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The European heat market of the future

The role of CHP and district heating in Europe

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1 Introduction

The future development of the European electricity market in the EU 30 is characterised by the process of liberalisation and the goal of climate change protection. Several measures have been initiated on European or national levels to combat climate change, e.g. emission trading, promotion of renewables or national quotas or targets for electricity production out of CHP. In the context of these measures a large amount of power plants in Europe has to be replaced within the next two decades. The chances of building up new and additional CHP capacities depend on the national situation and on the potentials in the local heat market. This might be influenced by insulation requirements and the opportunity to build up additional local and district heating systems, respectively.

The objective of the DIRECTIVE ON PROMOTION OF COGENERATION BASED ON A USEFUL HEAT DEMAND IN THE INTERNAL ENERGY MARKET (2004/8/EC) is to increase energy efficiency and improve security of supply by creating a framework for promotion and development of high efficiency cogeneration of heat and power (CHP) based on useful heat demand and primary energy savings in the internal energy market, taking into account the specific national circumstances especially concerning climatic and economic conditions. In the short term the intention of the Directive is to support existing CHP installations and create a level playing field in the market. The Directive provides harmonisation of definitions of CHP, efficiencies, micro/small scale CHP etc. and it establishes a framework in order to issue guarantees of origin for electricity coming from (or generated by) CHP.

On May 31, 2002 the European Union ratified the Kyoto protocol to the United Nations Framework Convention on Climate Change (UNFCCC) as another step forward in coming into force. Within the first period of commitment between 2008 and 2012 the European Union has to fulfil the obligation to reduce total emissions of

greenhouse gases (GHGs) by 8 % relative to the reference year (i.e. 1990). This obligation was allocated between the member states of the European Union according to their respective capabilities in a burden sharing agreement.

The guideline of the European Union for emission certifications trading offers a novel approach for further emission reductions. This guideline passed the European Parliament on a second reading on July 2, 2003 and planned on introducing two trading steps for the periods of 2005 to 2007 and/or of 2008 to 2012. In this context, the European Union has already begun trading emission allowances for greenhouse gases in 2005. In some countries (for example in Austria and Germany) additional emission permit have been taken for CHP plants. Without any heat credits especially CHP plants with a size greater than 20 MW_{el} have disadvantages under an emission trading regime.

The promotion of renewable energy projects is an avowed target of national governments and the European Union. With the EU Renewable Directive 2001/77/EC the National indicative targets of the gross electricity consumption from renewable energy sources in the year 2010 are given. There are no distinctions between energy carrier and technology in this Directive.

At the moment, the different directives' influence on the future development of CHP is not clear. Therefore, the long term development of the European electricity market and public heat supply is subject of a closer investigation with the regionalised EU 30 Electricity and Gas Supply model **TIMES-EG**.

2 The Model TIMES-EG

The European Electricity and Gas Supply model **TIMES-EG** is a technically oriented model which illustrates in detail the electricity supply industry of the EU-30 member states for the period from 2000 to 2030. Furthermore, CHP plants are also considered within the model. The different basic conditions of the different regions are seized through regionally differentiated parameters such as fuel prices, data for the potentials of renewable energy sources and region characteristic load curves for the different customer groups (residential, commercial, energy-intensive and energy-extensive industry, traffic). Not only the energy flows but also the energy-related greenhouse gas emissions are modelled. Thus, it is possible to analyse the potential of an emission trading scheme.

Figure 1: Regional coverage of TIMES EG

It is assumed that in the sense of a complete competition within the European electricity market the total costs for the entire regarded region are to be minimized. In order to simulate the economical behaviour of the enterprises, a real discount rate of 10 % is used. Restricted by the technical parameters of the plants, the enterprises' decision is made based on economic values. By coupling different regions an inter-regional competition structure arises (see figure 1). This leads to an electricity exchange within the system whenever the difference of the marginal costs of covering the load in a certain load segment at a certain time is larger than the total costs for transmission and transmission losses. By this the national competition is assigned to the inter regional competition markets.

3 Scenario analysis of the European Public Power and heat Supply

In order to analyse the role of CHP and district heat (DH) within the European electricity market the reference scenario is compared with two scenarios aiming for a reduction target and one scenario aiming for a renewable target.

In the reference scenario (**REF**) the assumption is that national policies will be continued in the future. These policies include the promotion of CHP, renewable

technologies or the decision about the national future of nuclear power. In the reference scenario it is assumed, that the national phase out agreements are valid and that other European countries which still support the use of nuclear power today can also build up plants in the future.

In two CO_2 reduction scenarios (**RED_ELEC** and **FLEX**) it is assumed that the Kyoto target is assigned to the electricity and heat production sector in the same share as for the whole energy system. Beyond the Kyoto target, in the period between 2010 and 2030, it is assumed that additional 9 % of the CO_2 emission must be reduced for the whole EU25. At the moment the emission trading system more or less has not foreseen the possibility of CO_2 reduction of CHP plants in the residential sector. To analyse this effect, in the scenario ELEC_RED the emission targets have to be met without any contribution of the residential sector in contrast to scenario FLEX, where CO_2-reductions based on CHP plants in the residential sector are taken into account to fulfil the reduction target.

In case of the renewables (oder: renewable sources) scenario the national targets of the individual countries are translated in a common EU25 target, in which a certain portion of the electricity production from renewable energies is reached (**EU_RES**) for the entire EU. To make a projection until the year 2030 the renewable targets of the European Union is updated with the same growth rate as between the year 1995 and the target value of the year 2010. In this case, the implicit assumption of an open and well functioning market for green certificates is made, and the portion reached in each country is not a default but a distinct result of the scenario calculation. For this scenario the policy assumption is that the total amount of subsidies for renewable electricity generation (feed-in tariffs, investment contributions, and reduced interest rates) is at the same level as in the reference scenario. The additional share of renewables will be achieved by a quota which triggers an EU25 certificate system.

The results of this scenario analysis are shown in figure 2. Based on the increasing electricity demand the electricity generation grows by 26.8 % until the year 2010 or by approx. 56.8% until the year 2030 compared with the year 2000. The electricity generation in the reference scenario is mainly based on coal (hard coal and lignite) with a share of 47 % in the year 2030. In the case of CO_2 emission targets the electricity generation by coal power plants decreases to around 31 % in the scenarios RED_ELEC and FLEX.

In the scenario with CO_2 emission targets (RED_ELEC and FLEX) the role of electricity generation based on natural gas will grow until the year 2030. The share of total net electricity generation in 2030 based on gas will then reach a level of approx. 20 % compared to 10 % in the reference scenario (REF).

With a portion of renewable energies of approximately 19.6 % in the year 2010 the EU-25 will miss its ambitious target of 21 % without using special additional political

measures in the reference scenario (REF). This target is still not expected to be achieved in the reference scenario by the year 2020. Then portions of the potentials will be economical for electricity production from biomass, since at the same time the prices of fossil fuels will reach a relative peak.

The electricity production from renewable energy sources rises in the reference scenario (REF) from 17.3 % in the year 2000 to 22.6 % in 2030. Thus, the absolute contribution grows from 430 TWh to 848 TWh. Their portion increases as expected with the default ratios for the portion of the renewable energies of the electricity production (EU_RES). Thereby the absolute portion of the fossil and nuclear electricity production reduces in equal parts. On European level the development of renewable energies takes place substantially via the intensified electricity production from wind energy and bio-energies (categorised as 'others'). In the scenario EU_RES the uniform green certificate price in every period is approximately on the level of 48 €/MWh.

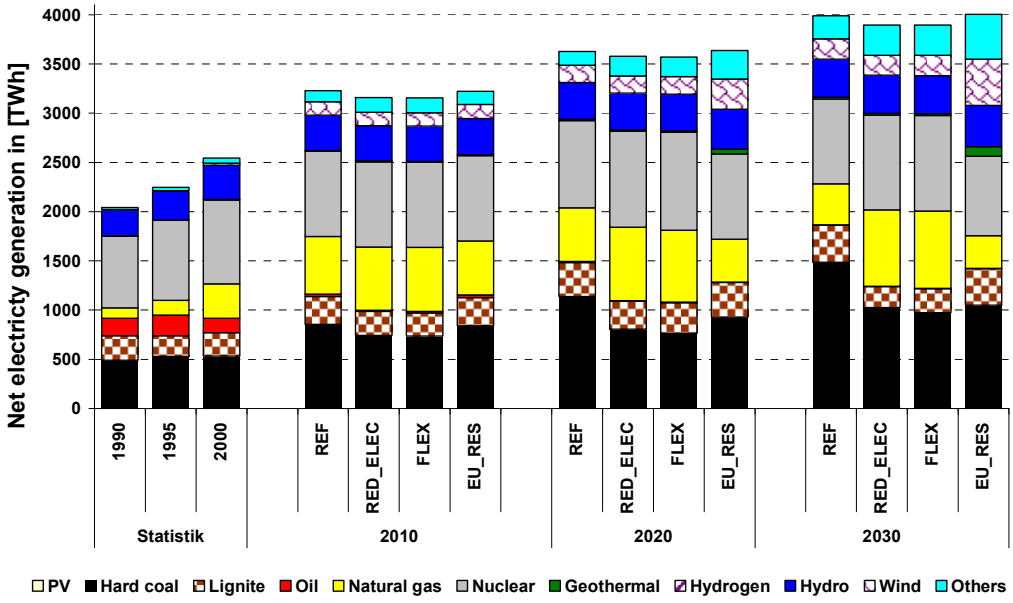

Figure 2: **Net electricity generation in the EU-25 by energy carriers in different cases**

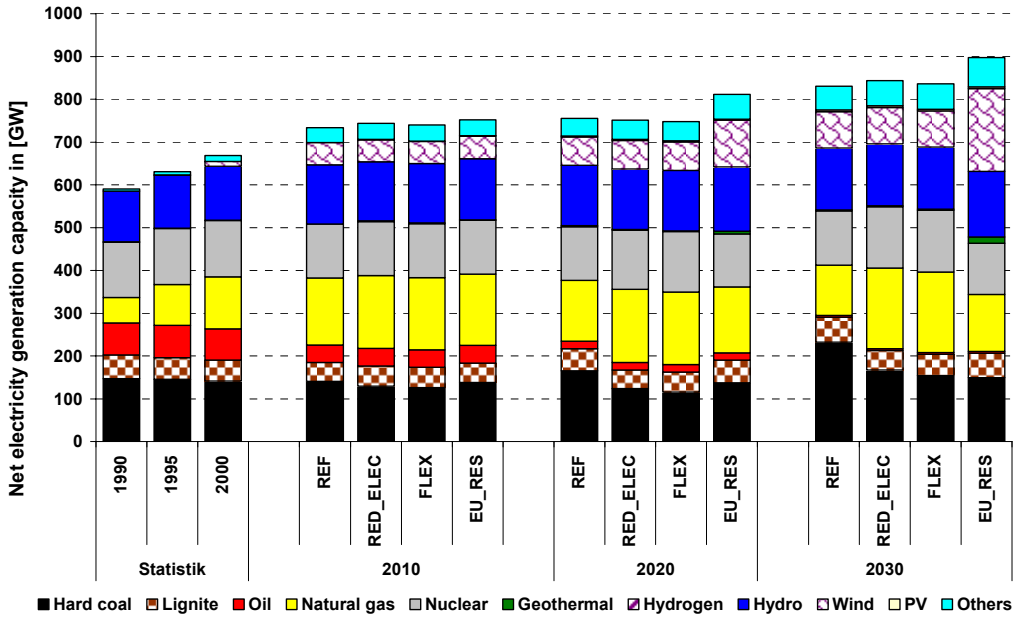

Figure 3: **Installed net capacity in the EU-25 by energy carriers in different cases**

The net generation capacity's (see Figure 3) development follows the increased electricity production quantities. Since the availabilities of the renewable energies (especially those of wind energy and photovoltaics) are smaller than those of fossil electricity production techniques, a far higher installed capacity is necessary. This rise in capacity in the reference scenario (REF) is determined by the future development of the electricity demand. In the scenarios with a target for renewable energies (EU_RES) 21 GW wind capacity are installed in the year 2030. The installed capacity of photovoltaics amounts to 21.5 GW in the year 2030. According to that the total power station capacity installed in the European Union is significantly higher in these scenarios. On the other hand, biomass from energy crops or forest wood will be used in these countries and additionally in Finland, UK, Ireland, Greece, Germany, the Netherlands, Spain and Sweden to fulfil the quote.

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In particular the use of geothermal energy in Organic Rankine Cycle (ORC) power plants in Italy, Germany and Belgium will increase until 2030 in the EU_RES scenario compared to the other scenarios.

The electricity generation of CHP plants in the EU25 increases by 14 % from about 316 TWh in the year 2000 to 365 TWh by the year 2010 in the reference scenario (see Figure 3). The extension of the electricity generation of CHP plants is essentially supported by gas-fired and biomass based CHP plants. Additionally, existing public CHP plants with an extraction condensing turbine are substituted by CHP plants with higher power-to-heat ratio and there is also an extension of industrial

CHP plants which are often used in cooperation of communal facilities. Until the year 2030 the electricity production by CHP plants in the reference scenario keeps approximately constant on the level of the year 2010.

In the case of the CO_2 reduction scenario the development of electricity by CHP plants turns out to be different. Based on the lower specific emissions of natural gas compared to coal the electricity generation by gas increases.

The renewable scenario (EU_RES) does not show any influence on the total amount of electricity generation by CHP plants until the year 2030. The electricity generation based on biomass CHP plants is around 24 TWh higher in 2030 as in the reference scenario. Based on the higher heat to power ratio from biomass CHP compared to gas and coal CHP the district heat generation is in scenario with renewable targets higher than in the reference.

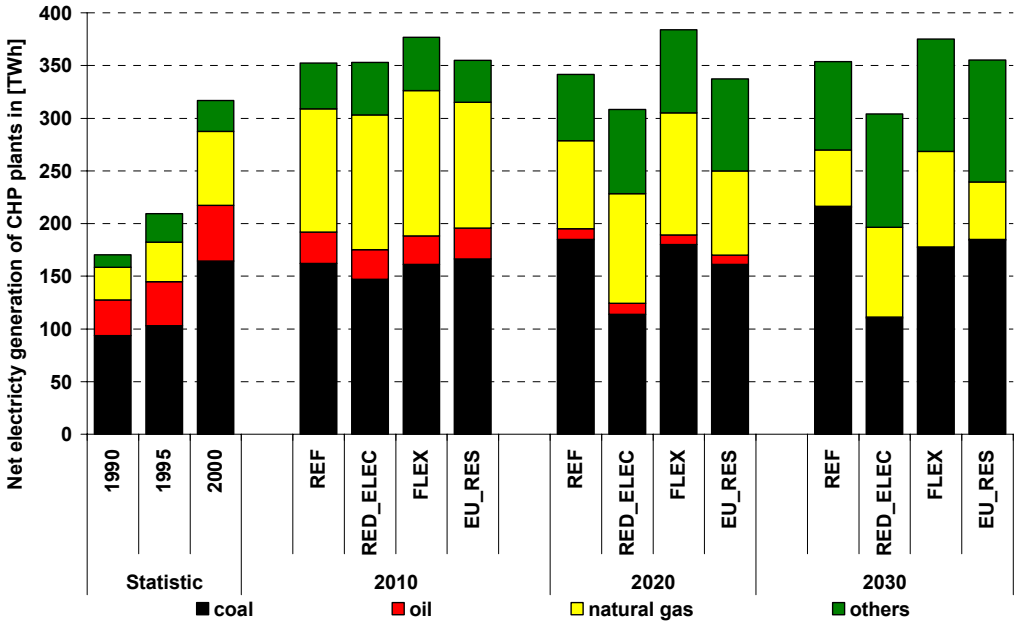

Figure 4: **Net electricity generation of CHP plants in the EU-25 by energy carriers in different cases**

In the reference scenario the district heat generation increases from approximately 2010 PJ in the year 2000 to 2270 PJ in the year 2030. The extension of district heat happens independently of an increasing efficiency in the distribution and operation system and the extension of energy saving measures in the residential sector. In the case of reduction targets for public electricity and heat generation the increase in the year 2030 will be 250 PJ higher. An additional potential (490 PJ) could be identified if the CO_2-reduction was not only restricted to the public electricity

generation sector and the energy intensive industry but also to the residential and commercial sector (FLEX). According to the lower power-to-heat ratio of biomass power plants the district heat production in the CO_2 reduction scenario and the renewable scenario EU_RES is higher than in the reference scenario.

The development of DH generation in the different regions within the EU 25 during the past and in the future was and will be different based on varying economic and social starting points.

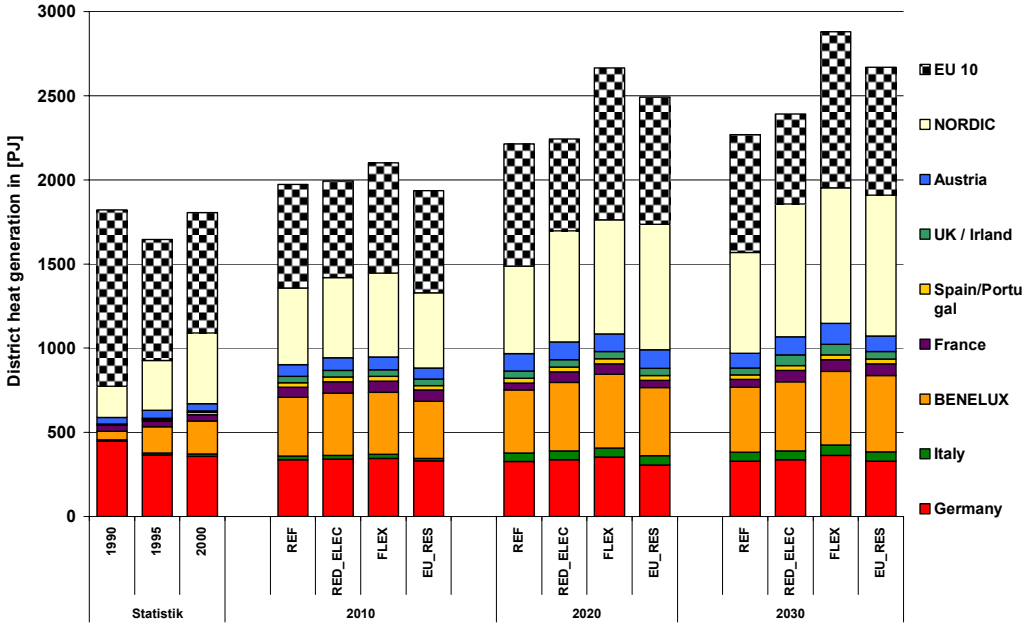

Figure 5: District heat **generation in the EU-25 by aggregated regions**

The declining development of district heat generation in Germany between the year 1990 and the year 2000 is primarily according to the decreasing demand of district heat of the New Federal States. The reduction of heating demand of existing buildings is particularly caused by refurbishment and urban development. This trend is enforced by the project “urban reconstruction east” of the New Federal States in which the inventory of multi-family houses built between 1949 and 1990 is reduced by about 30 %. These buildings are especially supplied by district heat. Thus, the share of district heat supplying households in the new Federal States will be reduced from 17 % today to 12 % until 2010. Again, an additional potential could be identified if the CO_2-reduction was not only restricted to the public electricity generation sector and the energy intensive industry but also to the residential and commercial sector.

In the Scandinavian countries (Sweden, Finland and Denmark) during the last years the share of district heat in the heat market has been increasing. Today, the contribution of district heat at the heat market in Sweden is 50 %. The situation in Finland and Denmark is nearly similar. In future times (oder: In the future) the growth of district heat will be slower because the main parts of the economic district heat areas are still connected.

The UK has the widest range of CHP plants operating from 1 kW residential micro-CHP units to the largest CHP plant in Europe with an output of 740 MW (ConocoPhillips CHP plant). During the last 10 years the utilisation of CHP has been remaining at 7% of total electricity supply. Today, the total capacity of CHP for district heat is lower than 100 MW_{el}. The future increase of DH generation is represented by gas fired CHP plants and will be even higher under the CO_2 reduction scenarios than in the reference or renewable scenario.

The generation of DH in Austria has been increasing within the last years. The amount of installed capacity is mainly represented by CHP with a size lower 20 MW_{el}. In the future there still exists a potential of 7.5 GW_{el} to extend and build up new public district heating systems. Depending on the particular scenario a part of this potential will be based on biomass CHP plants.

The DH production has been decreasing significantly in several of the EU10 countries between 1990 and 2000 due to the reduction of heat consumption both, in industrial and residential sectors. High district heating prices, energy savings on the demand side especially in the residential sector, modernisation and refurbishment of the DH schemes are one reason for this reduction of demand. A second important point is that a lot of dwellings' heating was switched from district heat to gas because of the cross-subsidies between large and small gas customers and the political interference in tariffs. However, in relative terms the DH share in the residential market in the EU10 (2004) maintained its level of the year 2000 which means that certain stability was registered in these last four years in this segment.

Some particularities should be mentioned also: in the Czech Republic, one of the countries with the largest DH production and share in the residential heat market, there is a tendency towards increasing the DH share in large urban areas. In Slovakia the trend was similar to the Czech Republic. The increase compared to the Czech Republic was lower because temporary cross-subsidies of gas simultaneously promoted the use of gas in the residential sector. In the future, both countries have an additional district heat potential which will be partly used.

In Hungary, the decrease in the residential sector is to a certain extent compensated by an increase of DH supply to the tertiary sector (services). In the future the prevention of subsidies for natural gas and the obstructions for households to turn away from the DH system will lead to a Growing share of CHP in Heat Production and hence, reverse the current trend of declining DH.

From the operational point of view, DH schemes in the EU10 countries were characterised by considerable heat losses in the range of 12-20 % corresponding to high operational costs. It is assumed for the model calculation that the improvements of the last years were successful and the losses and the operational costs are now comparable with the average in the EU15.

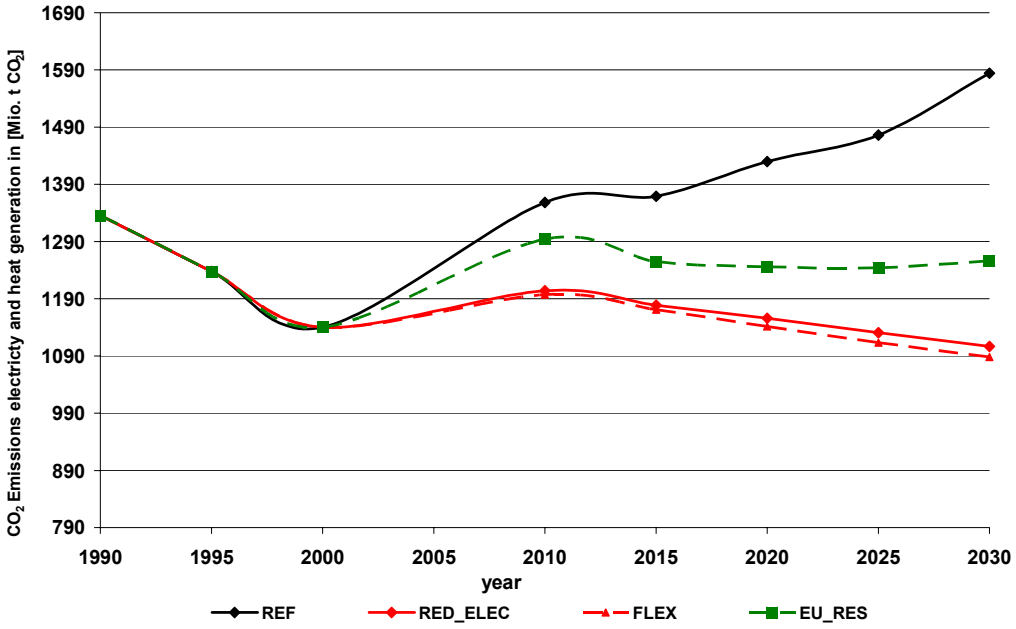

Figure 6: CO_2-Emission of the electricity and heat generation in EU–15 in the different scenarios

The base value of the CO_2 emissions for 1990 of the EU25 has been determined by means of model calculations and an alignment with available statistics of the fuel inventory and amounts to 1335 Mio. t for the modelled range of the electricity and district heating production. The regarding CO_2 emissions from electricity and district heating production for the reference scenario (REF) sum up to 1336 Mio. t in the year 2010. This is around 2.3 % higher than in the year 1990 (see figure 5). Therefore, the considered Kyoto reduction target for the year 2010 (-9.4 %) is not reached in the reference scenario. In the scenario RED_ELEC and FLEX the Kyoto target and its continuation will be achieved automatically due to the scenario's boundary conditions. The marginal cost of CO_2-reduction are expected to be in the range of 22 Euro/ t CO_2 in the year 2010 going up to 30 Euro / t CO_2 in the year 2030. These figures are comparable to the CO_2 certificate prices on the Leipzig European Energy Exchange (EEX) of today.

In the scenario EU_RES, the indicative targets for the electricity consumption from renewable energies in 2010 are achieved and hence, the CO_2 emissions in the EU-25 in the year 2010 are lower by approximately 65 Mio. t in comparison to the

reference scenario. The emissions stay in a range between 1300 and 1260 Mio. t until 2030 in the renewable scenario. This leads to an increase of 80 to 115 Mio. t above the Kyoto target assigned to the electricity and district heating production.

4 Conclusions

District heating generation offers an economic potential for extension in the future. Depending on the regions or countries the development will be different because the starting point is of economical growth, national existing laws or cross-subsidies for competitor's energy carriers. In addition, it is necessary to take into account that the climate conditions within Europe differ substantially.

Moreover, the additional co-generated electric power is produced tendentiously out of natural gas and biomass. The scenarios show that the power-to-heat ratio of CHP plants increases and that the share of district heat from CHP plants gradually rises instead from heating plants.

A more thorough analysis of the arrangement of the EU system of emission trading certificates shows some crucial deficits of the system which could counteract the aim to reduce greenhouse gas emissions at the most reasonable and lowest costs. Essentially, these deficits are:

- The restriction of the certificate trading system on facilities of the energy generation sector and of the energy-intensive industry; hence, only the smaller part of the total CO_2 emissions is covered by the emission trading system.
- The restriction to the emissions for single facilities; for this reason the extension of the certificate trading system to the multitude of small sources both in the sector of private households and in the sector of commerce and transportation is excluded from the system a priori.

If all sectors were included efficiently, the whole system would be improved. DH systems have equal competitive conditions in the heat and electricity market.

The target for a given national or EU25 quota of 33 % of renewable electricity generation in 2020 will only be reached, if it is possible to double the wind power generation and the use of biomass. In order to achieve this significant increase the wind offshore technology will have to accomplish its technical maturity concerning the supply system and its integration into the electrical grid. On the other hand, technologies for biomass and biogas power plants are already established on the market but the utilisation of large amounts of biomass will require an advanced supply chain.

Finally, the scenario analyses have shown that the progression of district heat crucially depends on the costs of opening up new district heating supply areas in the future. Only provided that the costs of the extension of supply areas and the costs of

starting losses reduce significantly, new district heating supply areas can be opened up economically.