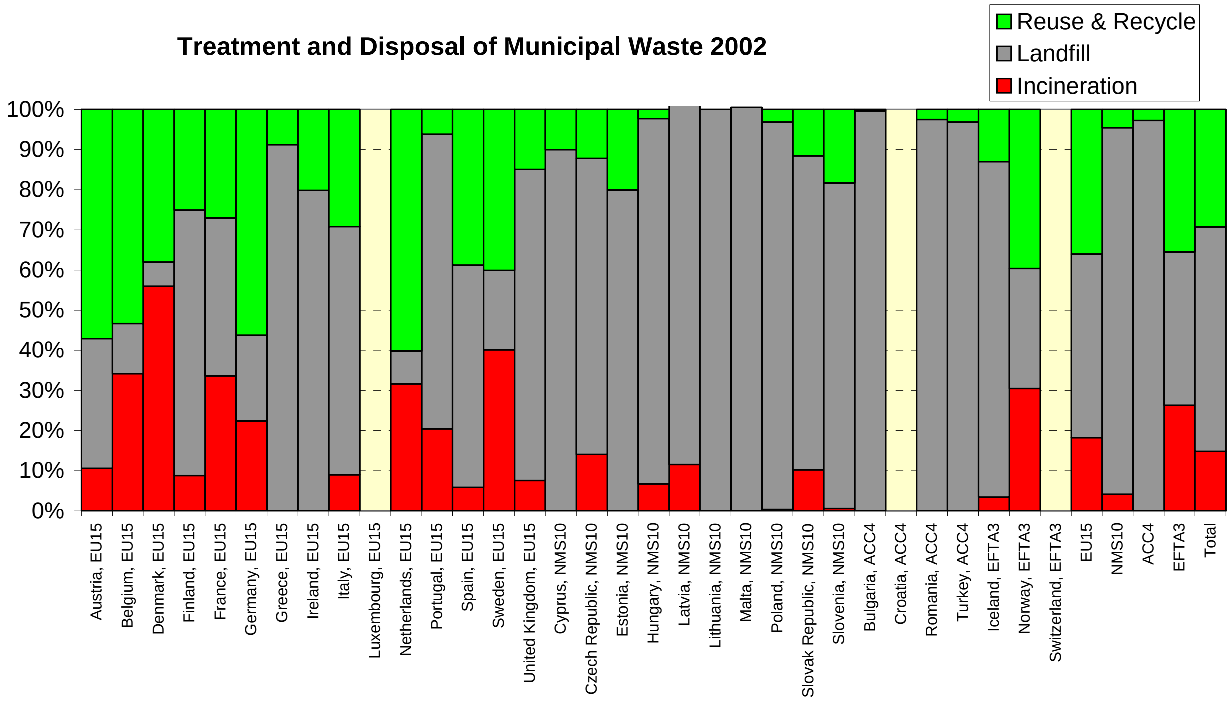

Figure 12. Current Waste Management for Municipal Waste during 2002 in the 29 of the 32 countries (missing information from Luxembourg, Croatia, and Switzerland). Source: Eurostat online database.

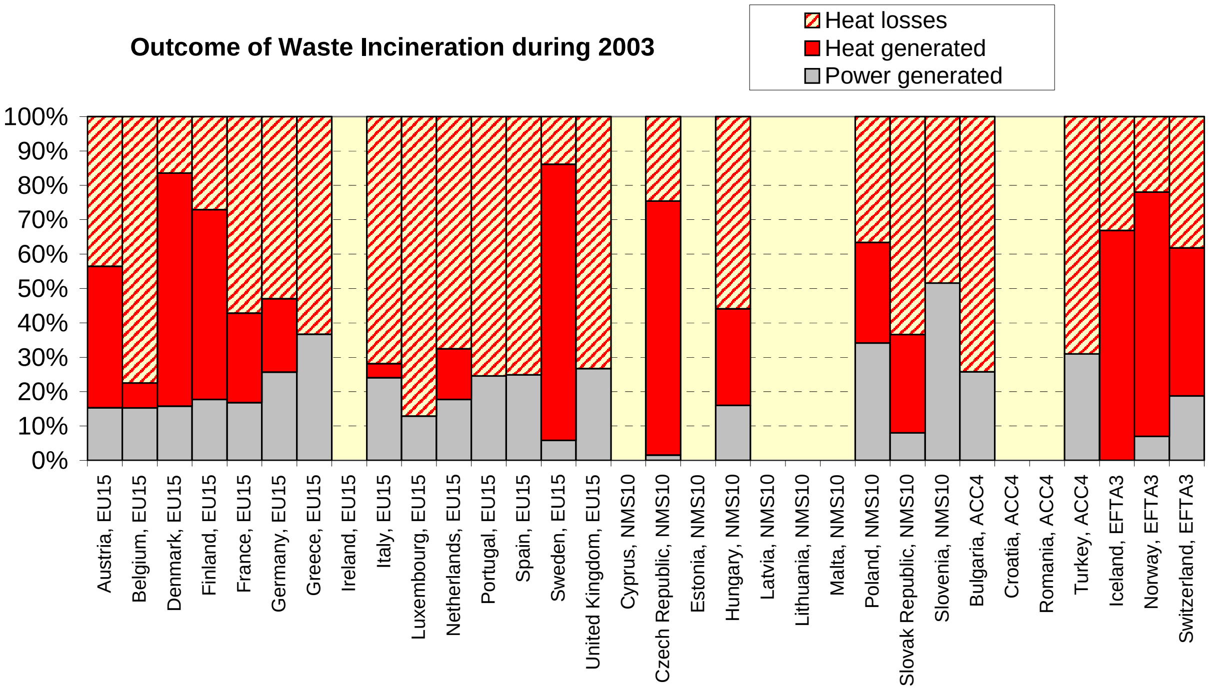

Figure 13. Outcome of waste incineration in the target area during 2003. Source: IEA Energy Balances.

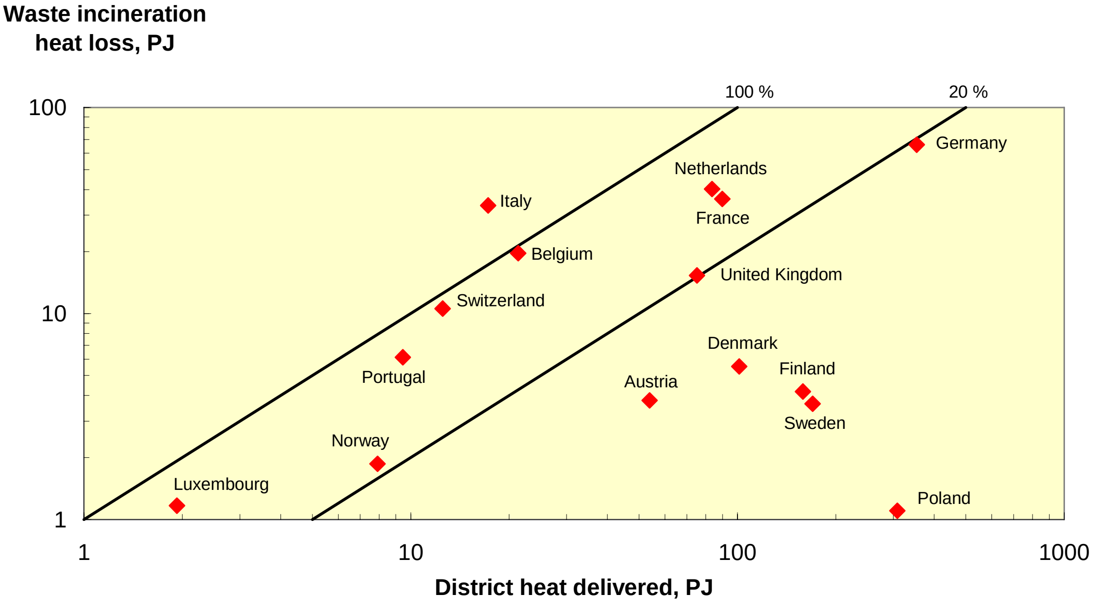

Figure 14. Correlation between district heat delivered and the current national waste incineration loss during 2003. The lines in the graph refer to fraction between incineration loss and heat delivered.

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4.3 *Surplus heat*

4.3.1 Current use of surplus heat

Energy balance sheets in international energy statistics normally do not consider the use of industrial surplus heat in district heating systems. This heat flow is based on the use of industrial fuels and the primary heat used in industrial processes. After heat recycling, the heat is transferred back to the energy transformation sector (the district heating system) and this heat flow is not foreseen in energy balance sheets. The input for heat generated by heat pumps is considered in the IEA energy balance sheets by adding the heat recovered as a domestic energy resource and adding the electricity input to the electricity consumed in district heating systems.

The industrial surplus heat is mainly recycled from the paper & pulp, metal, and chemical industries and petroleum refineries. The surplus heat is easily recycled by heat exchangers and cooling of hot flue gases or warm process waters. A major barrier for use of industrial surplus heat is the expected future for the company having the surplus heat. A major risk is that the industrial plant will be closed within a few years. On the other side, a heat recycling will strengthen the competitiveness for the industrial product manufactured, since the heat recycling will bring a financial contribution to the industrial process.

The current use of external surplus heat in European district heating systems is presented in Figure 15. Surplus heat includes mainly heat recycled from oil refineries and energy intensive industries. But here is also heat recovered by the cold end of large heat pumps included.

Figure 15 reveals that use of surplus heat is not common in the European district heating systems. The total amount was only 42 PJ during 2003. Sweden was almost the sole user with a supply of 36 PJ, corresponding to 19 % of all district heat generated in Sweden. This amount is divided between 19 PJ of industrial surplus heat and 17 PJ heat recovered by large heat pumps. Minor use of surplus heat appeared in Germany (3,7 PJ), France (1,7 PJ), Norway (0,5 PJ), and Italy (0,3 PJ).

Whether Figure 15 reflects the real situation can be discussed, since this heat recycling is not considered in international energy statistics as mentioned above.

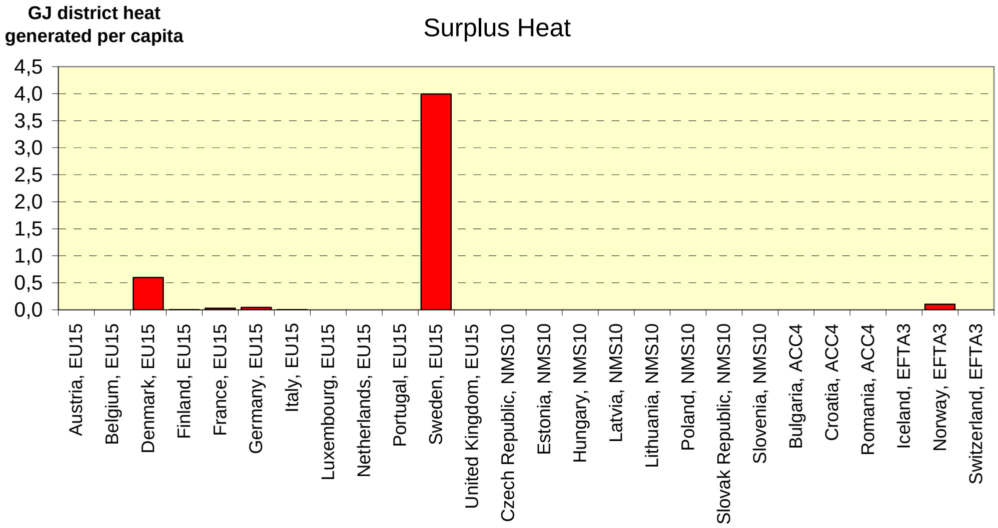

Figure 15. District heat supplied from surplus heat during 2003. Source: Mainly based own corrections from various national information, since this information is not available in the IEA Energy Balances. During the proof reading stage of this report, surplus heat was also identified for Denmark (3,1 PJ during 2003). This information is included in the figure, but not used elsewhere in the report.

4.3.2 Industrial surplus heat resources

The industrial surplus heat resources in the target area are estimated in Table 4. The estimation is based on the total energy supply to petroleum refineries and five energy intensive industrial branches. The second stage in the estimation is the Swedish experiences of practical heat recycling factors. These factors have been estimated from the ratio of actual surplus heat recycled and total energy supply in operating heat recycling projects. The source for method and input data for this estimation is (SDHA, 2002). Hence, the theoretical recycling factors are higher. This means the estimation made is based on practical experiences and not on theoretical considerations.

Table 4 shows finally that the total potential in the target area is about 1100 PJ/year, corresponding to 8% of all industrial end use of net heat and electricity. The current use is only 25 PJ.

Table 4. Estimation of total industrial surplus heat potential in the target area during 2003.

Sector	Total energy supply 2003, PJ	Swedish heat recovery factor	Total industrial surplus heat potential, PJ
Petroleum refineries	33202	0,6%	196
Food and Tobacco	1443	3,6%	53
Pulp & paper	1616	2,4%	38
Chemical	2573	12,2%	315
Non-Metallic Minerals	1890	2,9%	55
Basic Metals	2602	17,3%	449
Total			1106

The main barrier for exploitation of this potential is of course the distance between the current heat sources and appropriate urban settlements with heat demands. Some locations have also only short heating seasons. But surplus heat can also be used to cool buildings with absorption chillers during warm summer days as explained in the preceding part about waste incineration.

A possible future surplus heat source for district heating systems can be new plants for liquid biofuels for transportation purposes transformed from biomass. These plants will generate more heat than the current conventional oil refineries since the heat loss fraction is higher.

The future possibility with respect to industrial surplus heat is:

- Extend the use of industrial surplus heat from 25 to 200 PJ/year, corresponding to 18 % of the current practical recycling potential.

4.3.3 Industrial surplus heat references

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4.4 Geothermal heat

4.4.1 Current use of geothermal heat

The current use of geothermal heat in European district heating systems is presented in Figure 16, revealing that the use of geothermal heat is not common today in the district heating systems. The total amount was only 26 PJ during 2003, corresponding to 1,1% of all heat generated. Iceland was the main user with a supply of 19 PJ, with Reykjavik as the world capital of geothermal district heating. Minor use appeared in

- France (4,4 PJ) with many small systems in the Paris area (Dogger aquifer) and some in the Bordeaux area (Aquitaine basin)
- Italy (0,5 PJ) with systems in Ferrara, Larderello, and Castelnuovo
- Germany (0,4 PJ) with systems in Erding and Prezlau as examples
- Austria (0,4 PJ) with systems in Altheim, Bad Blumau and Simbach-Branau

Minor district heating installations are also known from Hungary, Denmark (Thisted), Sweden (Lund), United Kingdom (Southampton), Romania (Oradea), Lithuania (Klaipeda), Poland (Zakopane and Pyrzyce), and Switzerland (Riehen). A new project started in August 2005 to deliver 0,4 PJ annually to the Copenhagen district heating system. These installations use either geothermal water of 70-120°C directly by heat exchangers, water of 20-60°C with heat pumps or a combination of heat exchangers and heat pumps. Heat pumps can either be of absorption type using heat as driver or of the compression type using electricity.

Geothermal district heating systems have also been introduced in Turkey during recent years. The annual current use is estimated to be 6 PJ according to (Lund et al, 2005). 13 Turkish cities are partially heated by these systems according to (Mertoglu, 2005). The average annual growth rate for installed geothermal capacity was 11 % per year between 2000 and 2004. Current plans presume annual growth rate of 55% until 2010.

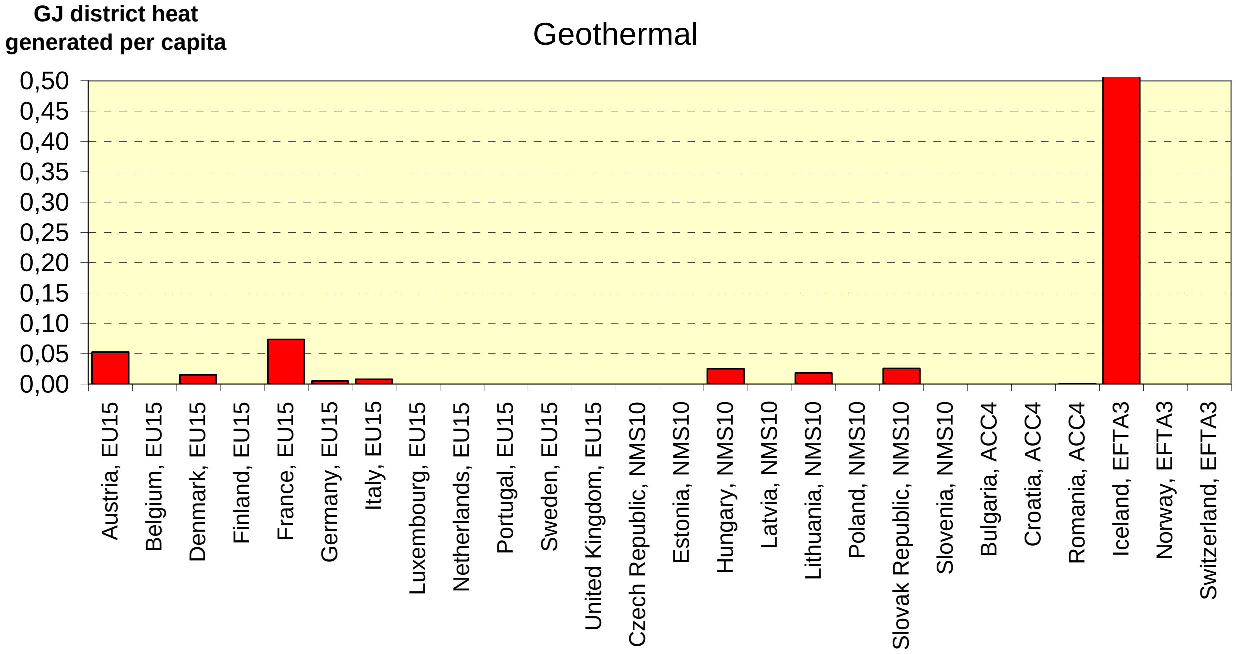

Figure 16. Geothermal district heat supplied during 2003. Broken bar for Iceland due to a high value (66,7 GJ). Source: IEA Energy Balances with own corrections.

The IEA Energy Balances contain only 10 PJ in the world of geothermal use in district heating systems for 2003, mainly the use in the Reykjavik system in Iceland and some minor use in Austria, Germany, Hungary, Slovak republic, Lithuania, and Denmark. Within the global geothermal community, (Lund et al, 2005) estimates the direct use to 41 PJ/year in district heating systems. Hence, the IEA Energy Balances do not collect this information properly, since China, France, Iceland outside Reykjavik, Italy, Romania, Turkey, and United States are missing.

4.4.2 Geothermal heat resources

Geothermal fields in Europe are mapped in (Hurter & Haenel, 2002) country by country. At the 2000 m depth, areas of 80°C and above are found in Iceland, Turkey, Italy, Hungary, Slovak republic, Croatia, Switzerland, Germany, France and Netherlands. Major cities located near these geothermal fields are Reykjavik, Izmir, Budapest, Bratislava, Zagreb, Bern, Stuttgart, Frankfurt am Main, Berlin, Paris, and Amsterdam. As reported above, geothermal heat is already used in Reykjavik and in the Paris area.

The current European low-temperature resources of geothermal heat are huge compared to the current use. The International Geothermal Association estimated in (IGA, 2001) the lower limit of the total European potential for direct heat use (excluding power generation) to be 370 EJ/year, while the current use was only 70 PJ. Hence, the use was only 0,02 % of the potential identified.

The European Geothermal Energy Council expressed in their Ferrara declaration (EGEC, 1999) that direct use of geothermal heat in Europe should increase with 10-11% per year until 2020. This growth rate is actually the same as obtained in Turkey during recent years. This expectation would give a European direct use of 170 PJ in 2010 and 530 PJ in 2020.

The use of district heating systems must be a vital part of this expected expansion of geothermal heat in Europe. Otherwise, urban heat users cannot be reached in a cost effective manner.

The future possibility for geothermal heat can be:

- Increase the use of geothermal heat in European district heating systems from 26 to 50 PJ/year at the current heat sales.

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4.5 Combustible renewables

In the IEA Energy Balances, combustible renewables comprises solid biomass, biogas, and liquid biomass, where biomass is defined as any plant matter used directly as fuel. These fuel fractions can be defined as:

- **Solid biomass** can be purpose-grown energy crops as willow or poplar, firewood for direct use, waste from the forest industry (wood chips, bark, etc), waste from the paper & pulp industry (black liqueur), waste from saw-mills (sawdust and shavings), and agriculture waste (straw, nut shells, olive stones etc).
- **Biogas** comprises all gases with a significant content of methane and with an origin from anaerobic digestion of biomass. Main sources are landfills, sewage sludge, animal slurries, and agricultural waste.
- **Liquid biomass** considers methanol, ethanol, and oils with a biomass origin and is mostly used as biofuel in the transportation sector.

The total primary energy supply of combustible renewables was 2974 PJ in the target area of 32 countries during 2003. However, only 354 PJ (12%) of the combustible renewables was supplied to CHP and heat plants in the energy transformation sector. The other parts were used in power generation (7%), in industrial applications (24%), for transportation (3%), and mainly for heating of rural buildings (55%).

4.5.1 Current use of biomass

Several hundreds of European cities, towns, and villages are using solid biomass or biogas in CHP or heat-only plants for heat supply to the local district heating systems (Lensu & Alakangas, 2004). Some typical examples with respect to sizes and locations can be found in the enclosed reference list in section 4.5.3.

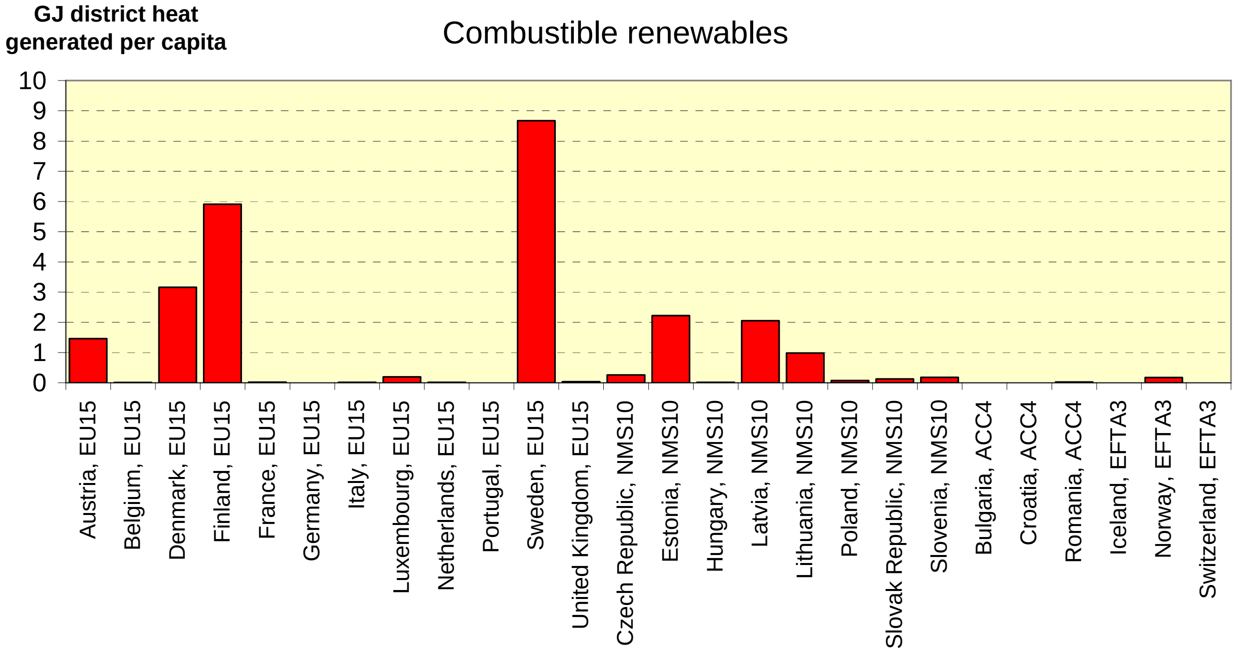

Figure 17. District heat generated from combustible renewables (mostly solid biomass) during 2003. Source: IEA Energy Balances with own corrections.

The current use of heat from combustible renewables in European district heating systems is presented in Figure 17. The highest per capita values are found in, Sweden, Finland, Denmark, Estonia, Latvia, Austria, and Lithuania. Other countries use almost no combustible renewables in district heating systems. The total amount of heat generated from biomass was 165 PJ, corresponding to 7 % of all heat generated. This volume considers own corrections of the IEA energy balances.

The total current supply of combustible renewables of 354 PJ to all CHP and heat-only plants was converted to 83 PJ of electricity and 168 PJ of heat, according to the uncorrected IEA Energy Balances for 2003. This gave a total conversion efficiency of 71%, revealing that some electricity was also generated in condensing mode in CHP plants. Otherwise, the conversion efficiency would have been higher. Out the total fuel supply, 95% considered solid biomass and the remaining 5% was biogas. No liquid biomass was reported.

4.5.2 Solid biomass resources

The current forestry growing stock in the target area was estimated to about 20 billion m^3 in (FAO, 2002). This represents a calorific value of about 150 EJ. The growing stock is defined as the forest where any legal, economic, or specific environmental restrictions do not have a significant impact on the supply of wood. Hence, the net annual increment of about 600 million m^3 represents the base for the whole forest industry. This annual increment corresponds to a fuel value of 4,4 EJ/year. But this valuable resource shall also be used as input to the paper & pulp and wood industries. Without the restrictions set in the FAO estimation, a larger annual increment of solid biomass is available.

The current national total uses of combustible renewables versus the net annual increment are presented in Figure 18. The figure shows that the current use is highly correlated to the net annual increment, revealing that the current use of combustible renewables in Europe is based mostly on forest residues. The highest per capita use appears in Finland, Sweden, Latvia, Estonia, and Austria, since large forest areas are available per capita. Some countries (Netherlands, Greece, Denmark, and Portugal) have a total use higher than the net annual increment, revealing that also agricultural biomass is used.

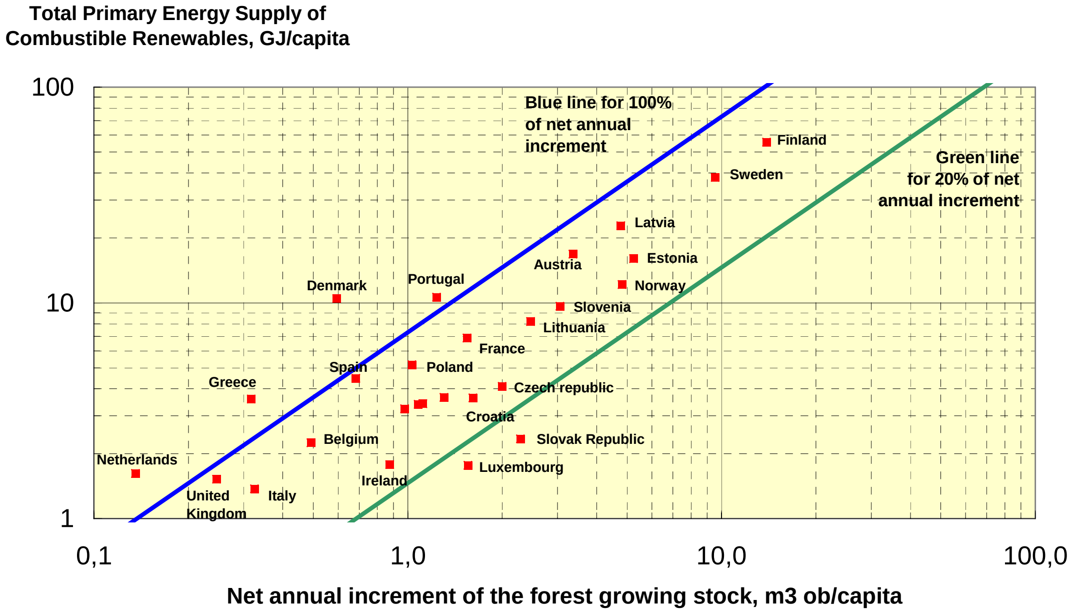

Figure 18. National per capita combinations of total primary energy supply of combustible renewables (excluding the biomass part in municipal waste) and the net annual increment of the forest growing stock. Reference lines added for 20% and 100% fuel use of the net annual increment, assuming a calorific value of 7,3 GJ/m^3 ob.

It must be possible to increase the use of solid biomass in Luxembourg, Slovak republic, Croatia, Ireland, and Czech republic since the current use is low compared to the net annual instalment. Forest residues should be available for fuel purposes in these countries.

An assessment of the potential biomass supply in Europe has been performed by (Ericsson & Nilsson, 2006). They estimated the total potential to be 13-18 EJ/year for EU25 together with Bulgaria and Romania. Forestry residues and forest industry waste made up about 2 EJ, while energy crops of 11-15 EJ/year dominated the potential. Less than 1 EJ/year was expected from agricultural residues. Hence, the total current annual use of about 3 EJ can increase in the future.

The total renewable use in the target area was 5,9 EJ during 2003, corresponding to 7,3% of all primary energy supply. This volume considers all hydropower, wind power, solar and geothermal energy, combustion renewables, and all waste incineration. The European Union has a 12 % target for 2010 for this fraction from the 1997 white paper on renewables. This target becomes 9,7 EJ for the target area in 2003. In (European Commission, 2005), the Commission expects the current use of biomass to be doubled in order to support the target. Hence, the EU target of 12 % would require a biomass use of about 6 EJ/year. The European Renewable Energy Council puts forward the new target 20 % for 2020 in (EREC, 2004). The expected contribution from biomass was set by EREC as 13 % of all primary energy supply, giving 10,5 EJ/year and more than a threefold increase of the current use. The (Ericsson & Nilsson, 2006) estimation of the potential verifies that this is possible, but only with a massive introduction of energy crops.

These large expectations of more biomass use make it necessary to also use biomass for urban heat demands, making district heating the appropriate distribution method in urban areas. This conclusion was also communicated in (European Commission, 2005). In order to support the expansion of biomass use in European district heating systems, it will be essential that transparent information will be available for all local actors about biomass fuel prices, suitable technologies, and corresponding operating experiences. Expansion of the biomass fuel supply in district heating systems is then mainly a large European dissemination project, since hundreds of European cities, towns, and villages already use this renewable resource.

More information becomes also available with respect to fuel prices, (EUBIONET, 2003 & 2005) and (BioXchange, 2006). Regional projects also appear concerning dissemination of technologies for biomass CHP and heat-only plants, as (BASREC, 2005). Operating experiences will be collected and shared in the Altener BIO-CHP project. More than 20 years of Swedish experiences of biomass combustion are summarised in (Strömberg, 2006).

The future possibility for district heat generated from combustion renewables can be:

- The current volume of 165 PJ/year of heat generated from combustion renewables should increase to 500 PJ/year at the current heat sales.

4.5.3 Biomass references

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4.6 Other resources

4.6.1 Solar district heating

In some European district heating systems, large central solar heating plants supply heat to the systems. The 8 largest solar plants are listed in Table 5. They are all located in Germany, Denmark and Sweden and generate together about 70 TJ of heat each year.

The IEA Energy Balances contain for 2003 a total heat supply of 3616 TJ of heat generated from Solar/Wind/Others for the target area. However, a closer look in the extended balances reveals that almost all of this heat supply comes from unknown fuels in Denmark, Lithuania, and Slovak republic. Albania and Denmark are the only countries in the world that report supply of solar heat into district heating systems. Hence, the total solar heat supply to district heating systems cannot be found in the IEA Energy Balances.

The 2003 volume for Denmark was 51 TJ in the IEA Energy Balances. From Swedish sources, 7 central solar heating plants are known and they generate about 30 TJ per year. The two German plants in Table 5 generate about 12 TJ/year. Together, these three countries have a total annual solar heat supply of almost 100 TJ, corresponding to 0,004% of all heat generated in the target area in 2003.

The future possibility is that

- Solar heat can be transferred in district heating systems to customers having high willingness to pay for solar heat. An ambition can be to increase the annual heat generation from 0,1 PJ to 2 PJ at the current heat sales.

Table 5. Large solar heating plants connected to district heating systems. Source: (Dalenbäck, 2006).

Location	In operation since	Owner	Country	Collector area, m^2	Capacity, MWth
Marstal	1996	Marstal Fjernvarme	Denmark	18 300	12,8
Kungälv	2000	Kungälv Energi AB	Sweden	10 000	7,0
Nykvarn	1984	Telge Energi AB	Sweden	7 500	5,3
Falkenberg	1989	Falkenberg Energi AB	Sweden	5 500	3,9
Neckarsulm	1997	Stadtwerke Neckarsulm	Germany	5 263	3,7
Ærøskøping	1998	Ærøskøping Fjernvarme	Denmark	4 090	2,9
Friedrichshafen	1996	Techn. Werke Friedrichsh.	Germany	4 050	2,8
Rise	2001	Rise Fjernvarme	Denmark	3 575	2,5
				58 278	41

Figure 19. View of the Marstal solar collector area in Denmark. Photo by permission from Leo Holm, Marstal Fjernvarme.

4.6.2 *Electric boilers, heat pumps and surplus electricity*

Electricity was used in Sweden, France, Norway, and Iceland as input to electric boilers and large heat pumps. The current use is presented in Figure 20.

Iceland has the highest per capita use. This country has an isolated power market without connections to other national power markets. Therefore, power surplus during spring flood months cannot be exported to other countries. The domestic alternative is then to absorb the surplus in the district heating systems.

The Swedish large electric boilers and heat pumps were mainly introduced in the 1980's. Many large nuclear power stations came into operation during that decade without corresponding more electricity consumption, creating a national surplus of power. Hereby, the local district heating systems became the angel of mercy and absorbed partly the power surplus by reversing CHP operation and by introduction of large electric boilers and heat pumps. The situation with surplus electricity does not appear anymore with Sweden as a part of an integrated European power market. Now the CHP operation increase and large electric boilers and heat pumps are reversing. Probably, the existing large heat pumps will not be replaced by reinvestments in the future.

The Norwegian large electric boilers have a similar background as the situation in Iceland. Also in Norway, a more integrated European power market will reduce local and national electricity surpluses in the future. The new Norned HVDC link between Norway and Netherlands will be in operation in December 2007. This new link will further reduce the possibility of using surplus electricity from hydropower for heat generation purposes.

The future possibilities with respect to large-scale electricity use for heat generation in district heating systems are:

- No use of electric boilers or large heat pumps in district heating systems
- Some heat pumps can be in operation for upgrading the temperature from low-temperature geothermal heat sources and heat recycling from district cooling systems

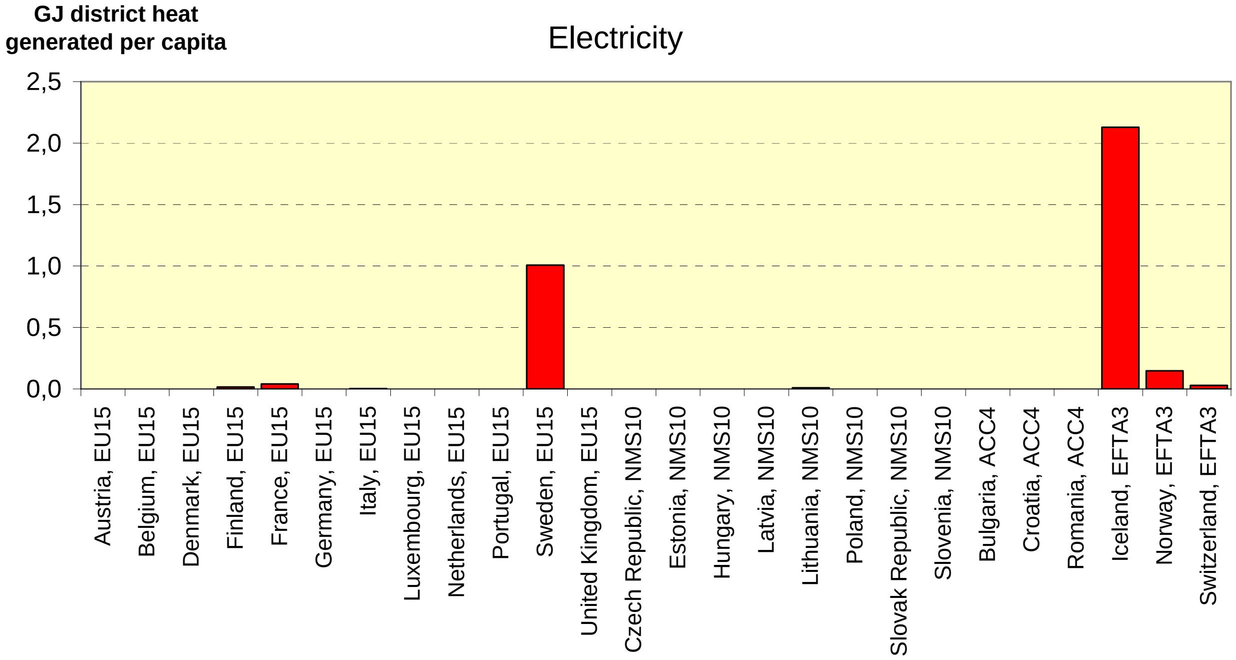

Figure 20. Supply of electricity for district heat generation during 2003.

4.6.3 Nuclear heat

Heat was recycled from six nuclear power stations in five countries during 2003: Lithuania (Ignalina) , Slovak republic (Bohunice), Switzerland (Beznau and Gösgen), Bulgaria (Kozloduy), and Hungary (Paks). However, the total utilisation was low, only 6 PJ in the whole target area.

The Swiss nuclear reactor Beznau delivers since 1984 heat to the Refuna district heating system located in the Aare valley near the German border. District heat of 0,6 PJ/year was delivered during 2003 to several small towns through a 35 km long transmission network, while the distribution network was 85 km. Hence, the linear heat density was low, only 5 GJ/m.

The possibility concerning utilisation of nuclear heat can be:

- Increase the use of nuclear heat from 6 to 20 PJ/year at the current heat sales

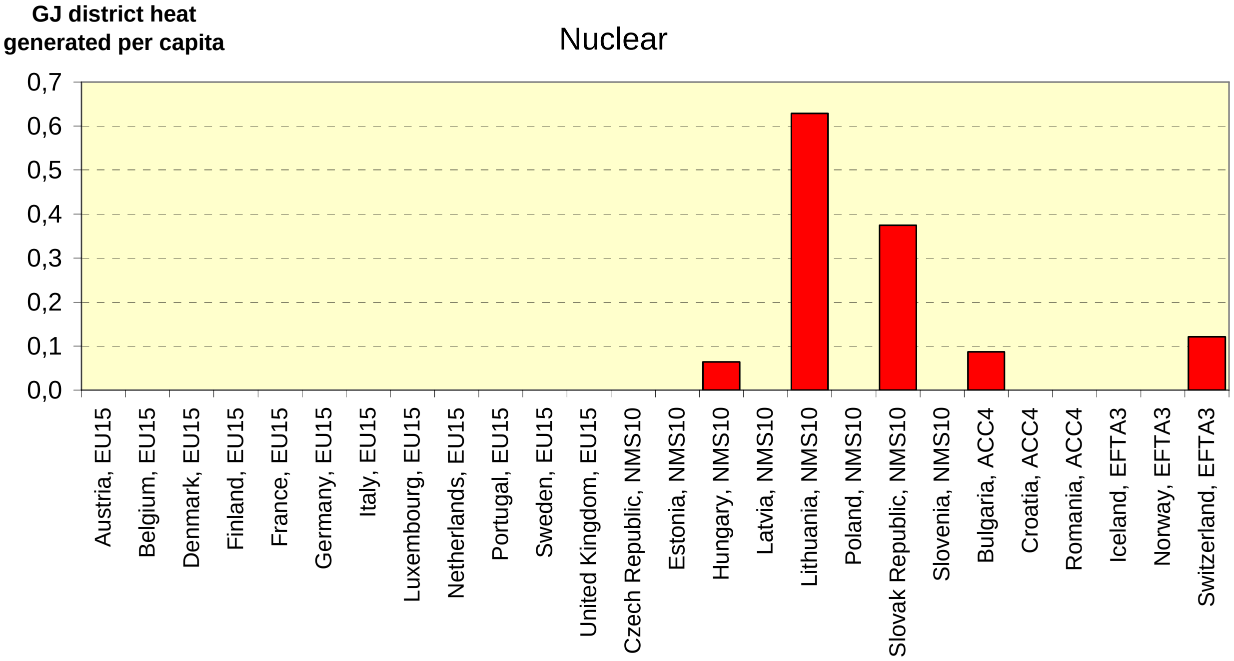

Figure 21. District heat generated from nuclear power stations during 2003.

4.6.4 References for other resources

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4.7 Summary of strategic heat source options

The volumes of the five strategic heat source options (CHP, waste incineration, surplus heat, geothermal heat, and combustible renewables) are summarised and compared to the current district heat generated in Figure 22.

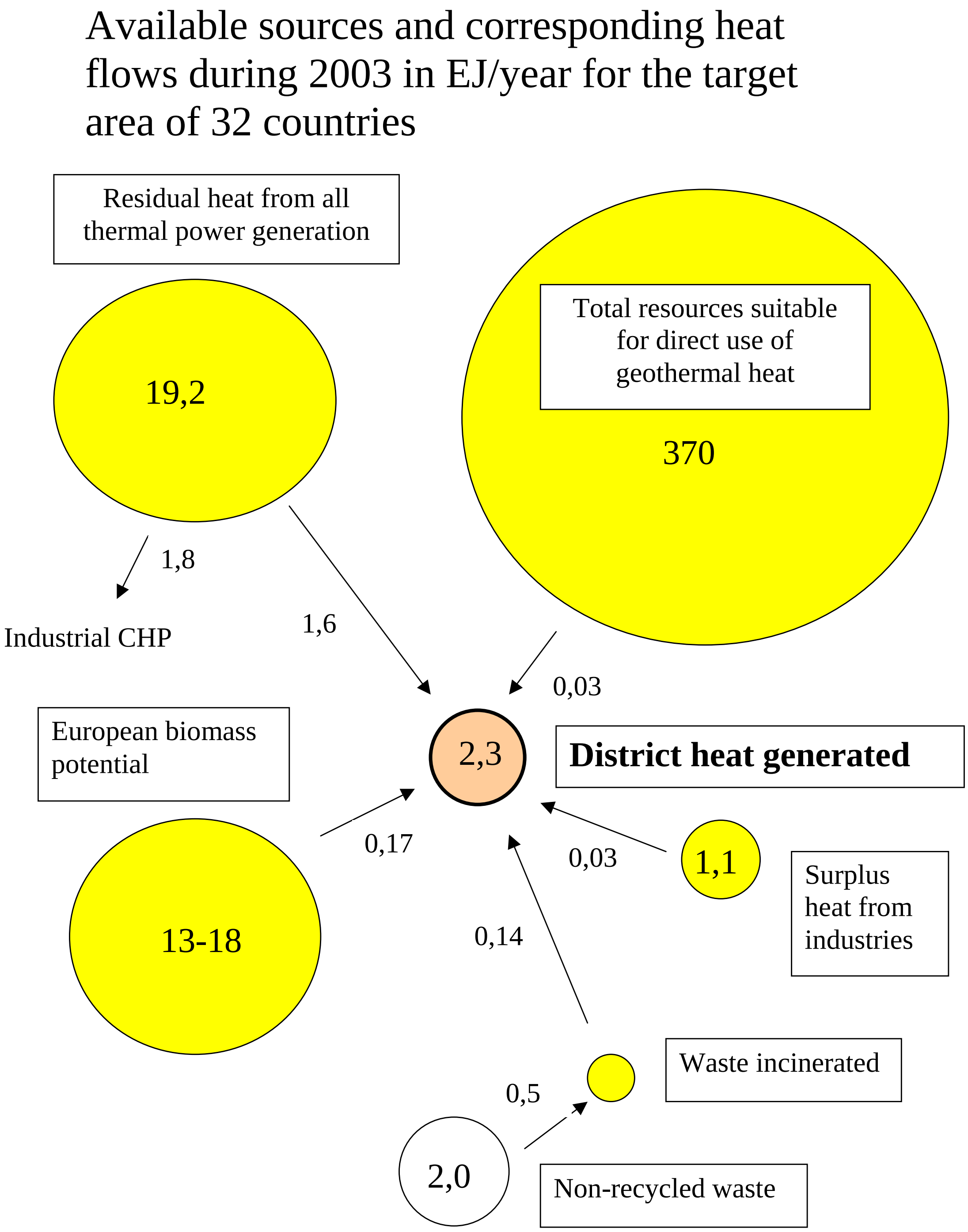

Figure 22. Summary of the five strategic district heat sources with the current contributions to the district heat generated during 2003 in the target area of 32 European countries. The picture contains some double counting since some heat from biomass and waste are generated in CHP plants.

5 Institutional and market barriers

The institutional and legal frameworks for district heating are mainly national: district heating laws, energy tax systems, social assistance, price regulation, state support for investments etc. One of the few international frameworks influencing the competitiveness of district heating is the European Emissions Trading System introduced in 2005.

No general overview is available for various barriers preventing or mechanisms supporting expansion of district heating in Europe. Available information are scattered in the documents included in the enclosed reference list. Some of the typical barriers for expansion of district heating in Europe during recent years are or have been:

Low fuel and electricity prices	The main advantage with district heating is the low input of primary energy supply, giving less expense for the heat supply. This advantage has a considerable market value when the international market prices of oil, natural gas, and electricity are high. In times of low energy prices, district heating systems do not expand, but are waiting for better times or fights for their future survival. The world history of district heating tells that district heating systems have mainly expanded in times of high energy prices for end users.
Short term investments	District heating is a long-term commitment comparable with investments in roads, bridges, railways, and buildings. This commitment is made in each local urban heat market. A deregulated and privatised energy market prioritises more short-term commitments having shorter paybacks.
Legal framework	The influence of a national legal framework for district heating is very different in the target area. Hence, the national playing fields are very different from country to country. This situation gives an un-harmonised European district heating sector. The national conditions are so different that some market actors avoid entering a heat market in another country.
Energy supply focus	By tradition, the main focus is on energy supply from fossil fuels, nuclear, electricity, and biomass in European or national energy policies. Much less attention is given to the actual heat demands. District heating is an efficient short cut between energy supply and heat demands, getting little or no attention when European or national energy policies is discussed.
Ownership shifts	In many European countries, a general shift from municipal ownership to private owners is going on. New capital is then mainly used for equity investments. Less capital is used for expansion of district heating systems. The energy companies grows by mergers and the top management will focus more on large global and national investments and less on local investments in urban district heating systems. You can simply say that the large international energy companies are moving away from the local level, where district heating systems operate.
Price regulation	In most NMS10 and ACC4 countries, extensive price regulation is applied due to protection of the poorest part of the population. This prevents rehabilitation and expansion of the networks, since the owner in many cases cannot keep the full return on investments. This situation prevents many private investors to enter the district heating sector.
Distorted market prices	In some NMS10 and ACC4 countries, price regulation is un-harmonised between various energy commodities. Natural gas has been sold to final customers at the same prices paid by large power and power plants. The long-term retail distribution costs have not been regarded in the price regulation. This has not been a level playing field for district heating.

Cost allocation	The major driving force for district heating is the benefit of combined heat and power. This CHP benefit must be shared between the electrical and heat side. Sometimes the whole CHP benefit is allocated to the electrical side, giving the district heat side no market advantage at all. This situation appears both in price regulation schemes and when a power company owns the CHP plant. District heating systems cannot expand without having a significant advantage compared to the market alternatives. The solution is to have no rules at all, so that the cost allocation between heat and electricity can be decided in each project, based on the prevailing local conditions. The solution is not harmonised rules for cost allocation in CHP in Europe. Similar cost allocation situations appear also when waste incineration and industrial surplus heat are used.
Social considerations	In some NMS10 and ACC4 countries, district heating operators must also take social considerations for poor customers, since general municipal or state social assistance programs have not been introduced. By local decrees, the district heat providers are obliged to assist with discounts for the poorest part of population.
Emissions trading	Potential customers for district heating using fuel oil or natural gas are not normally included in the European emissions trading system. When connected to district heating, the district heating operator must buy more emissions quotas in order to compensate for the new heat delivery. This is not a level playing field for district heating. This barrier can be removed by accepting all new district heating customers as new entrants to the trading system and entitled to additional allocations of emission quotas.

Removal of many of these barriers for district heating would create a more level playing field for district heating in Europe. However, barriers to district heating are moving targets and some of the barriers will be removed during the coming years in many transition economies.

Many former barriers for district heating have also been removed or met by support during the recent years:

- Bad access to the electricity market was for very long time a major barrier for local CHP plants. This barrier was easily removed by the deregulation of the European power market.
- Another barrier was that competing electricity and natural gas were among the commodities listed for reduced VAT rates in the sixth EU VAT directive and district heat was not on that list. But according to a decision at the ECOFIN meeting on January 24, 2006, district heat is to be included in the list giving a more level playing field for district heat in this respect.
- Some countries also apply high taxes for the domestic use of fuel oil, natural gas, and/or electricity in order to promote the use of renewables and recycled heat, giving district heating systems a national market advantage. According to the WP1 report, this situation is prevailing in Italy, Denmark, Netherlands, Sweden, Greece, and Hungary. These energy tax policies are examples of removing market barriers for district heat.

5.1 References

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6 District heating projections

6.1 International apprehensions about district heating

In general, the international community has very low expectations concerning the future growth of district heating systems in Europe. In (European Commission, 2004), the National Technical University of Athens has presented many different scenarios for the European energy system in EU25 until 2030. The development of all heat centrally generated in their baseline scenario is presented as the upper red curve in Figure 23. This baseline scenario has a lower estimation for 2002 compared to the actual amount of heat generated in 2002 according to the red triangle. The baseline volume of heat generated of 3,5 EJ in 2030 is just above the current volume of 3,3 EJ. The analysis team used statistical information from Eurostat, which is missing information about some national district heating sectors.

The baseline development in Figure 23 presumes an annual growth of only 1,4 % until 2030. The growth rates in the other scenarios vary between 1,1 and 1,6 %. In (IEA, 2004), the annual growth rate of 1,3% was used between 2002 and 2030. These low expectations of growth are much lower than many national growth rates achieved during the last 11 years, according to Table 1.

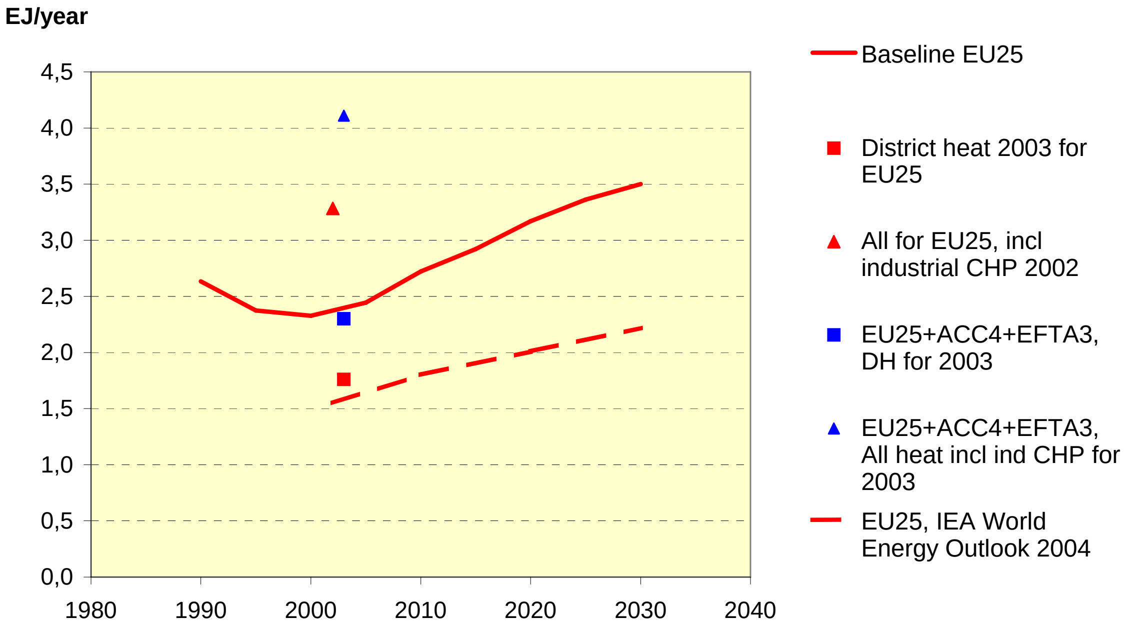

Figure 23. Comparison between two projections of total heat generated, from (European Commission, 2004) and (IEA, 2004), and the current district heat generated and total heat generated in EU25 and EU25+ACC4+EFTA3.

The World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) have established the Intergovernmental Panel on Climate Change (IPCC) to assess scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation.

In the Mitigation part of its third assessment report (IPCC, 2001), district heating is just mentioned a few times. In the technical summary on page 48, the only recognition is: ”The implementation of CHP is closely linked to the availability of industrial heat loads, district heating, and cooling networks”. In conjunction with space heating in chapter 3 on page 188, the only identification is: “District heating systems are common in some areas of Europe and in the EIT region”. District heating is also briefly mentioned when geothermal and CHP systems are discussed on pages 239 and 249. But nowhere in this extensive 752 pages report, the general benefit of lower carbon dioxide emissions in district heating systems is acknowledged.

Working group III of IPCC is now preparing the mitigation part of the fourth assessment report to be published in 2007. Nothing in the outline for this next report reveals that district heating will be identified as a cross cutting option for mitigation of carbon dioxide emissions.

Hence, the major conclusion must be that the environmental benefit of district heating is not recognised on the international policy level concerning climate change.

6.2 Future possibilities

In chapter 4, the various future possibilities for the five strategic district heat sources and some other heat sources were elaborated with respect to existing potentials. These possibilities are summarised below:

For heat generated from CHP plants, two stages of future possibilities appear:

- The CHP share should increase from the current share of 68 % to about 80 %
- The overall average power-to-heat ratio should increase from the current level of 0,33. An increase with 40 % would give a new average power-heat-ratio of 0,46.

For waste incineration, the following future possibility appear:

- Increase heat generated from waste incineration from 165 to 350 PJ/year at the current heat sales. This can firstly be achieved, by increasing the overall total conversion efficiency for waste incineration plants from the current 47% to about 70%, and secondly, by increasing the incinerated volume from the current 50 million tons of waste.

The future possibility with respect to industrial surplus heat is:

- Extend the use of industrial surplus heat from 25 to 200 PJ/year, corresponding to 18 % of the current practical recycling potential.

The future possibility for geothermal heat can be:

- Increase the use of geothermal heat in European district heating systems from 26 to 50 PJ/year at the current heat sales.

The future possibility for heat generated from combustion renewables can be:

- The current volume of 165 PJ/year of heat generated from combustion renewables should increase to 500 PJ/year at the current heat sales.

The future possibilities for other heat sources can be:

- Solar heat can be transferred in district heating systems to customers having high willingness to pay for solar heat. An ambition can be to increase the annual heat generation from 0,1 PJ to 2 PJ at the current heat sales.
- No use of electric boilers or single-purpose large heat pumps in district heating systems
- Some heat pumps can be in operation for upgrading the temperature from low-temperature geothermal heat sources and heat recycling from district cooling systems
- Increase the use of nuclear heat from 6 to 20 PJ/year at the current heat sales

All these possibilities will be used in chapter 7 in order to improve the existing district heating systems when the overall benefits of district heating will be estimated.

6.3 Current potential for expansion of district heating

The current potential for expansion of district heating in the area of 32 countries depends on the actual heat demands, the current market share for district heat, the availability for district heating technology etc. The remaining market shares for fossil fuels in the urban industrial, residential, and service sectors are the main target market for expansion of district heating. Hence, the expansion of district heat in each country should be proportional to the remaining market for fossil fuels. Hereby, existing use of combustible renewables and electricity are excluded from the remaining market. The magnitude of the fossil market shares on the heat market was 15,8 EJ during 2003.

In order to compensate for national conditions in each country, some reducing expansion factors have been used as estimates of the share of remaining fossil fuels for possible substitution by district heating. These expansion factors are presented in Table 6.

It should be impossible to introduce district heating in Cyprus and Malta, giving an expansion factor of 0. In Mediterranean countries, as Turkey, Greece, Italy, Spain, and Portugal, the demand for space heating is limited, giving a low expansion factor of 0,2. In very mature district heating countries, as Denmark, Finland, and Sweden, the market shares for district heat are already high, giving an expansion factor of 0,4. In immature district heating countries, as Belgium, Ireland, and United Kingdom, the national attitudes concerning district heating are more reluctant, giving an expansion factor of 0,5. In the 8 remaining NMS10 countries, the demand for heat is expected to increase due to more residential buildings and higher pay ability in the future, giving an expansion factor of 1. All other countries were given an expansion factor of 0,7, reflecting that district heating is only possible in urban areas. Since all combustible renewables are not included in the remaining market, further consideration has been taken for the rural use of heat.

For all industrial heat demands, the expansion factor of 0,3 was used, since only 30% of the these demands can be fulfilled by district heating with respect to prevailing industrial temperature demands.

Table 6. Expansion factors describing the possibility for expansion of district heating in various countries

General market conditions	Expansion factor = possible market of remaining fossil net heat
NMS10 country	1,0
Established DH	0,7
Reduced availability	0,5
Mature market	0,4
Mediterranean area	0,2
DH not possible	0
Industrial heat sector	0,3

By use of the estimated expansion factors, the potential market for district heat was reduced with 57 % to 6,8 EJ/year from the remaining 15,8 EJ heat from fossil fuels. This potential is then a first estimate of the complete European district heat potential. Due to various constraints and barriers, the complete potential can be impossible to reach. A doubling of the current annual heat sales from 1,95 EJ to 3,9 EJ will require that 29% of the potential market for district heat will be converted to district heat.

This overall estimation of the district heat potential is illustrated in Figure 24.

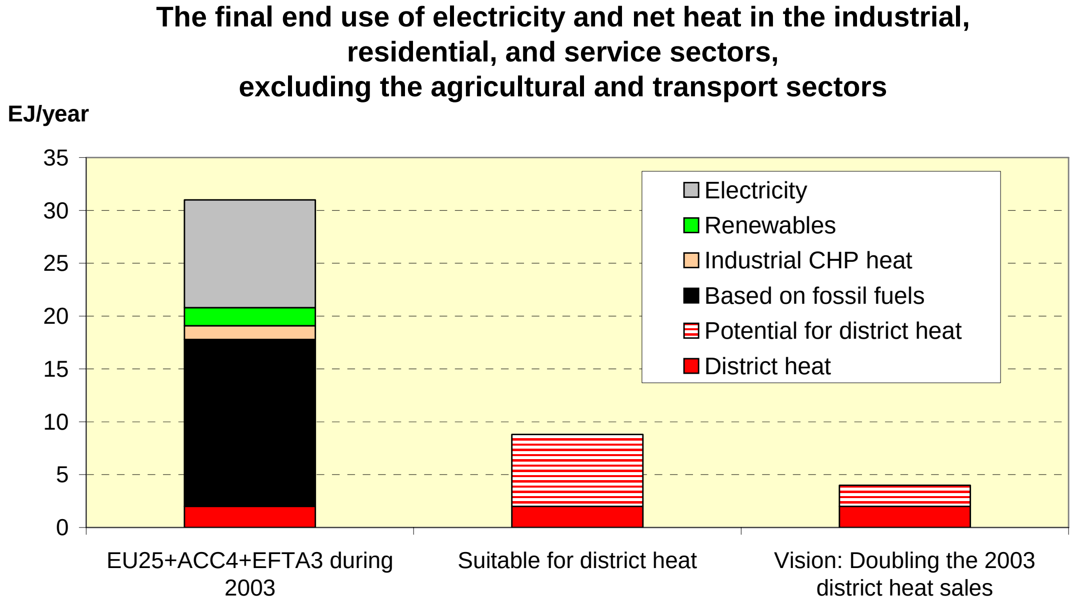

Figure 24. Estimation of the district heat potential in the target area from the total net heat demand in the industrial, residential, and service sectors.

The national distribution of the doubling of district heat sales have been estimated by using the remaining market shares for fossil fuels and the expansion factors defined. The result of these estimations can be seen in Figure 25. It is evident that district heating must expand in three large EU countries having low market shares for district heat (United Kingdom, France, and Germany). According to the estimation, 56 % of district heat expansion must appear in these countries in order to fulfil the doubling of all European district heat sales. Barriers for more district heat sold in these countries will also be major barriers for more district heat in Europe.

Doubling heat sales corresponds to an annual growth rate of 4,7 % during 15 years, as between 2005 and 2020. This growth rate is normal and possible compared the growth rates achieved in some countries during the last 11 years, see Table 1.

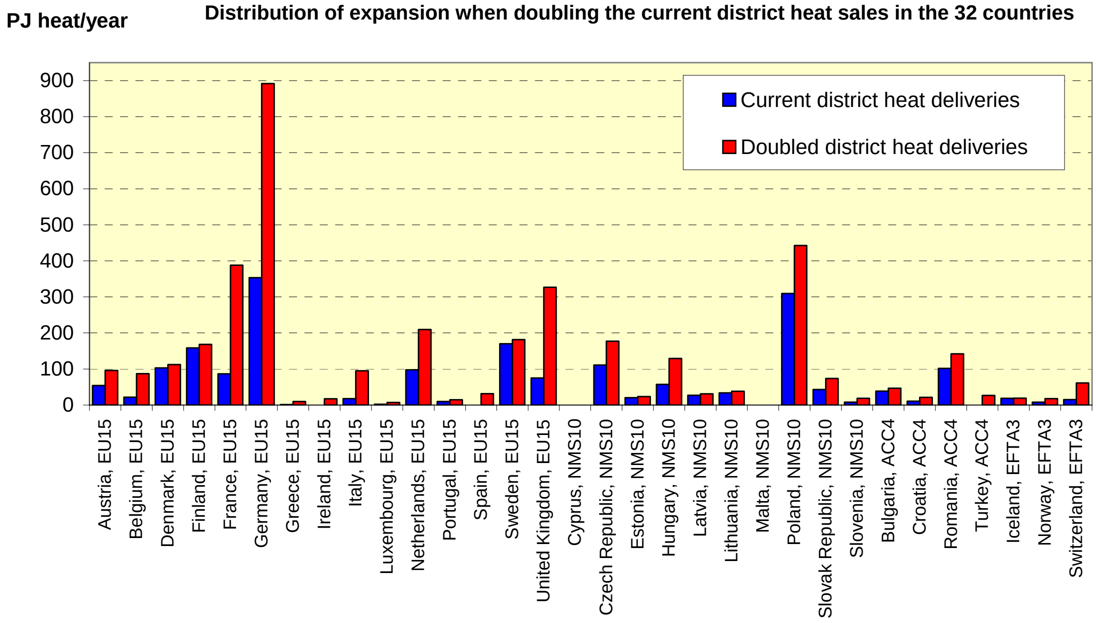

Figure 25. Distribution by country of doubling all heat sales in the whole target area.

6.4 *Investment cost and profitability for doubling heat sales*

The overall profitability of district heating can be simply estimated by just comparing the investment in heat distribution with the annual cost reduction from fossil fuels replaced by district heat. All other infrastructure costs are neglected in this simple estimation. Investments in heat generation are neglected since electricity must be generated, waste must be incinerated in order to reduce future methane emissions from landfills, and industrial processes would need heat, if no district heat were available.

The total investment cost for doubling the heat sales can be estimated to almost 150 billion EUR for the new 1,95 EJ of heat sales in the whole target area. About 40 % of the total investment cost considers the investment in the heat distribution part and the rest considers various heat generation facilities. Hereby, the overall investment in heat distribution networks can be estimated to 60 billion EUR. This estimation is based on the typical total replacement investment of 75 EUR/GJ for Swedish district heating systems. These systems have in average a quite low specific linear heat demand of 13 GJ/m, giving relatively high heat distribution investments.

It should be emphasised that this is not a final consumer cost, but only the required investments to be performed by the district heating companies. An investment is only made if the overall net present value from the investment is positive. Therefore, the consumer costs will not increase from introduction of more district heat. The level of consumer cost for heating is more related to the international crude oil price and the political will to reduce the carbon dioxide emissions, as presented in the section 6.4 in the WP1 report from this Ecoheatcool project.

The simple estimation of the overall profitability is performed in Figure 26. The figure verifies that district heating systems are more profitable at high international energy prices. This estimation of the overall profitability is based on the basic fact that the main alternative to recycled heat losses into district heating systems is import to Europe of natural gas or oil at international market prices.

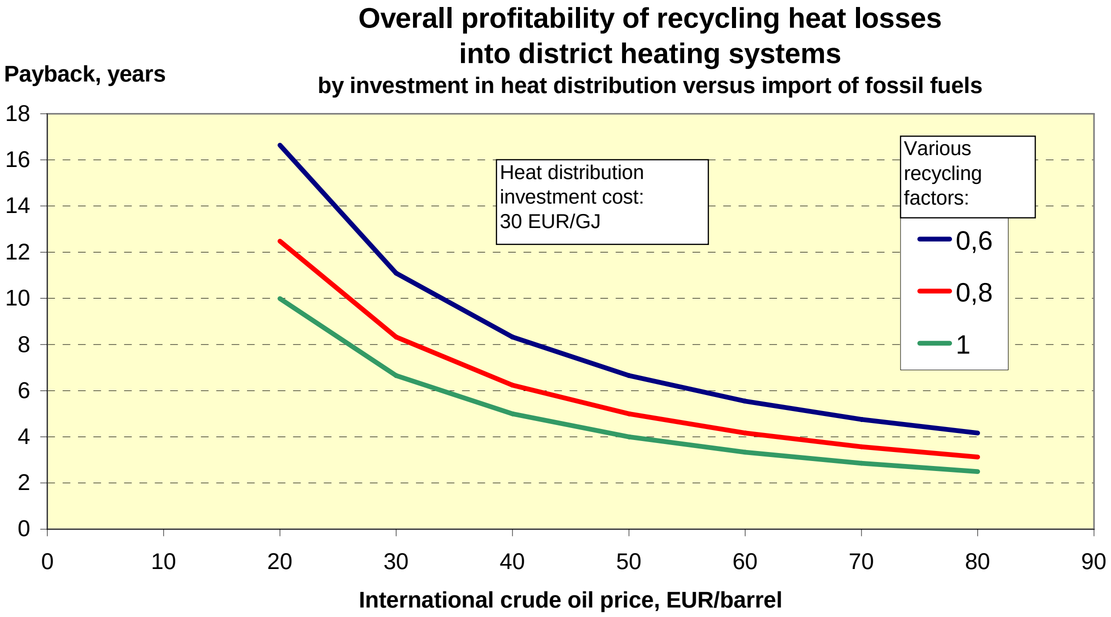

Figure 26. The overall profitability for a district heating system recovering existing heat losses. The analysis is only based on the international crude oil price and the heat distribution investment cost, since the alternative is to use a fossil fuel instead of district heating. The various recycling factors reflect that recycled heat losses cannot cover the whole heat demand in the district heating system. A heat recycling factor of 0,6 means that 60 % of the district heat demand is covered by recycled heat losses and 40 % from fossil fuels.

The annual average international crude oil price has varied between 11 and 50 EUR/barrel during the last 10 years. The average import price has been about 25 EUR/barrel, with the lowest level in 1998 and the highest level in early 2006. The total heat renewable and recycled factor in district heating systems varies among countries as stated in section 3.1 and Figure 6. The European average recycling factor was 0,78 in 2003. Hence, a recovery factor of 0,8 and crude oil price of 50 EUR/barrel will give a simple payback of 5 years for district heating systems in Europe.

Each project based profitability deviates from Figure 26, since other local costs must be added. The customers cannot use crude oil directly, giving extra costs for a refined quality and local transport. National taxes for use of fossil fuels must also be added. The district heating operator must also share the benefits of district heating with the suppliers of heat, as the owner of the CHP plant, the waste incinerator, and the industrial company having surplus heat. The district heating company must also use human resources in order to operate the system. But the base profitability comes always from Figure 26.

6.5 References

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7 Implications from improved and more district heating

In order to communicate the benefits of district heating, the overall import dependency, the energy efficiency, and the corresponding carbon dioxide emissions are quantified for the following three cases:

1. Outcome for 2003, based on the information presented in section 3.1.
2. Improved systems, based on a probable and possible substitution of the heat generation in the current district heating systems. These improvements were suggested in the various sections in chapter 4 and summarised in section 6.2. The total heat sales are unchanged compared to the 2003 outcome.
3. Doubling heat sales, by increasing the heat sales from expansion of existing systems and introduction of new systems. The heat sales are doubled compared to the 2003 outcome and the same heat generation composition is used as used in the improved systems case. Doubling heat sales means that the market share of district heat in all net heat and electricity demands in the industrial, residential, and service sectors in the target area will increase from 6 to 12 %.

The energy supplies for all district heating systems in the whole target area in each case are summarised in the first page of Appendix 2 and in Figure 27. This summary is only available for the whole target area, since detailed reliable national information concerning CHP fuel supply and CHP electricity generation is not available. Therefore, the three benefits can neither be estimated for countries nor for regions.

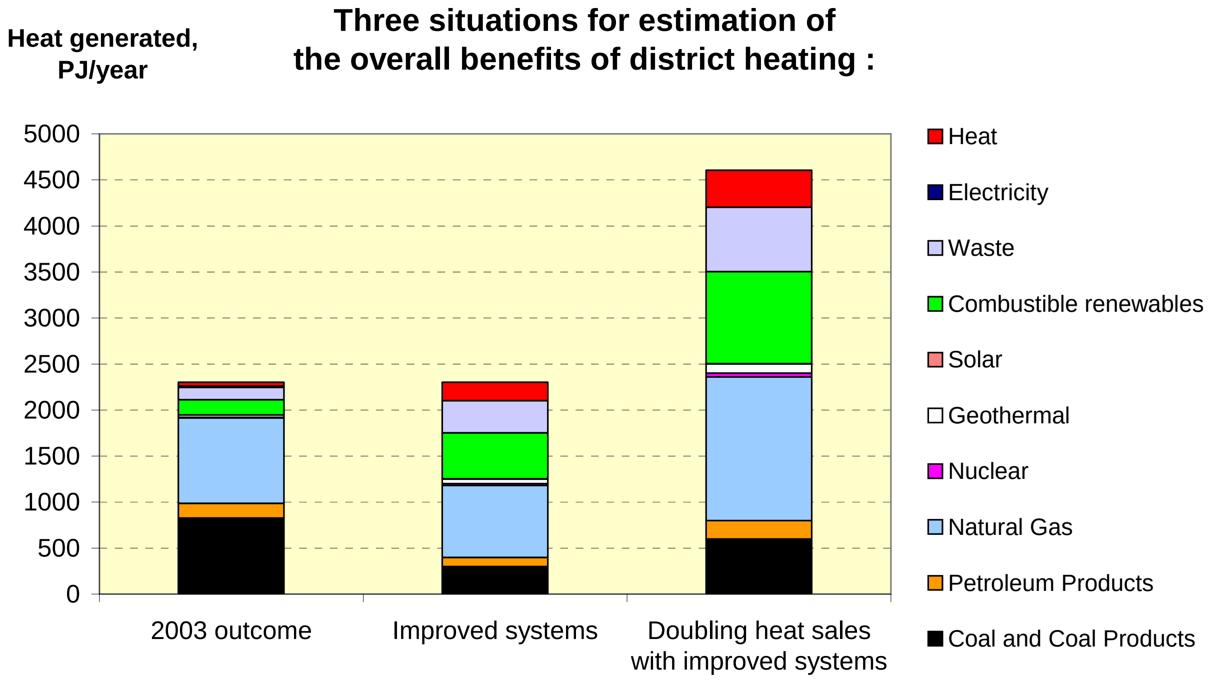

Figure 27. Summary of heat generated in the three situations analysed.

For the 2003 outcome, the conversion efficiencies and power-to-heat ratios have been assumed, since neither the actual fuel supply nor the corresponding electricity generation from CHP plants are known from international energy statistics. The power-to-heat ratios were assumed so that the total estimated electricity generated in Table 3 of 744 PJ was almost reached.

For improved systems, the composition of heat generated are changed with higher shares for nuclear, solar thermal, combustion renewables, and waste incineration and the corresponding lower share for heat from coal, oil, and natural gas. The various fractions of CHP heat and power-to-heat ratios are also increased compared to the 2003 outcome case. The improved systems will get a renewable share of 38 % in the fuel supply, compared to 13 % in the current situation.

For doubling heat sales, all information from the improved systems case is just doubled. Since all estimations are made from the 2003 outcome, no implications are considered from lower future heat sales due to higher energy efficiencies in the buildings connected to district heating systems.

7.1 Security of supply

The security of supply will increase in the improved systems and the doubling heat sales cases, since the total primary energy supply will decrease from more CHP heat and energy production will increase from more use domestic renewable energy resources as geothermal heat, solid biomass, and waste. All estimations concerning the security of supply issue are found in the second page of Appendix 2.

In the 2003 outcome case, the import dependency was estimated to 37,5 %. This dependency is substantially lower than the 50 % normally communicated for the current EU25 and the former EU15 area. This deviation depends on that Norway, a major energy exporter, is a part of the current target area of 32 countries.

In the improved systems case, the import dependency will decrease to 35,9 %. This dependency will further decrease to 32,9 % in the doubling heat sales case, since the overall import dependency will decrease with 4,45 EJ. This change is higher than to the total energy balance of Poland.

These facts show that district heating systems can play an important role in a European strategy for higher security of supply through lower import dependencies.

7.2 Energy efficiency

At doubling heat sales, the overall primary energy supply in the whole target area will decrease with 2,14 EJ, corresponding to a 2,6 % reduction of the total primary energy supply of 81,1 EJ during 2003. This reduction is equivalent to the total energy balance of Sweden. During 2003, district heat sales of 1,95 EJ corresponded to only 3,4 % of all final energy consumption. By improving and doubling this very small share, considerable changes can be implemented on the whole primary energy supply.

This reduction fact was also recognised in the recent EC green paper about energy efficiency (European Commission, 2005), stating that district heating and CHP together "may save 3-4% in primary energy use compared to separate production". But this statement included also all industrial CHP.

7.3 Carbon dioxide emissions

Use of district heat reduces the carbon dioxide emissions by two major reasons: Reuse of heat losses from other activities and use of renewables as biomass or geothermal heat as input to district heating systems. The Nordvärme countries (Denmark, Finland, Iceland, Norway, and Sweden) communicated this fact clearly at the 18th WEC congress in Buenos Aires in 2001, (Gunnarsdottir et al, 2001).

In (Euroheat & Power, 2001), the current avoided carbon dioxide emissions from all district heating and CHP plants in EU15 were estimated to 186 million tons/year. Furthermore, it was stated that doubling the electricity generation from CHP plants according the 1997 CHP communication would increase this reduction with further 194 million tons/year.

In (Werner et al, 2002), the total avoided carbon emissions from all global district heating and CHP were estimated to about 900 million tons per year. This reduction corresponded to 3,8 % all global carbon dioxide emissions from fuel combustion in 1998. The corresponding reduction for EU15 was estimated to 182 million tons, very similar to the Euroheat & Power estimate mentioned above.

The total carbon dioxide emissions from fuel combustion in the target area were 4330 million tons during 2003, according to (IEA, 2005). The corresponding emission was 3890 million tons for the EU25 area.

All estimations concerning the carbon dioxide emissions in the three cases are found in the third page of Appendix 2. The current avoided carbon dioxide emissions due to only district heating and the connected CHP plants are estimated to 113 million tons annually, corresponding to 2,6 % of all carbon dioxide emissions.

If the district heating systems are improved with other energy supply and higher CHP shares, this reduction will increase with further 146 million tons. In the case of doubling heat sales, the total reduction will be 404 million tons/year compared to the 2003 situation. This is a relative reduction of 9,3 %, just above the European Kyoto commitment for 2008-2012. The change corresponds also to the current carbon dioxide emissions from all fuel combustion in France.

Also these facts show that district heating can and should play an important role in a future European strategy for lower carbon dioxide emissions.

7.4 Overall primary resource factors

Within Work Package 3 in the Ecoheatcool project, the primary resource factor was defined for district heating systems (Ecoheatcool, 2005).

Based on the energy supply composition in Appendix 2, the overall primary resource factor for the whole target area can be estimated to 0,80 for the 2003 outcome. This primary resource factor reveals that district heating systems are still dependent of fossil fuels and have a rather low overall power-to-heat ratio of 0,33.

The primary resource factor for improved European district heating systems as defined in Appendix 2 can be estimated to 0,00, revealing that the improved district heating systems will have no net use primary energy resources at all. This reduction of the primary resource factor is achieved by increasing the heat supply from renewables, recycled heat, and a higher overall power-to-heat ratio.

7.5 References

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8 Conclusions

International energy statistics

Currently, international energy statistics do not describe heat flows properly with respect to heat deliveries, fuel supply for cogeneration modes in CHP plants, energy supply, and recovery of industrial surplus heat. Therefore, estimation of the benefits of district heating cannot be completely based on international energy statistics due to missing or inadequate information. In order to estimate the overall benefits, some assumptions are still needed.

International energy statistics have really improved the heat parts during the last 10-15 years, but the current statistical information about heat has still the following flaws:

- In Italy, the whole district heating sector is missing
- In France, only one third of the district heating sector is reported.
- In Iceland, only the Reykjavik system is included. All other district heating systems are classified as geothermal direct use in each consuming sector.
- In Germany, the whole district heating sector is mostly missing or wrong in the Eurostat databases. All non-industrial district heat use is classified as residential use in the IEA Energy Balances, ignoring proper allocation of district heat use between the residential and service sectors.
- Electricity generation and fuel supply are not consistently allocated to condensing and cogeneration modes for CHP plants. Eurostat has been working on this issue for some years. Eurostat have so far only succeeded to allocate electricity generation, but not fuel supply.
- Recycling of industrial surplus heat into district heating systems is not reported
- Use of geothermal heat for distribution in district heating systems is only reported for some countries.

Each national statistical body can only eliminate these flaws, since they provide the national energy statistics to Eurostat and IEA. Each national district heating community should therefore inform the responsible statistical body about the current situation. The whole European district heating community have a responsibility to inform Eurostat and IEA about the current flaws about district heating in international energy statistics.

Improvement of international energy statistics with respect to district heating is important, since most international analyses by universities and research institutes use the databases of Eurostat and IEA. If district heating is not reported correctly, less attention will be directed to district heat.

Current energy supply for district heating

The share of renewables is higher in district heat supply (14 %) compared to the overall primary energy supply (7 %). Hence, the district heating sector already fulfils the EU ambition of a 12 % share in 2010. Many national district heating sectors fulfils already the new EREC ambition of an overall renewable share of 20 % in 2020. This implies that district heating systems can be an efficient tool for the ambition of increasing the renewable share in the European energy supply.

The share of heat from CHP plants was 68 %, which mainly can be improved by using more CHP heat in France, Sweden, and in the NMS10 countries.

The combined average share of renewables and heat recycled from electricity generation and industrial surplus heat was 78 % during 2003. This implies the fundamental idea of district heating is fulfilled to a high degree in Europe. Only 22 % of all district heat generated came from heat only generation from fossil fuels. This fraction can be reduced mainly in NMS10 countries.

Strategic heat source options

The presentation of the five major strategic heat source options (CHP, waste incineration, industrial surplus heat, geothermal heat, and biomass) shows that the total available magnitude of these sources (about 400 EJ/year) is much higher than the current district heat generated (2,3 EJ/year) and the total net heat demand (20,8 EJ/year) in the industrial, residential, and service sectors. The highest potential appears for the geothermal heat (370 EJ/year), while significant resources are available for CHP (15 EJ/year) and biomass (13-18 EJ/year). Further resources appear both in waste incineration (2 EJ/year) and industrial surplus heat (1 EJ/year).

Minor heat flows can appear also with respect to solar heat, nuclear heat, and heat recovered by large heat pumps.

Institutional and market barriers

No general overview is currently available for various institutional and market barriers preventing or mechanisms supporting expansion of district heating in Europe. Available information are scattered in several different documents. In order to understand the complete situation, the European district heating community should perform an all-European survey of major barriers for district heating.

Potential for expansion

The analysis shows that district heating can expand in the European energy system with respect both to available heat resources and existing heat demands. The identified additional possible heat market for district heating has been estimated to 6,8 EJ/year, or 3,4 times higher than the current district heat sales.

The analysis shows (according to Figure 28) that the smaller countries in the target area have a more diversified energy supply and more pronounced district heat sectors. This fact implies that local energy solutions as district heating systems are not recognised as possibilities in large countries. The explanation for this fact needs to be discussed. It seems that the large EU countries can learn from successful experiences obtained in the smaller countries.

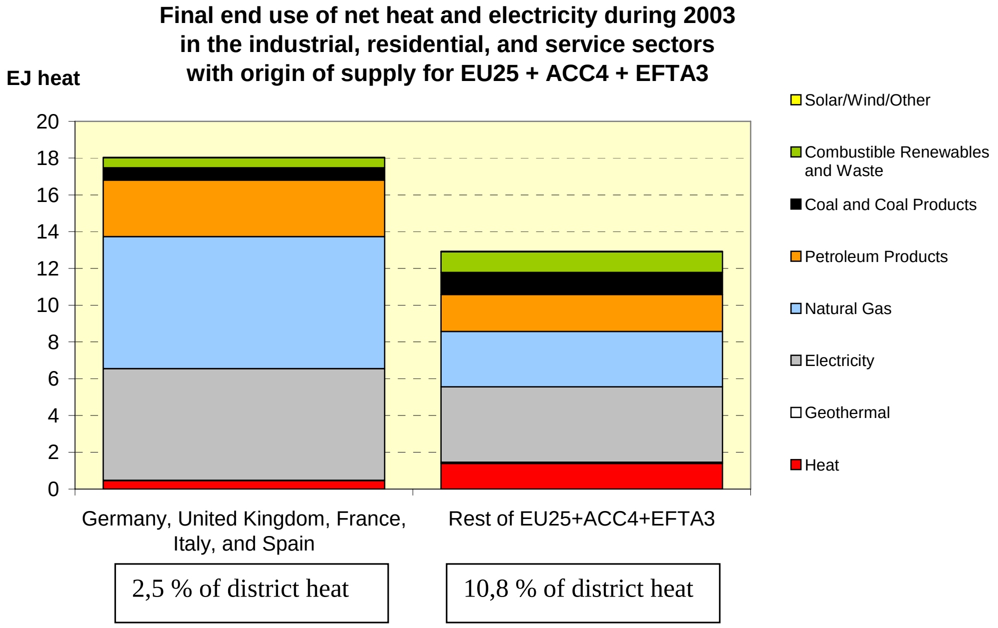

Figure 28. Comparison of the composition of the net heat and electricity demand in the five largest energy economies and the 27 remaining countries in the target area. The total final demand amounted to 31,0 EJ, excluding the agricultural and transportation sectors.

About half of the total remaining district heat potential appears in Germany, France, and United Kingdom. These three large countries have currently no or little annual growth of district heat delivered. Hence, barriers for district heating in these countries have a major impact for the future possibilities for use more district heat in Europe.

Overall benefits

The overall benefits with district heating systems are:

- **Higher energy efficiency**, since primary energy supply for local heat demands are mainly replaced with recycling of heat losses from the energy system. The current benefit is 0,9 EJ/year, reducing the overall primary energy supply from 82,0 to 81,1 EJ/year. If the current district heating systems are improved and heat sales are doubled, this benefit will increase to 3,0 EJ/year. The possible reduction of 2,14 EJ/year is equivalent to the whole annual energy balance of Sweden.
- **Higher security of supply**, since imports of fossil fuels are reduced and use of domestic renewable resources are increased when district heating systems are improved and district heat sales are doubled. This combined effect will reduce the current import dependency with 4,45 EJ, or 5,5 % of all primary energy supply. This is more than the whole energy balance for Poland.
- **Lower carbon dioxide emissions**, since fossil primary energy supply is reduced from improved and doubling district heat sales. Currently, the avoided carbon dioxide emissions from district heating in the target area can be estimated to 113 million tons annually. These avoided emissions can increase to 516 millions tons, if the district heating systems are improved and district heat sales doubled. The reduction will be 404 million tons annually, corresponding to 9,3 % of all carbon dioxide emissions from fuel combustion in the target area (4330 million tons). This reduction is also slightly more than all annual carbon dioxide emissions from fuel combustion in France.

Final conclusion

Currently, just above 5000 district heating systems exist in the target area. Many of them are classified as small and medium-sized enterprises (SME). Their staffs know how to operate the systems and are very familiar with the local users and their heat demands. If changes have to be implemented in the European district heating systems, mainly existing organisations, technologies, and business models can be utilised. There is no need for completely new organisations, new technologies, or new business models in order to obtain higher energy efficiency, higher security of supply, and lower carbon dioxide emissions by improving district heat generation and doubling district heat sales. However, an extensive dissemination program can be needed in order to transfer vital knowledge between countries and between district heating systems.

Appendix 1. Detail information

Table 7. Energy supply composition for district heat generated during 2003 in PJ heat.

Country	Label	Group	Coal and Coal Products	Petroleum Products	Natural Gas	Nuclear	Geothermal	Solar/Wind/ Other	Combustible renewables	Waste	Electricity	Heat	Total
Austria	AT	EU15	3,5	8,1	28,0	0,0	0,4	0,0	11,8	3,6	0,0	0,0	55
Belgium	BE	EU15	0,0	0,0	21,1	0,0	0,0	0,0	0,1	1,8	0,0	0,0	23
Bulgaria	BG	ACC4	25,4	2,1	25,8	0,7	0,0	0,0	0,0	0,0	0,0	0,0	54
Croatia	HR	ACC4	0,0	3,9	9,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	13
Cyprus	CY	NMS10	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0
Czech Repu	CZ	NMS10	96,6	6,7	38,6	0,0	0,0	0,0	2,6	2,7	0,0	0,0	147
Denmark	DK	EU15	36,9	7,9	41,9	0,0	0,1	0,1	20,1	22,9	0,0	0,1	130
Estonia	EE	NMS10	8,1	2,6	11,9	0,0	0,0	0,0	3,0	0,0	0,0	0,0	26
Finland	FI	EU15	70,2	13,2	47,6	0,0	0,0	0,0	30,8	8,5	0,1	0,0	170
France	FR	EU15	14,0	14,0	52,8	0,0	4,4	0,0	1,3	18,3	2,4	1,7	109
Germany	DE	EU15	132,3	16,3	211,3	0,0	0,4	0,0	0,0	26,6	0,0	3,7	391
Greece	GR	EU15	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1
Hungary	HU	NMS10	12,4	3,7	46,4	0,7	0,3	0,0	0,2	0,4	0,0	0,0	64
Iceland	IS	EFTA3	0,0	0,0	0,0	0,0	19,3	0,0	0,0	0,1	0,6	0,0	20
Ireland	IE	EU15	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0
Italy	IT	EU15	2,4	1,4	12,3	0,0	0,5	0,0	0,7	1,9	0,2	0,3	20
Latvia	LV	NMS10	0,6	2,6	25,5	0,0	0,0	0,0	4,8	0,0	0,0	0,0	34
Lithuania	LT	NMS10	0,3	5,4	32,6	2,2	0,1	0,0	3,8	0,0	0,0	0,0	44
Luxembour	LU	EU15	0,0	0,0	1,9	0,0	0,0	0,0	0,1	0,0	0,0	0,0	2
Malta	MT	NMS10	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0
Netherlands	NL	EU15	4,8	2,3	99,7	0,0	0,0	0,0	0,2	7,8	0,0	0,0	115
Norway	NO	EFTA3	0,4	2,1	0,3	0,0	0,0	0,0	0,8	6,0	0,7	0,5	11
Poland	PL	NMS10	335,5	8,8	20,2	0,0	0,0	0,0	2,8	0,9	0,0	0,0	368
Portugal	PT	EU15	0,0	3,1	6,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	9
Romania	RO	ACC4	32,6	34,4	83,2	0,0	0,0	0,0	0,5	0,1	0,0	0,0	151
Slovak Rep	SK	NMS10	12,0	0,9	39,4	2,0	0,1	0,0	0,7	0,3	0,0	0,0	56
Slovenia	SI	NMS10	5,9	0,2	3,1	0,0	0,0	0,0	0,4	0,0	0,0	0,0	10
Spain	ES	EU15	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0
Sweden	SE	EU15	18,5	15,1	8,0	0,0	0,0	0,0	77,7	21,2	9,0	35,8	185
Switzerland	CH	EFTA3	0,0	0,0	6,5	0,9	0,0	0,0	0,0	12,0	0,2	0,0	20
Turkey	TR	ACC4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0
United Kin	UK	EU15	13,7	5,3	54,2	0,0	0,0	0,0	2,1	0,0	0,0	0,0	75
		total	827	160	928	6	26	0	165	135	13	42	2302
			36%	7%	40%	0%	1%	0%	7%	6%	1%	2%	100%

Table 8. Energy supply composition for district heat generated during 2003 by percent.

Country	Coal and Coal Products	Petroleum Products	Natural Gas	Nuclear	Geothermal	Solar/Wind /Other	Combustible renewables	Waste	Electricity	Heat
Austria, EU15	6%	15%	51%	0%	1%	0%	21%	6%	0%	0%
Belgium, EU15	0%	0%	92%	0%	0%	0%	0%	8%	0%	0%
Denmark, EU15	28%	6%	32%	0%	0%	0%	16%	18%	0%	0%
Finland, EU15	41%	8%	28%	0%	0%	0%	18%	5%	0%	0%
France, EU15	13%	13%	48%	0%	4%	0%	1%	17%	2%	2%
Germany, EU15	34%	4%	54%	0%	0%	0%	0%	7%	0%	1%
Italy, EU15	12%	7%	63%	0%	2%	0%	4%	10%	1%	1%
Luxembourg, EU15	0%	0%	96%	0%	0%	0%	4%	0%	0%	0%
Netherlands, EU15	4%	2%	87%	0%	0%	0%	0%	7%	0%	0%
Portugal, EU15	0%	33%	67%	0%	0%	0%	0%	0%	0%	0%
Sweden, EU15	10%	8%	4%	0%	0%	0%	42%	11%	5%	19%
United Kingdom, EU15	18%	7%	72%	0%	0%	0%	3%	0%	0%	0%
Czech Republic, NMS10	66%	5%	26%	0%	0%	0%	2%	2%	0%	0%
Estonia, NMS10	32%	10%	46%	0%	0%	0%	12%	0%	0%	0%
Hungary, NMS10	19%	6%	72%	1%	0%	0%	0%	1%	0%	0%
Latvia, NMS10	2%	8%	76%	0%	0%	0%	14%	0%	0%	0%
Lithuania, NMS10	1%	12%	73%	5%	0%	0%	9%	0%	0%	0%
Poland, NMS10	91%	2%	5%	0%	0%	0%	1%	0%	0%	0%
Slovak Republic, NMS10	22%	2%	71%	4%	0%	0%	1%	1%	0%	0%
Slovenia, NMS10	61%	2%	33%	0%	0%	0%	4%	0%	0%	0%
Bulgaria, ACC4	47%	4%	48%	1%	0%	0%	0%	0%	0%	0%
Croatia, ACC4	0%	30%	70%	0%	0%	0%	0%	0%	0%	0%
Romania, ACC4	22%	23%	55%	0%	0%	0%	0%	0%	0%	0%
Iceland, EFTA3	0%	0%	0%	0%	97%	0%	0%	0%	3%	0%
Norway, EFTA3	4%	20%	3%	0%	0%	0%	7%	56%	6%	4%
Switzerland, EFTA3	0%	0%	33%	5%	0%	0%	0%	61%	1%	0%

Table 9. Renewable shares, CHP heat shares, and combined shares for heat generated for countries.

Country	Renewable share	CHP share	Total renewable and recycled share
Austria, EU15	29%	65%	87%
Belgium, EU15	8%	99%	100%
Denmark, EU15	33%	81%	96%
Finland, EU15	23%	76%	83%
France, EU15	22%	32%	56%
Germany, EU15	7%	81%	85%
Italy, EU15	16%	64%	77%
Luxembourg, EU15	4%	100%	100%
Netherlands, EU15	7%	100%	100%
Portugal, EU15	0%	100%	100%
Sweden, EU15	53%	33%	87%
United Kingdom, EU1	3%	100%	100%
Czech Republic, NMS	4%	76%	77%
Estonia, NMS10	12%	40%	52%
Hungary, NMS10	1%	69%	69%
Latvia, NMS10	14%	45%	59%
Lithuania, NMS10	9%	52%	59%
Poland, NMS10	1%	61%	61%
Slovak Republic, NM	2%	54%	56%
Slovenia, NMS10	4%	69%	72%
Bulgaria, ACC4	0%	78%	78%
Croatia, ACC4	0%	74%	74%
Romania, ACC4	0%	74%	74%
Iceland, EFTA3	97%	20%	97%
Norway, EFTA3	63%	34%	72%
Switzerland, EFTA3	61%	71%	99%
Total	14%	68%	78%

Table 10. Renewable shares, recycled heat shares (including non-renewable CHP shares), and combined shares for heat generated for regions

Region	Renewable heat, PJ	Recycled heat, PJ	Total heat generated, PJ	Renewable share	Recycled share	Total renewable and recycled share
EU15	263	844	1285	20%	66%	86%
NMS10	23	458	748	3%	61%	64%
ACC4	1	163	218	0%	75%	75%
EFTA3	38	8	50	76%	16%	92%
EU25+ACC4+EFTA3	325	1473	2301	14%	64%	78%

Table 11. Treatment of municipal waste in 2002. Source: Eurostat online database 2005. Missing information from Luxembourg, Croatia, and Switzerland.

Country	Incineration	Landfill	Reuse & Recycle	Municipal waste, millions of tons
Austria, EU15	11%	32%	57%	4,6
Belgium, EU15	34%	12%	53%	4,8
Denmark, EU15	56%	6%	38%	3,6
Finland, EU15	9%	66%	25%	2,3
France, EU15	34%	39%	27%	33,0
Germany, EU15	22%	21%	56%	52,8
Greece, EU15	0%	91%	9%	4,6
Ireland, EU15	0%	80%	20%	2,5
Italy, EU15	9%	62%	29%	29,9
Luxembourg, EU15	0%	0%	0%	0,0
Netherlands, EU15	32%	8%	60%	9,9
Portugal, EU15	20%	73%	6%	4,6
Spain, EU15	6%	55%	39%	26,6
Sweden, EU15	40%	20%	40%	4,2
United Kingdom, EU15	8%	78%	15%	35,5
Cyprus, NMS10	0%	90%	10%	0,5
Czech Republic, NMS10	14%	74%	12%	2,8
Estonia, NMS10	0%	80%	20%	0,5
Hungary, NMS10	7%	91%	2%	4,3
Latvia, NMS10	12%	138%	-50%	0,5
Lithuania, NMS10	0%	100%	0%	1,0
Malta, NMS10	0%	101%	-1%	0,2
Poland, NMS10	0%	97%	3%	10,5
Slovak Republic, NMS10	10%	78%	12%	1,5
Slovenia, NMS10	1%	81%	18%	0,9
Bulgaria, ACC4	0%	100%	0%	3,2
Croatia, ACC4	0%	0%	0%	0,0
Romania, ACC4	0%	98%	2%	6,9
Turkey, ACC4	0%	97%	3%	25,4
Iceland, EFTA3	3%	84%	13%	0,3
Norway, EFTA3	31%	30%	40%	1,6
Switzerland, EFTA3	0%	0%	0%	0,0
EU15	18%	46%	36%	218,9
NMS10	4%	91%	5%	22,7
ACC4	0%	97%	3%	35,4
EFTA3	26%	38%	36%	1,9
Total	15%	56%	29%	279,0

Table 12. Net annual incremental of the forest growing stock. Main source: (FAO, 2002) concerning the forest growing stock.

Country	Label	Group	Growing stock	Net annual increment		TPES of Combustible Renewables	Population
			million m3 o b	million m3 o b	net growth	PJ	million
Austria	AT	EU15	1037	27,3	2,6%	136,7	8,1
Belgium	BE	EU15	140	5,1	3,6%	23,3	10,4
Bulgaria	BG	ACC4	401	10,2	2,5%	28,6	7,8
Croatia	HR	ACC4	338	7,1	2,1%	16,0	4,4
Cyprus	CY	NMS10	3	0	0,0%	0,3	0,7
Czech Repu	CZ	NMS10	668	20,4	3,1%	41,9	10,2
Denmark	DK	EU15	54	3,2	5,9%	56,4	5,4
Estonia	EE	NMS10	307	7,1	2,3%	21,7	1,4
Finland	FI	EU15	1867	72,5	3,9%	289,8	5,2
France	FR	EU15	2836	92,3	3,3%	410,6	59,8
Germany	DE	EU15	2820	89	3,2%	279,8	82,5
Greece	GR	EU15	140	3,5	2,5%	39,6	11,0
Hungary	HU	NMS10	295	9,9	3,4%	32,7	10,1
Iceland	IS	EFTA3	0	0	0,0%	0,0	0,3
Ireland	IE	EU15	43	3,5	8,1%	7,1	4,0
Italy	IT	EU15	877	18,7	2,1%	79,3	57,6
Latvia	LV	NMS10	409	11,1	2,7%	53,0	2,3
Lithuania	LT	NMS10	314	8,5	2,7%	28,3	3,5
Luxembour	LU	EU15	20	0,7	3,5%	0,8	0,4
Malta	MT	NMS10				0,0	0,4
Netherlands	NL	EU15	52	2,2	4,2%	26,3	16,2
Norway	NO	EFTA3	671	22	3,3%	55,5	4,6
Poland	PL	NMS10	1771	39,4	2,2%	197,7	38,2
Portugal	PT	EU15	188	12,9	6,9%	111,1	10,4
Romania	RO	ACC4				119,0	21,7
Slovak Rep	SK	NMS10	446	12,3	2,8%	12,6	5,4
Slovenia	SI	NMS10	293	6,1	2,1%	19,3	2,0
Spain	ES	EU15	487	28,6	5,9%	187,0	41,9
Sweden	SE	EU15	2567	85,4	3,3%	341,6	9,0
Switzerland	CH	EFTA3	353	8,2	2,3%	25,0	7,3
Turkey	TR	ACC4				242,1	70,7
United Kin	UK	EU15	293	14,6	5,0%	90,5	59,4
			19690	**622**	**3,2%**	**2974**	**572,5**

Appendix 2. Estimation of overall benefits for improved systems and doubling heat sales

Heat, power and fuel balance for the three cases analysed 2006-03-10
Ecoheatcool, Sven Werner, Chalmers

Outcome for 2003

	Heat generated, PJ	Conversion efficiency	Fraction of CHP	Power-to-heat ratio	Power generated, PJ	Fuel for heat, PJ	Fuel for power, PJ	Avoided fuel for power, PJ (by alt.)	Avoided fuel for heat, PJ
Coal and Coal Products	827	85%	76%	0,42	265	973	312	-1903	
Petroleum Products	160	85%	60%	0,5	48	188	56		-958
Natural Gas	928	90%	71%	0,6	392	1031	436	-1315	-1496
Nuclear	6								
Geothermal	26					26			
Solar	0					0			
Combustible renewables	164	85%	55%	0,36	33	194	38		
Waste	135	80%	75%	0,24	24	169	31		
Electricity	13				-13				
Heat	42								
Total generated	2302		68%	0,33	749	2580	873		-2454
Distribution losses	-283		(1574 PJ)		(208 TWh)				
Heat sold and own use	2019								
Carbon dioxide emissions, Mton									
With gas combined cycle condensing as avoided power						162	58	-74	-156
With coal condensing as avoided power						162	58	-177	-156

Improved systems

	Heat generated, PJ	Conversion efficiency	Fraction of CHP	Power-to-heat ratio	Power generated, PJ	Fuel for heat, PJ	Fuel for power, PJ	Avoided fuel for power, PJ (by alt.)	Avoided fuel for heat, PJ
Coal and Coal Products	300	85%	100%	0,5	150	353	176	-2699	
Petroleum Products	100	85%	70%	0,5	35	118	41		-958
Natural Gas	780	90%	100%	0,8	624	867	693	-1865	-1496
Nuclear	20								
Geothermal	50					50			
Solar	2					2			
Combustible renewables	500	85%	85%	0,4	170	588	200		
Waste	350	80%	80%	0,3	84	438	105		
Electricity	0								
Heat	200								
Total generated	2302		81%	0,46	1063	2415	1216		-2454
Distribution losses	-283		(1855 PJ)		(295 TWh)				
Heat sold and own use	2019								
Carbon dioxide emissions, Mton									
With gas combined cycle condensing as avoided power						90	58	-104	-156
With coal condensing as avoided power						90	58	-251	-156

Doubling heat sales

	Heat generated, PJ	Conversion efficiency	Fraction of CHP	Power-to-heat ratio	Power generated, PJ	Fuel for heat, PJ	Fuel for power, PJ	Avoided fuel for power, PJ (by alt.)	Avoided fuel for heat, PJ
Coal and Coal Products	600	85%	100%	0,5	300	706	353	-5398	
Petroleum Products	200	85%	70%	0,5	70	235	82		-1916
Natural Gas	1560	90%	100%	0,8	1248	1733	1387	-3730	-2993
Nuclear	40								
Geothermal	100					100			
Solar	4					4			
Combustible renewables	1000	85%	85%	0,4	340	1176	400		
Waste	700	80%	80%	0,3	168	875	210		
Electricity	0								
Heat	400								
Total generated	4604		81%	0,46	2126	4830	2432		-4908
Distribution losses	-566		(3710 PJ)		(591 TWh)				
Heat sold and own use	4038								
Carbon dioxide emissions, Mton									
With gas combined cycle condensing as avoided power						180	117	-209	-311
With coal condensing as avoided power						180	117	-502	-311

Supply balances for the three cases

Supply balances, PJ	Outcome for 2003		Improved systems		Doubling heat sales	
	CC gas cond. as avoided power	Coal cond. as avoided power	CC gas cond. as avoided power	Coal cond. as avoided power	CC gas cond. as avoided power	Coal cond. as avoided power
Coal and Coal Products	1285	1285	529	529	1059	1059
Petroleum Products	245	245	159	159	318	318
Natural Gas	1467	1467	1560	1560	3120	3120
Nuclear	0	0	0	0	0	0
Geothermal	26	26	50	50	100	100
Solar	0	0	2	2	4	4
Combustible renewables	232	232	788	788	1576	1576
Waste	199	199	543	543	1085	1085
Total primary energy supply	3454	3454	3631	3631	7262	7262
Domestic renewable supply	457	457	1383	1383	2765	2765
Renewable fraction	*13,2%*	*13,2%*	*38,1%*	*38,1%*	*38,1%*	*38,1%*
Avoided heat and power						
Avoided heat, gas	-1496	-1496	-1496	-1496	-2993	-2993
Avoided heat, oil	-958	-958	-958	-958	-1916	-1916
Avoided power, gas	-1315		-1865		-3730	
Avoided power, coal		-1903		-2699		-5398
Total	-3769	-4357	-4319	-5153	-8638	-10306
Net benefit	-315	-903	-688	-1522	-1376	-3044
	-8%	*-21%*	*-16%*	*-30%*	*-16%*	*-30%*
Total production 2003	50696	50696	50696	50696	50696	50696
Change of domestic production	0	0	926	926	2309	2309
Total production after change	50696	50696	51622	51622	53004	53004
Total primary energy supply 2003	81100	81100	81100	81100	81100	81100
Change of primary energy supply	0	0	-373	-619	-1061	-2141
Primary energy supply after change	81100	81100	80727	80481	80039	78959

Security of supply

Import dependency, PJ	30404	30404	29105	28859	27034	25954
Change, PJ	0	0	-1299	-1545	-3370	-4450
Relative import dependency	**37,5%**	**37,5%**	**36,1%**	**35,9%**	**33,8%**	**32,9%**
Change			**-1,4%**	**-1,6%**	**-3,7%**	**-4,6%**

Energy efficiency

Primary energy supply, PJ	81100	81100	80727	80481	80039	78959
Change, PJ	0	0	-373	-619	-1061	-2141
Change, percent	**0,0%**	**0,0%**	**-0,5%**	**-0,8%**	**-1,3%**	**-2,6%**

Carbon dioxide emissions

Net total emissions from heat generation, Mton	Outcome for 2003	Improved systems	Doubling heat sales
With direct fuel allocation	162	90	180
With gas combined cycle condensing as avoided power	146	44	88
With coal condensing as avoided power	43	-102	-205
Mix of natural gas and fuel oil as market alternative, Mton	156	156	311
Total avoided carbon dioxide emissions with DH, Mton			
With direct fuel allocation	-7	65	131
With gas combined cycle condensing as avoided power	9	112	223
With coal condensing as avoided power	113	258	516
Change of avoided carbon dioxide emissions compared to 2003, Mton			
With direct fuel allocation		72	138
With gas combined cycle condensing as avoided power		102	214
With coal condensing as avoided power		146	404
Relative change compared to all carbon dioxide emissions (4330 Mton) in the target area during 2003			
With direct fuel allocation		1,7%	3,2%
With gas combined cycle condensing as avoided power		2,4%	4,9%
With coal condensing as avoided power		3,4%	9,3%
Net specific carbon dioxide emissions, g CO2/MJ heat			
With direct fuel allocation	80	45	45
With gas combined cycle condensing as avoided power	73	22	22
With coal condensing as avoided power	21	-51	-51
With natural gas as alternative for heating	66		
With light fuel oil as alternative for heating	96		
Heat sales and own use, PJ/year	2019	2019	4038