THE POSITION OF DISTRICT HEATING IN THE WORLD AND THE CORRESPONDING USE OF RENEWABLES

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Abstract - The district heating and cooling (DHC) systems in the world deliver annually about 10 EJ. This volume is significant compared to the total global heat demand of about 100 EJ/year. The current energy supply to these district heating systems is dominated by the use of fossil fuels in combined heat and power (CHP) plants. However, the share of renewables in the energy supply is increasing or is already high in some countries. The combination of use of renewables and reused heat losses from power generation, industrial processes and waste incineration makes district heating to a carbon lean alternative in the heat market. Globally, DHC/CHP including industrial CHP reduces the existing carbon emissions from fuel combustion by 3-4%, corresponding to an annual reduction of 670-890 Mton compared to the global annual emissions of 23000 Mton from fuel combustion. The highest carbon dioxide reductions from DHC/CHP occur in Russia (15%), in the former USSR outside Russia (8%) and in the EU (5%).

1. INTRODUCTION

The fundamental idea of district heating is to use local fuel or heat resources, which 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 market heat demands, and the pipes as a connection between source and demands. 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.

The five suitable strategic local energy resources include useful waste heat from thermal power stations (cogeneration), heat obtained from refuse incineration, useful waste heat from industrial processes, natural geothermal heat sources or fuels difficult to manage as wood waste, peat, straw, or olive stones. These heat sources must be cheap in order to compensate for 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 source is temporarily unavailable.

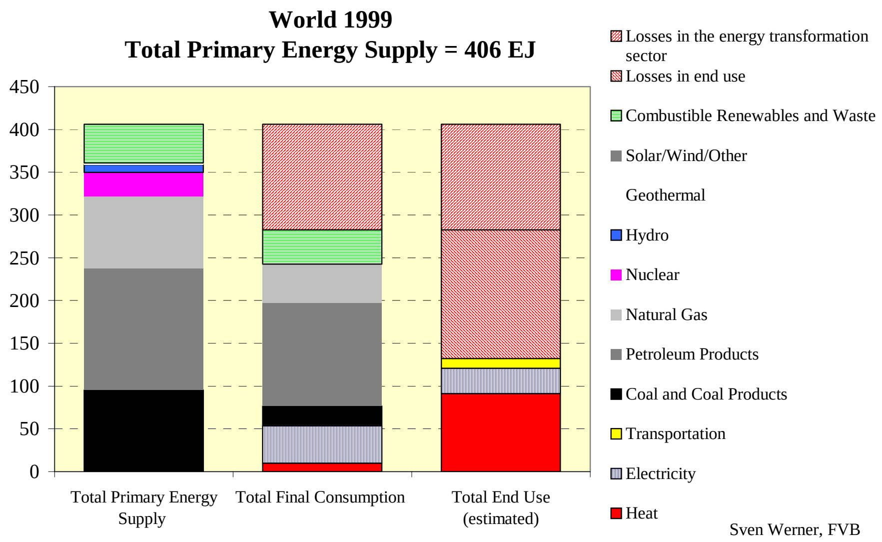

Figure 1. World energy balance 1999 with the three major steps: Total primary energy supply, Total final consumption, and Estimated total end use after all energy conversion. Information source: (IEA, 2001a and 2001b).

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

All district heating and cooling (DHC) systems in the world deliver annually about 10 EJ. This volume is significant compared to the total global heat demand of about 100 EJ/year as presented in **Figure 1**. The figure also reveals the current use of district heating is much less than the conversion losses of about 120 EJ in the energy transformation sector, containing many possible heat sources for district heating.

2. PENETRATION OF DISTRICT HEATING

Citywide district heating systems exist in Helsinki, Stockholm, Copenhagen, Berlin, Munich, Hamburg, Paris, Prague, Moscow, Kiev, Warsaw, and other large cities. Many systems supply a downtown district (such as in New York, San Francisco, Minneapolis, St. Paul, Seattle, Philadelphia and other cities) or a university, military base, hospital complex or an industrial area.

Currently, the total annual heat turnover is about 11 EJ in several thousands of district heating systems operating in the world. The amount of heat delivered corresponds to 3,5 % of the total global final energy consumption (1999). The composition of centralised heat generation for district heating systems with respect to various countries is presented in Figure 2, which is based on international energy statistics. Russia dominates the global district heating market by having more than half of all heat deliveries in the world.

Volumes of centralised heat generation in various regions and countries are presented in Figure 3. Other countries with large volumes of district heat are China, Ukraine, USA, Poland, and Germany.

However, many countries have undeveloped or no proper routines for gathering statistical information from district heating systems. This is valid for USA, Great Britain, France, China, and some other countries. An independent analysis has estimated the total annual heat deliveries from all district heating systems in USA to be more than 1000 PJ, about three times more than reported by the statistics. Hence, the real world market penetration is probably higher than presented in Figure 3

Deliveries to the residential, public, and commercial sectors for fulfilling heat demands for space heating and domestic hot water preparation constitute the dominating part of the deliveries. Among OECD countries, district heating has a strong, almost dominating market position in Denmark, Finland, Sweden, Poland, and the Czech republic. The same position appear in Russia, Belarus, Romania, and the three Baltic states among the non-OECD countries.

Heat generated annually per capita is presented in Figure 4. This value depends on market penetration, climatic location, and the specific heat demands. The world average is about 2 GJ, while established district heating countries have magnitudes of 10-40 GJ.

China is now the fastest growing district heating market in the world. The expansion of distribution pipes and area heated since 1990 is presented in Figure 5.

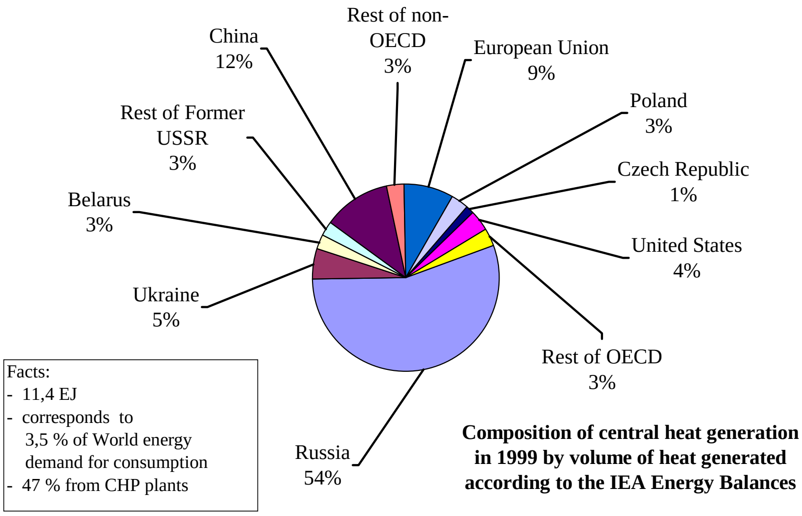

Figure 2. Global composition of central heat generation during 1999. Information source: (IEA, 2001a and 2001b).

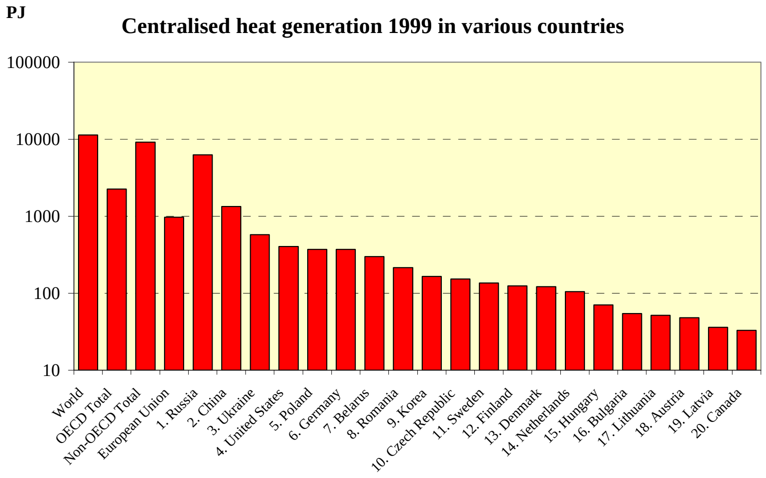

Figure 3. Volumes of heat generated in various countries 1999. Information source: (IEA, 2001a and 2001b).

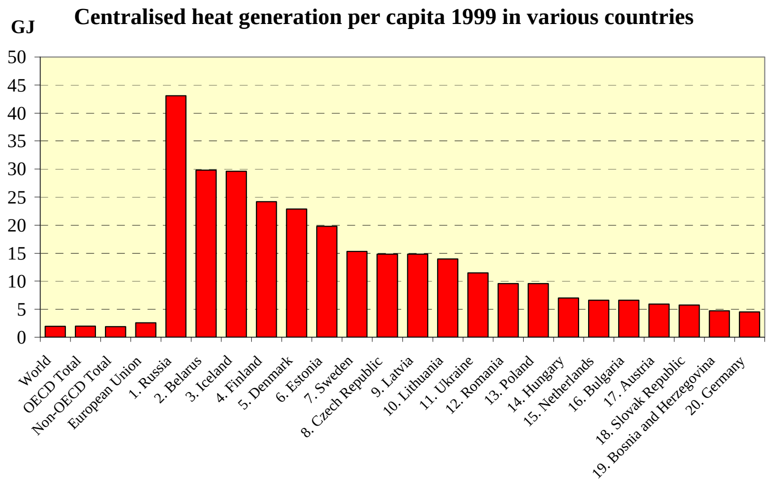

Figure 4. Centralised heat generation per capita in various countries 1999. Information source: (IEA, 2001a and 2001b).

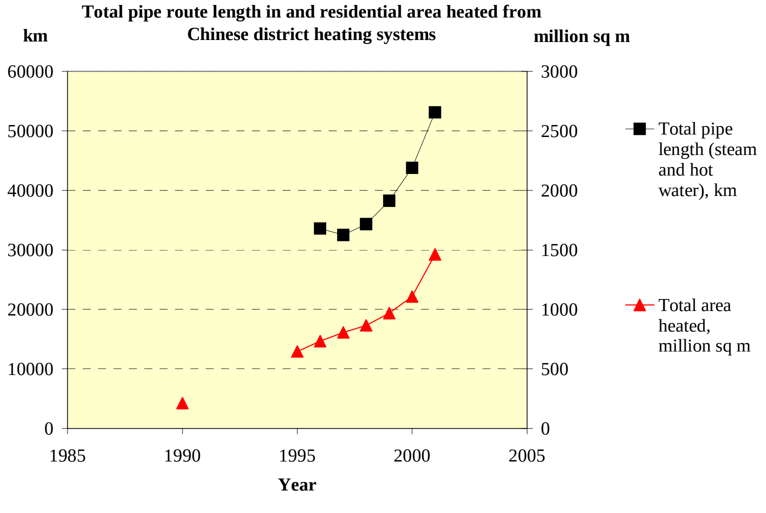

Figure 5. Total pipe route length in and residential area heated from Chinese district heating systems. Information source: (National Bureau of Statistics of China, 2002)

3. ENERGY SUPPLY

The total supply to all CHP and heat plants amounted to 30,2 EJ during 1999. The current energy supply to the district heating systems is dominated by the use of fossil fuels, mostly in combined heat and power (CHP) plants. Natural gas constitutes 45 % while coal corresponds to 37 %.

Only 8,2 % of the energy supply is coming from non-fossil and non-nuclear sources as illustrated in Figure 6. This fraction is lower than the non-fossil and non-nuclear fraction of 14 % for all global primary energy supply.

The 8,2 % fraction constitutes of primary solid biomass (5,4 %), municipal waste (1,5 %), industrial waste (1,0 %), geothermal heat (0,2 %), and biogas (0,1 %). No significant contribution is recorded from thermal solar collectors. However some large solar heating plants are connected to district heating systems in Germany, Denmark, the Netherlands and Sweden.

The total conversion efficiency for all CHP plants is only 50 %, which reveals that further heat can be distributed from the existing CHP plants. The corresponding conversion efficiency for heat only plants is 86 %.

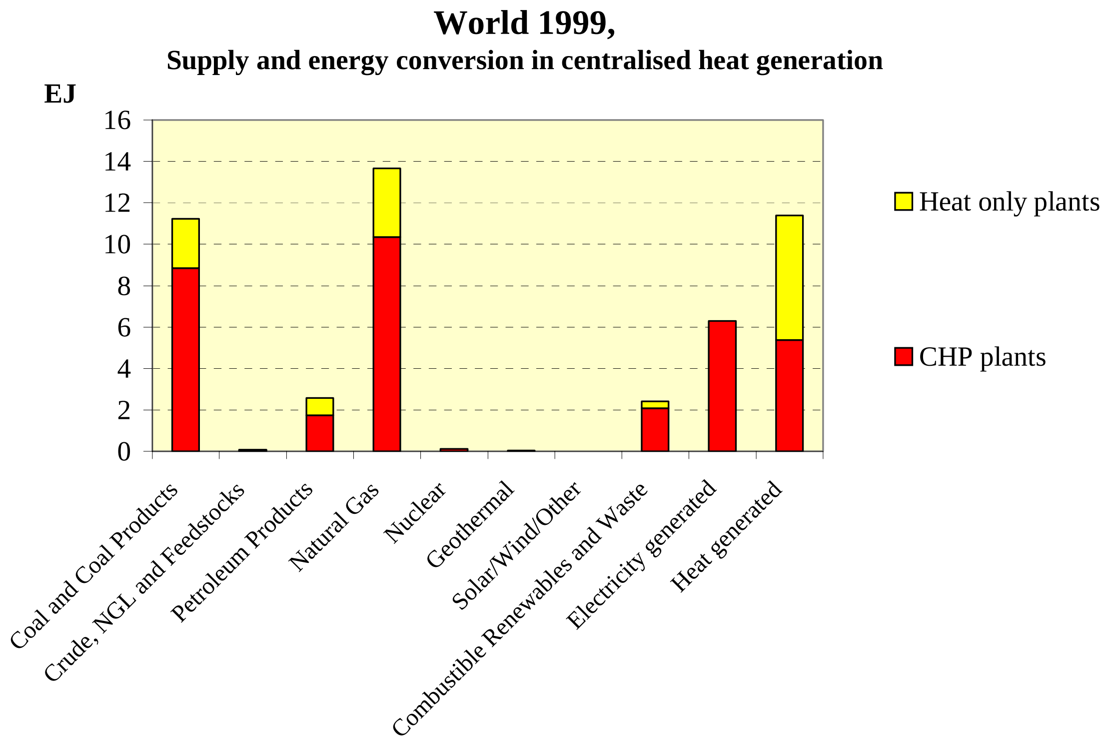

Figure 6. Energy supply and energy conversion in centralised heat generation in the world during 1999. Information source: (IEA, 2001a and 2001b).

4. RENEWABLES IN ENERGY SUPPLY FOR DISTRICT HEATING SYSTEMS

Although the share of renewables is low in the energy supply to the district heating system, the share is increasing or is already high in some countries.

In Figure 7, the non-fossil fractions are presented for various countries with respect to volumes of heat generated (the same order as in Figure 3). In average, OECD countries, mostly the EU and the USA, have higher fractions of non-fossil energy supply than non-OECD countries. Sweden has the highest fraction of renewables of the large district heating countries. High fractions of primary solid biomass exist in Sweden, Finland, USA, Latvia, and Austria.

In Figure 8, the non-fossil fractions are presented for various countries with respect to heat generated per capita (the same order as in Figure 4). Out of these countries, Iceland has the highest fraction of renewables by using 98,7 % of geothermal heat.

Non-fossil fractions in energy supply for centralised heat generation 1999, for various countries with respect to heat generation volumes

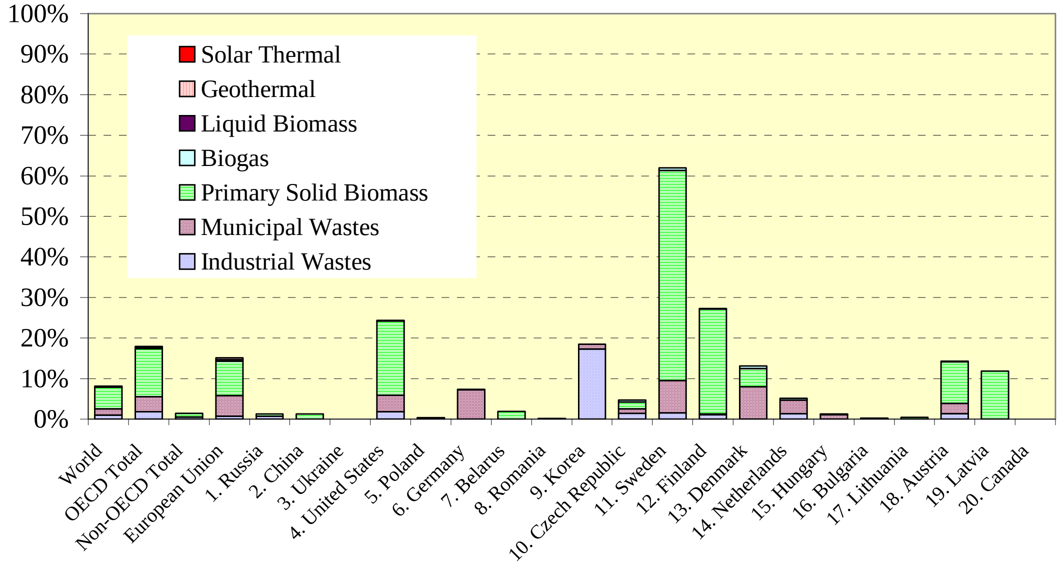

Figure 7. Non-fossil fractions sorted by volumes of heat generated 1999 in various countries. Information source: (IEA, 2001a and 2001b).

Non-fossil fractions in energy supply for centralised heat generation 1999, for various countries with respect to heat generation per capita

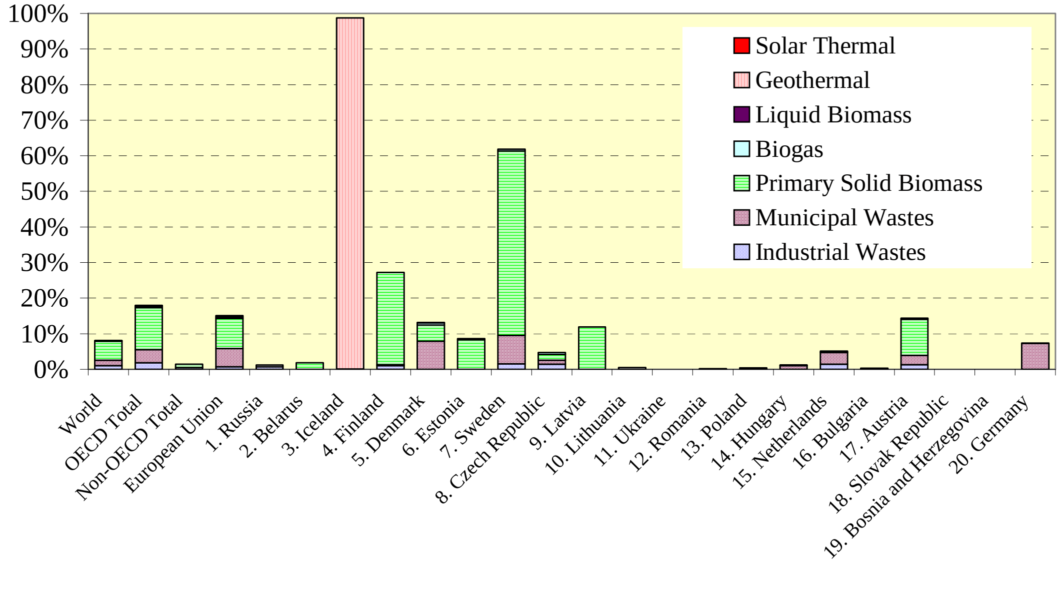

Figure 8. Non-fossil fractions sorted by heat generated per capita 1999 in various countries Information source: (IEA, 2001a and 2001b).

5. AVOIDED CARBON DIOXIDE EMISSIONS

The combination of use of renewables and reused heat losses from power generation, industrial processes and waste incineration makes district heating to a carbon lean alternative in the heat market. It is not a carbon free alternative, but the avoided carbon dioxide emissions from district heating systems is considerable,

The amount of avoided emissions is then estimated as the difference between emissions from alternative electricity and heat generation and actual emissions from all district heating systems and the corresponding CHP plants. This kind of estimation was performed in a project within the IEA implementing agreement about district heating and cooling, (Werner, Spurr, and Pout, 2002).

Globally, DHC/CHP including industrial CHP reduces the existing carbon emissions from fuel combustion by 3-4%, corresponding to an annual reduction of 670-890 Mton compared to the global annual emissions of 22700 Mton from fuel combustion. The highest carbon dioxide reductions from DHC/CHP occur in Russia (15%), in the former USSR outside Russia (8%) and in the EU (5%).

6. ASSESSMENT METHOD

An assessment method for comparing various heating technologies with respect to carbon dioxide emissions was also presented in (Werner, Spurr, and Pout, 2002).

Use of electricity has an anonymous emission of carbon dioxide for the user due to mixed generation. However, the marginal emission from the regional electricity market was used as the emission value for electricity used for heating or generated in CHP plants. Since this value is very high (about 1000 g/kWh) in the current situation due to many coal condensing plants, also another dimension was introduced for the future situation (about 350 g/kWh) corresponding to use of natural gas in plants with high conversion efficiencies.

The resulting assessment map with the two dimensions of the current and the future situation is presented in Figure 9. The complete presentation of the assessment method is also available in (Werner, 2001).

The assessment method has been extended with national combinations of carbon dioxide emissions for CHP and district heating systems in various countries. This extension will be reported in (Werner, 2003) and is presented in Figure 10. CHP and district heating systems in most countries and regions have low net emissions, since the generation of electricity is carbon rich today in the current situation. The net emissions will be much higher in the future situation, when alternative electricity generation will be more carbon lean.

Sweden has a unique position in the extended assessment map due to the high use of biomass in the energy supply. The national average for both the current and the future situation has been estimated to 110 kg of MWh delivered to customers. This value is below half of the average emissions for heating buildings within the European Union. Hence, the Swedish district heating systems have together already fulfilled ten Kyoto agreements.

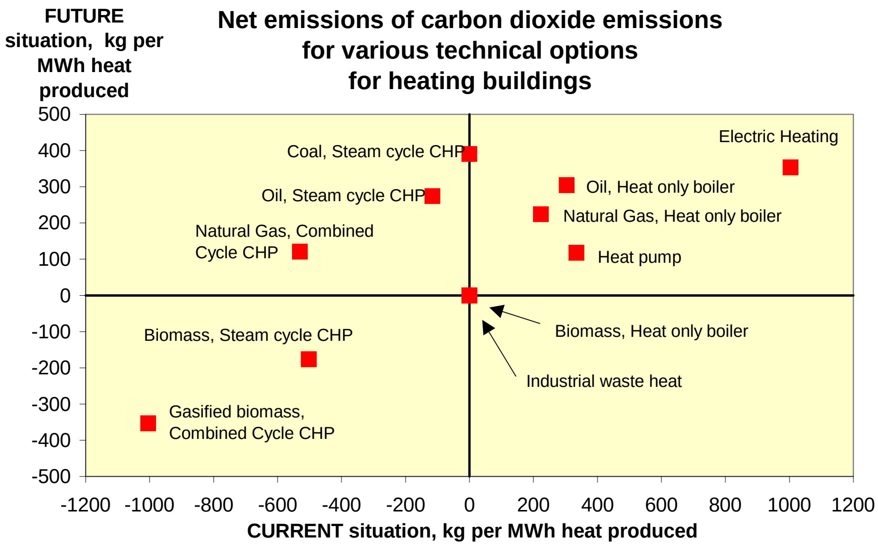

Figure 9. The assessment map for carbon dioxide emissions from various options for heating buildings.

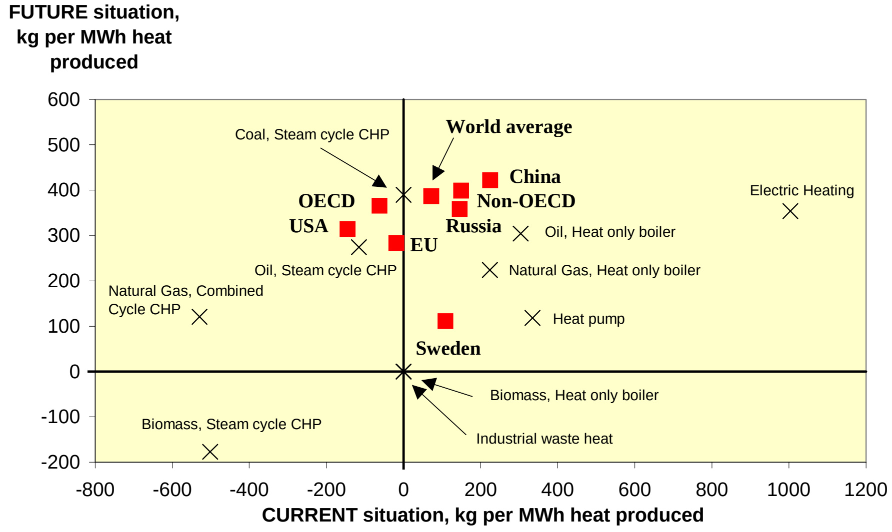

Figure 10. The assessment map with addition of national combinations for CHP and district heating systems.

7. CONCLUDING DISCUSSION

District heating systems exist since large amounts of heat losses can be retrieved from the inefficient global energy supply system, having a total conversion efficiency of about 30 %, see **Figure 1**. These systems will loose their competitiveness when the global energy conversion is reaching 100 % efficiency in decentralised energy supply systems. Solar energy can play an important role in such perfect system. However, it is very difficult to forecast when this situation will appear. Until then, district heating systems will hopefully play a significant role in the world energy balance.

The suitability of gathering solar heat by solar collectors in order to distribute the heat in district heating systems can be discussed. It is obvious that a conflict appear between the fundamental idea of district heating and large scale solar energy supply to district heating systems. Solar energy will partly substitute heat losses that still will exist.

Solar energy is already distributed by nature and should primarily replace energy supply based on fossil fuels.

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